OAK RIDGE NATIONAL LABORATORY

REVIEW

Vol. 39 • No. 3 • 2006
www.ornl.gov/ORNLReview

• MANAGED BY UT-BATTELLE FOR THE DEPARTMENT OF ENERGY •

MOVING Technology TO THE Marketplace

New Tools for Tech Transfer

Balancing Research and Commercialization

VOL. 39 • No. 2 • 2006

OAK RIDGE NATIONAL LABORATORY REVIEW

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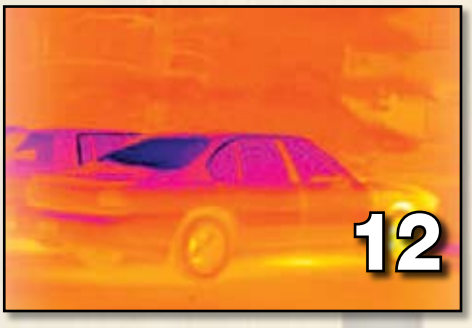


Cover: ORNL researcher Shaun Gleason co-founded ImTek, a company that made animal scanners for the preclinical market. In 2004 ImTek sold for $3.75 million to CTI Molecular Imaging, a Knoxville company that was later bought by Siemens.

An Important Part of the Mission

The Department of Energy manages what many believe is the greatest collection of scientific talent in the world. Each of the agency's national laboratories produces groundbreaking research of the highest caliber. Together, the laboratories represent what may be America's most dynamic source of creative discovery.

At Oak Ridge National Laboratory, we believe our mission calls us to go beyond the goal of solving scientific challenges. In a world in which high-tech economies are increasingly defined by breakthrough technologies, ORNL is actively engaged in a renewed effort to find new ways of moving our discoveries from the laboratory to the marketplace. Indeed, as the United States marshals the nation's resources for the economic competition that will shape our future, technology transfer is emerging as a critical component of the Department of Energy's research agenda.

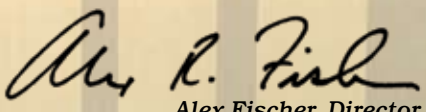
The relative emphasis on technology transfer to a great extent reflects the culture and management philosophy at individual laboratories. At some laboratories, commercialization of scientific research has long been a well-established priority within the Department of Energy's broader mission. For a variety of reasons, other laboratories have devoted fewer resources to technology transfer activities. In Oak Ridge, the University of Tennessee and Battelle have determined that moving new technologies from the bench top to the marketplace is a critical part of the Laboratory's support of the Department of Energy and the region's economic development.

UT-Battelle has assigned an unprecedented priority to a variety of technology transfer initiatives at Oak Ridge National Laboratory. Why this decision was made, and how ORNL is implementing a multi-faceted strategy to commercialize the Laboratory's discoveries, is the focus of this issue of the *ORNL Review*.

Although the details of technology transfer can sometimes be as complex as the science that precedes it, we are motivated by two simple assumptions—one moral, the other practical. As a national laboratory, we do not conduct research in isolation. Science is an integral component of America's economic vitality. We believe our mission includes not just the ability to develop technological solutions, but also the responsibility to see that those solutions are transmitted quickly into the economic mainstream.

Apart from this philosophical stance in support of technology transfer, we increasingly encounter a scientific community for whom a robust program of commercialization is an important consideration of employment. We do not view this attitude as a compromise of scientific commitment. To the contrary, we contend that commercial opportunity is an inevitable outcome of performing world-class research. The pursuit of these opportunities should by no means be required of the researcher. Each researcher is different, guided by individual goals. Recognizing this diversity, we believe that the tools for commercialization should be made available to those who are inspired by the chance to benefit from their discoveries.

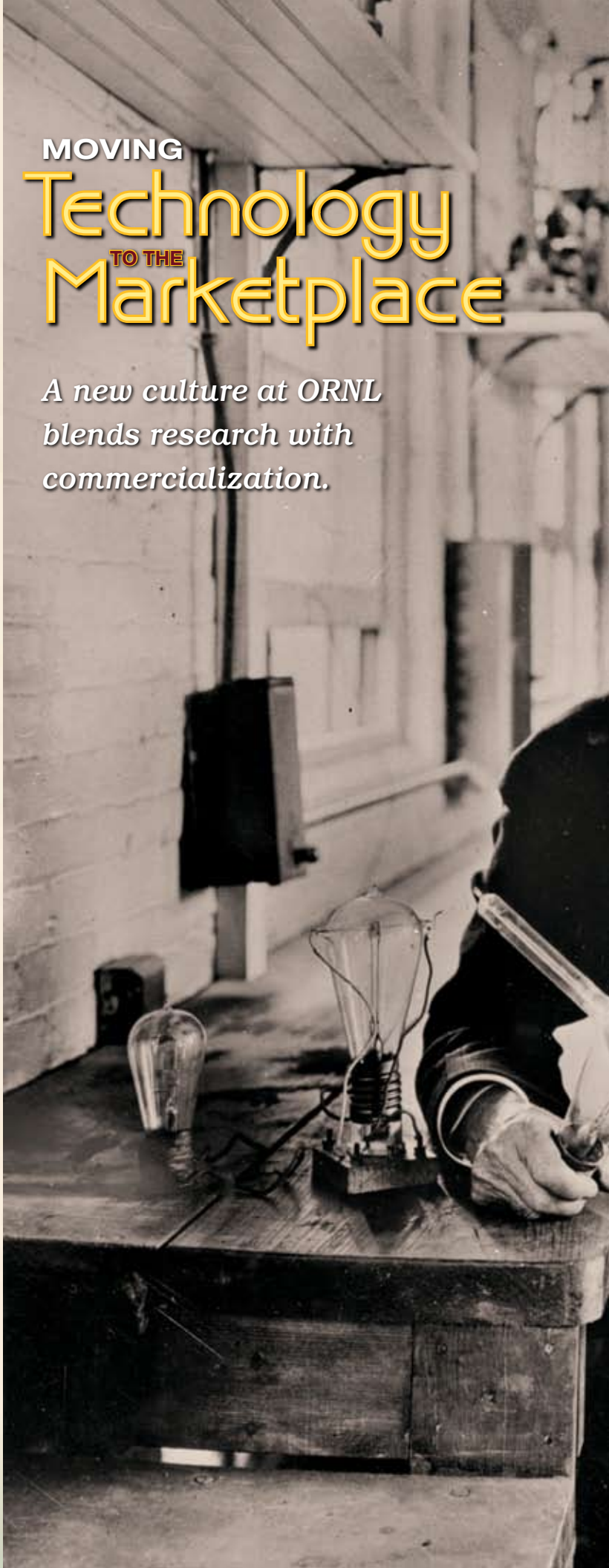
Creating an entrepreneurial culture, particularly in an institution that historically has had other priorities, is an enormous challenge. How we fashion our expectations, and how we measure our results, are questions we continue to address. More certain, however, is the purpose of our efforts. Since April 2000, ORNL has helped create 61 new companies. The new jobs represented by these companies, and more important their contributions to America's economic competitiveness, are rewards of lasting value. One by one, these successes are reshaping the spirit and focus of our Laboratory.



Alex Fischer, Director
Technology Transfer and
Economic Development

MOVING Technology TO THE Marketplace

A new culture at ORNL blends research with commercialization.



There is no question. Science brought Jeremy Smith to Oak Ridge National Laboratory.

Smith, a biophysicist, begins his appointment October 1 as the first joint Governor's Chair appointee at the University of Tennessee and Oak Ridge National Laboratory. A British native drawn to ORNL from the University of Heidelberg in Germany by the Spallation Neutron Source, Smith will use the new accelerator to support his research at the Joint Institute for Biological Sciences, located on the ORNL campus. He also will take advantage of the Laboratory's escalating supercomputing power, using simulation to aid his study of biological molecules.

However, Smith's interest in the properties of proteins and enzymes extends beyond the confines of the laboratory. Twice, he and colleagues drew up business plans to commercialize methods they had developed to design drugs computationally. The plans received "very enthusiastic" response from venture capitalists and the techniques "looked quite promising and still do," Smith says. Although in both cases start-up funding was promised, he did not pursue the businesses because circumstances did not permit—and, he adds, "Starting a company takes a lot of time and effort."

Smith's desire to see his research applied to the problems of everyday life has become increasingly common among today's top researchers, who often make commercialization part of their check-off list when evaluating a new job. At Oak Ridge National Laboratory, UT-Battelle has been working to develop a technology transfer program as robust as the science the Laboratory seeks to commercialize.

"An inevitable outcome of doing world-class science and technology is that commercial opportunities will arise. We should pursue those opportunities with vigor," says ORNL director Jeff Wadsworth.

"I am always very interested in how science can be commercialized in different countries with different systems," Smith says. "My impression is that many researchers would like to do that kind of thing if they saw a clear and uncomplicated path. Many of us want to be directly and immediately useful to industry, in addition to doing the conceptual groundwork of basic research."

Offering a successful tech transfer program is key to the Laboratory's efforts to attract today's leading scientists and sustain a position among the world's top research institutions, says Alex Fischer, director of ORNL's Technology Transfer and Economic Development office. Fischer spent time with Smith during the recruitment process, taking him to a UT Lady Vols basketball game and chatting him up on the Laboratory's commercialization program.

"More often than not today's top recruits are asking hard questions about commercialization. They are asking about the support structure and whether commercialization is something in which the Laboratory really believes," Fischer says. "This group in many ways represents the Laboratory of the future."

A Culture Shift

For much of the last 63 years, since the Laboratory's World War II

beginnings as a cloister for scientists secretly helping the Manhattan Project fuel the atomic bomb, technology transfer was not a mission of ORNL. In 1980 Congress began pushing to move research at Department of Energy labs into the public domain via commercialization. A series of laws, starting with the Stevenson-Wydler Technology Innovation Act and closely followed by the Bayh-Dole Patent and Trademark Act, paved the way for DOE technologies to be commercialized.

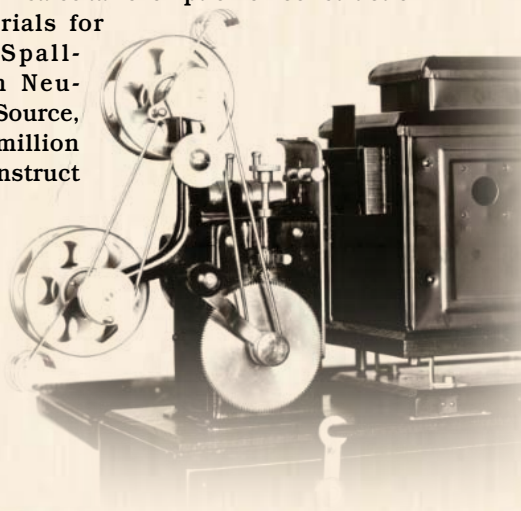
Subsequent legislation clarified and expanded the tech transfer mission. The most recent was the Energy Policy Act of 2005, which established a technology transfer coordinator for the Department of Energy to emphasize commercialization at its national laboratories. Early initiatives were aimed at creating partnerships with private industry through either cooperative research and development agreements, CRADAs, or work-for-others arrangements. These programs allow private companies to solve technological challenges by using the Laboratory's facilities and researchers.

ORNL also began licensing technology to industry. Early successful tech transfers included a super-tough ceramic now used to make commercial cutting tools and corrosion-resistant chrome-moly steel that is now found in utility boilers and oil refinery furnaces that produce unleaded gasoline.

"An inevitable outcome of doing world-class science and technology is that commercial opportunities will arise."

In 2000, new ORNL management contractor UT-Battelle brought renewed emphasis on making ORNL not only a first-rate center for scientific research, but business-friendly, as well. The partnership between the University of Tennessee and Battelle married Columbus, Ohio–based Battelle's seven decades of spinning basic research into marketable products—photocopy machines, compact discs, bar codes—with the state of Tennessee's desire to leverage a partnership with the Laboratory into a dynamic asset for technology-oriented capital investment and high-paying jobs.

"Two governors, along with the Legislature, have invested a lot of money in the partnership between the university and this Laboratory," Wadsworth says. He cites a $28 million sales tax exemption on construction materials for the Spallation Neutron Source, $30 million to construct



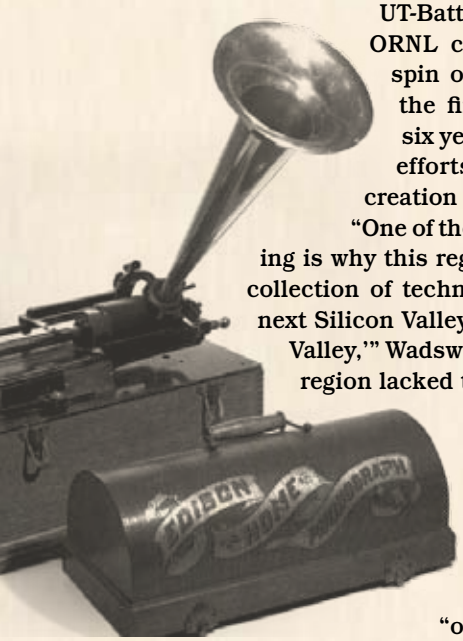
three joint institutes in biological, computational and neutron sciences at ORNL, $15 million to equip a Joint Institute for Advanced Material Sciences at UT and $10 million in matching money to establish UT-ORNL Governor's Chairs in the four joint institutes.

"The reason they made these investments is not because they want to see new buildings," Wadsworth says. "The Governor and the Legislature, along with many of us, believe that there is an inevitable tie between science and technology investment and economic development."

David Millhorn, vice president for research at the University of Tennessee, agrees. "What is really important to the state is to have an environment that will incubate new companies and add

jobs," he says. "Education, new jobs, a better quality of life—that is the endpoint. The people own us both, so whatever we do should benefit the people."

Robert Brown, chief operating officer for the Department of Energy's Oak Ridge Office, emphasizes that commercialization is part of the agency's responsibility to the local community. "Ethically, I think all of us believe we are indebted to communities that host operations like the DOE and that we need to return any advantage of those operations that we can," Brown says. "It's the right thing to do."



UT-Battelle's winning bid to manage ORNL contained a commitment to spin out 10 new companies during the first year of operation. In the six years since, technology transfer efforts have expanded beyond the creation of start-ups.

"One of the things we have been discussing is why this region, with such a tremendous collection of technologies, has not become the next Silicon Valley, 'Nano Valley' or 'Computing Valley,'" Wadsworth says. "We determined the region lacked three fundamental things."

The first is entrepreneurial spirit, a basic culture in which workers expect change and are willing to take risks, he says. The second is venture capital. And the third, Wadsworth stresses, is "opening up the Laboratory in a way that allows people to believe they can work with us. This includes both physical access on site as well as a minimum of bureaucratic hassles."

Modernization of the Laboratory's aging physical plant was important to create an inviting, open atmosphere for both researchers and businesses. The most recent addition, the Oak Ridge Science and Technology Park, will create a place for a start-up company, an industrial customer or a university partner to do business adjacent to the Laboratory's facilities and staff.

The second challenge is addressed by Battelle Ventures, a private fund spun out of Battelle in 2003 that provides $150 million in venture capital to promising technologies and start-ups connected to labs managed by Battelle. Last year a group of key business players in Knoxville added $35 million to the pot in a tandem investment fund. UT-Battelle has also supported the efforts of Technology 2020, a local not-for-profit dedicated to technology-based economic development. In recent years, Technology 2020 has launched two new venture capital funds and also provides debt and angel funding opportunities for new start-up technology businesses.

In addition, ORNL offers start-up assistance through the Center for Entrepreneurial Growth, operated by Technology 2020 with funding from UT-Battelle, as well as part- and full-time entrepreneurial leave.

Internally, UT-Battelle has both emphasized and broadened the Laboratory's approach to technology transfer by adding staff to the commercialization office, bringing in experts from private industry and university systems—where tech transfer historically has been more successful than at the national labs (see sidebar on p. 6, top)—and adding programs to encourage entrepreneurship as well as collaboration with existing industry.

UT-Battelle and Battelle also support tech transfer within the Laboratory through privately funded technology transfer, which allows for private investment in particularly promising technologies with resulting revenues flowing back, by agreement with the Department of Energy, to the Laboratory and to the local community. "It's not an individual tool," says Fischer.

PUTTING THE PIECES TOGETHER

ORNL's technology transfer program supports a variety of commercialization activities.

The Center for Entrepreneurial Growth: Operated by Technology 2020 in Oak Ridge to provide legal, marketing and other services for a start-up company that has a license or business partnership with the Laboratory or is founded by a former or current ORNL employee.

Contact: Bob Wilson, 865-220-2020, wilson@tech2020.org

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Oak Ridge Science and Technology Park: A planned, 40-acre, privately funded business park on the ORNL campus that will house a variety of organizations—start-ups, universities, corporations with research projects at ORNL and Laboratory contractors.

Contact: Lawrence Young, Community Reuse Organization of East Tennessee, 865-482-9890

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Contact: Casey Porto, Technology Transfer Director, 865-574-1051, portoca@ornl.gov

Cooperative Research and Development Agreement: An agreement between ORNL and a company (or other non-federal participant) that allows collaboration, cost sharing and pooling of R&D results to bring a specific technology to the marketplace.

Contact: Frank Damiano, Sponsored Research Group Leader, 865-576-2967, damianofv@ornl.gov

"We've got to do everything we can to make interactions with the private sector easier."

Business vs. Science?

Tech transfer initiatives are not without critics. Opponents of aggressive commercialization efforts at national laboratories worry that commercial interests will compromise DOE's scientific mission, whether it be by luring away quality researchers or by shifting the focus of basic research programs toward those with greater promise of commercial success.

Wadsworth points out that the Laboratory should welcome all comers. "I think a Laboratory like ORNL—a billion dollars a year with 4,000 people—should contain the spectrum of science and technology interests," he says. "It would be a mistake to force people to have economic development and commercialization goals if they are not doing work that can readily find expression in that part of the spectrum."

In recent years technology transfer has become an important component of certain research programs at the Laboratory, including the Biological and Environmental Sciences directorate, headed by Reinhold Mann—the directorate in which Jeremy Smith will work.

"Our strategic business plan contains a segment on commercialization," Mann says. "In the next five years we want to increase the number of licenses and patents. We also want to increase the revenue stream from commercialization and from licensing. We think we can accomplish these goals."

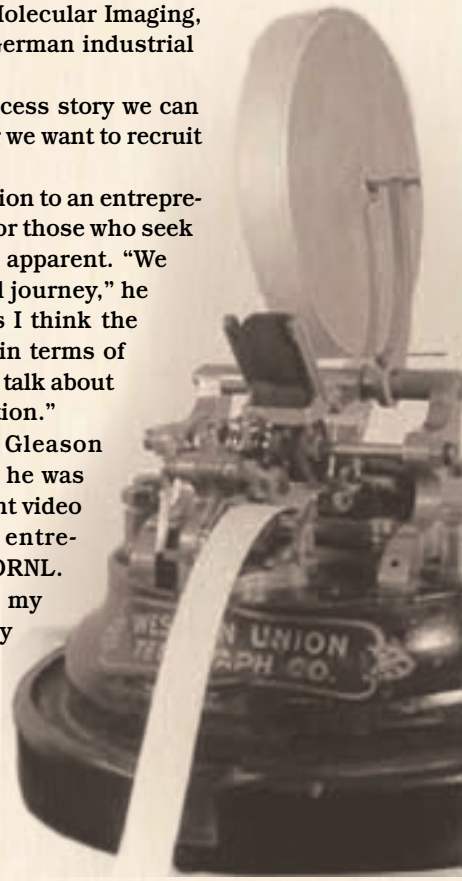
Mann says a proactive tech transfer office has become "increasingly important" in the cutthroat arena of recruitment. "We're competing for the same talent as major universities and other national labs," he says. "A school like MIT is within a mile of probably 40 biotech companies. They operate in an environment that encourages entrepreneurial behavior. Those are the centers we compete with when we recruit, so having a compelling story for technology transfer at ORNL is a very important part of our ability to remain competitive."

Mann points to a recent success, the commercialization of an animal scanner by ORNL researchers Shaun Gleason and Michael Paulus. Their company, ImTek, sold to Knoxville-based CTI Molecular Imaging, which subsequently sold to German industrial giant Siemens.

"This is a wonderful success story we can tell the next electrical engineer we want to recruit to Oak Ridge," Mann says.

Alex Fischer says transition to an entrepreneurial environment, at least for those who seek it, will be slow but is already apparent. "We have started down the cultural journey," he says. "Over the last five years I think the culture is very different here in terms of our researchers' willingness to talk about and engage in commercialization."

Imtek founder Shaun Gleason says he saw the change when he was filmed for an ORNL recruitment video specifically to discuss the entrepreneurial environment at ORNL. "When I talk to the people in my research group at ORNL, they seem more interested in doing a tech transfer project and getting something going," he says. The success of a company like ImTek, he adds, "really opens people's eyes to new possibilities." ®



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Work-for-Others Agreement: ORNL provides R&D or technical assistance to a company or government customer for a fee.

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User Agreement: An agreement between the Laboratory and a private company, university, DOE laboratory or other federal agency that allows the customer to conduct research or solve a problem using the special instruments and equipment in the Laboratory's designated user facilities. ORNL personnel may be used in a support capacity to complete an experiment or provide routine maintenance and repair. If the research is proprietary, the user pays a fee. Use is free to a user if the research results are published in the open literature.

Contact: Bill Painter, Sponsored Research Manager User Facilities, 865-574-5471, painterwp@ornl.gov

Technology Maturation Funds: Funding supplied either by commercialization royalties or private sources, including UT-Battelle and Battelle, that is used to ready technology for license.

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Venture Capital: Funding directly aimed at ORNL technologies that includes a $150 million fund, Princeton, N.J-based Battelle Ventures and a companion fund, $35 million Innovation Valley Partners. Other local funds include the $12.5 million Southern Appalachian Fund and $30 million Meritus Ventures, both co-managed by Technology 2020.

Contact: Battelle Ventures and Innovation Valley Partners, Glenn Kline, 865-329-6421, partners@innovationvalleypartners.com; Technology 2020, Grady Vanderhoofven, 865-220-2020, grady@tech2020.org

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Angel Funding: Available through the Innovation Valley Angel Network, facilitated by Technology 2020, that provides higher net-worth individuals an opportunity to invest in early-stage technology companies.

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Technology 2020: A regional economic development organization, based in Oak Ridge, that provides incubator space, business services and financial resources to technology-oriented companies in East Tennessee.

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PLAYING AT THE COLLEGE LEVEL

Many American research universities significantly outperform the Department of Energy's 10 national laboratories in moving technology from the bench to the marketplace. Indeed, each of the top 10 universities earns more licensing revenues than do all of the DOE laboratories combined.

Alex Fischer, director of ORNL's Technology Transfer and Economic Development office, aspires to position the Laboratory to compete with top universities on technology transfer metrics. Impressed by her successes at two universities, he recruited Casey Porto to direct ORNL's technology transfer effort in early 2005.

Porto headed Carnegie Mellon University's technology transfer office in the last two years of her seven-year stint in the 1990s. "Our office at Carnegie Mellon, which ranked number one in the world for computer science, started 46 companies," Porto says. "At the time many venture capital firms were interested in web-based start-ups."

In 2002, Porto left for a position as associate vice president of technology transfer at Case Western Reserve University. "We had to build a technology transfer team almost from scratch," she says. "I eventually hired 11 people. During my three years there, our office averaged about three start-ups per year."

According to Porto, universities often have more freedom to set and follow their own agenda, whereas national labs must follow the rules set by their Department of Energy customer, which in some cases must focus on research missions that take priority over aggressive technology transfer. Historically, national labs have not recruited researchers based on their track records as entrepreneurs. Porto seeks to help reshape ORNL's culture through three activities that could enable the Laboratory to compete more effectively with universities in the tech transfer arena.

Recruiting more entrepreneurial researchers. "How well we compete in tech transfer depends in part on how well we recruit to replace our researchers who retire," Porto says. "I recommend we consider a candidate's entrepreneurial track record along with the other credentials."

Championing maturation funding. Maturation funds can pay for the last phase of testing or prototype development required to make the invention licensable. Thirty-five percent of ORNL's royalty income is re-invested as technology maturation funding. ORNL inventors can apply for part of these funds during the annual Laboratory-wide call for proposals.

Modifying ORNL's entrepreneurial leave policy. More Laboratory researchers might consider starting a new company if they could avoid resigning their position. "Admittedly, this issue is not easily resolved," Porto says. "However, if we want to compete with universities for the best researchers, we should keep exploring ways to modify the policy to encourage our entrepreneurial employees."

THE LAB OF THE SOUTH

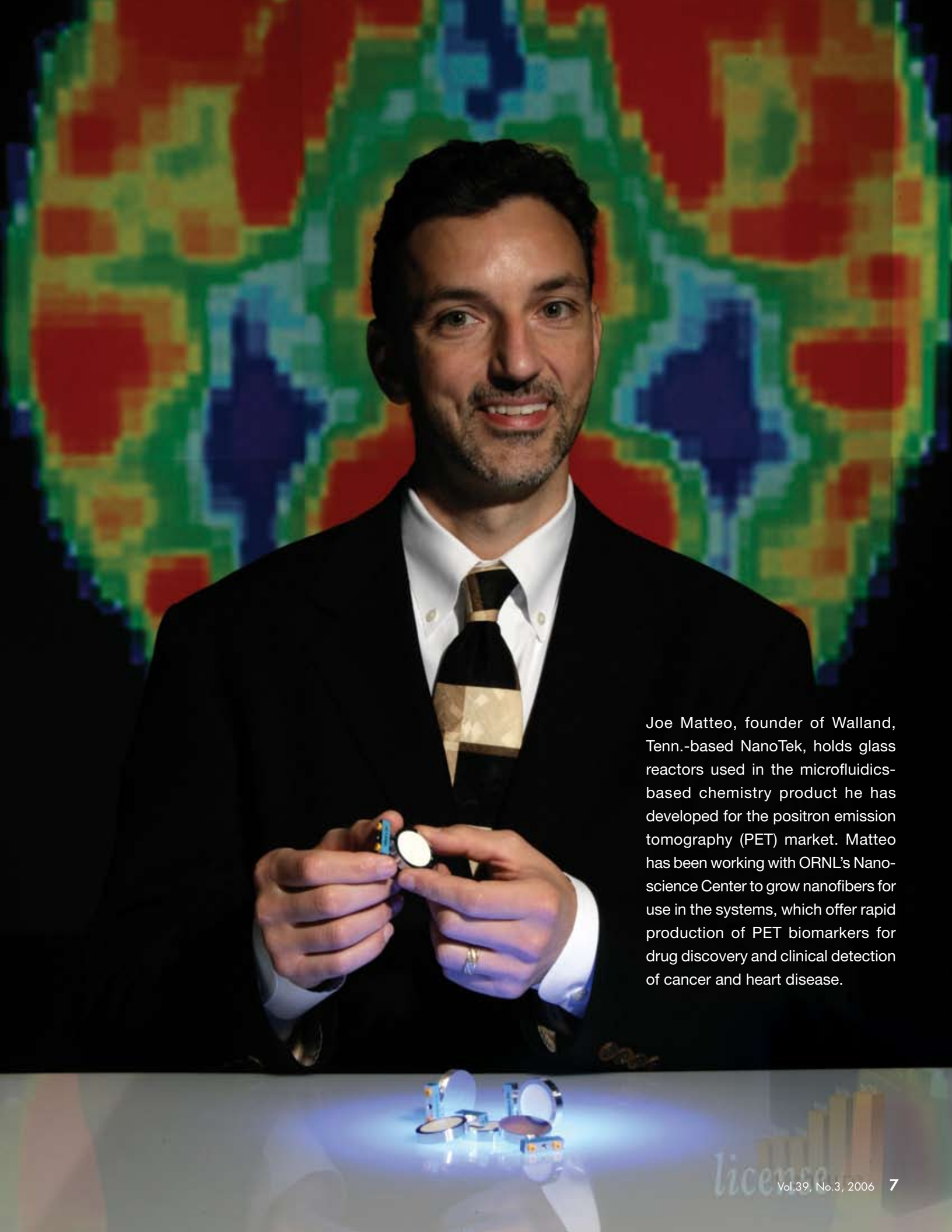
"I look at it as the little 'r,' the regular-sized 'R' and the bigger 'R,'" says Tom Ballard, director of economic development and partnerships in ORNL's Technology Transfer and Economic Development office. The "R"—which stands for "region"—begins with East Tennessee, expands to the rest of the state and, finally, embraces the South as a whole, he says, including 13 states.

To that end, ORNL has partnered with local, state and regional research and economic development organizations including Technology 2020 in Oak Ridge; Jobs Now!, a multi-county East Tennessee job creation effort; the University of Memphis FedEx Institute of Technology; the Mississippi Technology Alliance; and the Southern Growth Policies Board, an organization representing 13 states.

This "Lab of the South" initiative, Ballard says, endeavors to create partnerships throughout the region that enable companies, universities and others interested in research to take advantage of ORNL's capabilities in ways that build a technology-based economy and, through these arrangements, create local support that helps attract new research programs, and dollars, to the Laboratory.

Examples of regional efforts now in the works include:

- **The Southern Automotive R&D Initiative:** ORNL's collaboration with university R&D centers in southern states that are home to major automakers—Saturn and Nissan in Tennessee, BMW in South Carolina, Toyota in Kentucky and Mercedes Benz in Alabama, for example—to build a consortium specializing in automotive research that would mirror similar capabilities at the University of Michigan.
- **Southern Homeland Security Initiative:** An effort to use the South as a test bed and commercialization center for new homeland security technologies.
- **Southern Information Technology Initiative:** A linkage of universities throughout the South to ORNL's National Leadership Computing Facility.
- **Southern Nanotechnology Network:** A regional effort to create a nanotechnology "hot spot" utilizing new neutron scattering and neutron science capabilities at ORNL.



Joe Matteo, founder of Walland, Tenn.-based NanoTek, holds glass reactors used in the microfluidics-based chemistry product he has developed for the positron emission tomography (PET) market. Matteo has been working with ORNL's Nano-science Center to grow nanofibers for use in the systems, which offer rapid production of PET biomarkers for drug discovery and clinical detection of cancer and heart disease.

A CULTURE OF COMMERCIALIZATION

New tools make it easier for researchers to commercialize their innovations.

For researchers Mike Paulus and Shaun Gleason, ImTek began as a moonlighting job building miniature animal scanners for a handful of research customers. The business grew into a $3.75 million company that is now part of Siemens, one of the most noted R&D-driven companies in the world.

Gleason and Paulus attribute part of that success to new efforts at Oak Ridge National Laboratory aimed at encouraging start-up businesses born of technologies developed at the Laboratory or founded by ORNL researchers. "We initially had no expectations that our business would grow as quickly as it did," Gleason says. "It just kind of took on a life of its own."

Since April 2000, when UT-Battelle become ORNL's managing contractor, the Laboratory has launched several new programs to aid young companies connected to ORNL. Programs include part- and full-time entrepreneurial leave, business assistance and, potentially, venture capital through Battelle Ventures and Innovation Valley Partners, which together represent $185 million in financing for technologies that emerge from the laboratories Battelle helps to manage. (See sidebar on pp. 10–11.) ORNL also provides technology maturation funds to help ready inventions for license. (See sidebar on p. 11, bottom)

In the past six years, the Laboratory has helped generate 61 start-ups, of which 56 qualified for admission to the Center for Entrepreneurial Growth, a UT-Battelle–funded program operated by Technology 2020 in Oak Ridge. The CEG provides business counsel, financial planning, marketing assistance and other aid to companies in the formative stages. Of the 56 companies that have participated in the CEG program since its inception, 36 remain in business.

Technology 2020 was started in 1995, but president and CEO Tom Rogers says UT-Battelle's arrival marked ORNL's first active involvement with the organization, which focuses services toward high-tech companies. "I come to ORNL all the time now," Rogers says, adding that CEG director Shawn Carson has a permanent office there. "That's huge. These guys are so entrepreneurial. We really are the full partners with the Laboratory."

Companies that use the CEG must license technologies from ORNL, be founded by a current or former Laboratory employee or be working with the Laboratory through cooperative research and development or work-for-others agreements. The CEG helps researchers transition from a world where technology is the primary focus to a market-oriented environment, says Shawn Carson, CEG director of training and incuba-

ORNL employee Wendell Ely models the SeizAlert device, which monitors brainwaves to pre-warn epileptic patients of a seizure.

SeizAlert: Forewarning Epileptics

- **Company:** Hercules Development Corp.
- **Founded:** 2005
- **Headquarters:** North Attleboro, Mass.
- **Relationship to ORNL:** Licensee
- **Product description:** SeizAlert, a software program that uses brain wave data from four scalp electrodes at the front of the head to forewarn epilepsy patients of seizures in up to 4.5 hours before they happen and allows patients to take steps to prepare (i.e., stopping current activities, taking medications, lying down, etc). The underlying technology can also forewarn of heart arrhythmias (also included in Hercules' license) and fainting spells, detect the onset of septic shock due to inhaled endotoxin, and track breathing difficulties. The technology also has potential applications for first responders and the military.
- **Customers:** Clinical testing to begin this year.
- **On commercializing research:** "Epilepsy affects roughly 3 million Americans who are in constant fear of the next seizure event and injuries that could result. Patients also experience degraded quality of life due to medication side effects. I'm thankful that ten years of research and development is coming to fruition in the commercialization of SeizAlert for seizure forewarning."—*Lee Hively, ORNL researcher and SeizAlert inventor.*

TECHNOLOGY spotlight

tor operations. "What brings scientists out of the lab is a vision for this technology that they have," Carson says. "But in the private marketplace, the central issue is not your technology. The issue is whether there is a problem that needs to be solved and whether your technology can solve it."

In ImTek's case, the venture began as a project funded internally by ORNL's Laboratory Directed Research and Development program to create new technology for the Life Sciences Division's mouse genetics research facility. Gleason and Paulus, two electrical engineers working in the then Instrumentation and Controls Division, developed a computerized tomography, or CT, scanner that could image mice without sacrificing them for preclinical research. One day in 1998, officials from pharmaceutical company Parke-Davis, now owned by Pfizer, toured ORNL, and requested a machine.

"We obtained permission to form a company to deal with this initial customer," Paulus says. The new company licensed from UT-Battelle a copyrighted software package for processing images and the MicroCAT trademark. Other orders came in and Paulus and Gleason built machines around their work schedules at the Laboratory. Customers, consisting primarily of universities with some private labs in the mix, paid 50 percent up front, which funded early manufacture of the scanners.

ImTek's founders say joining the Center for Entrepreneurial Growth resulted in a major turning point in the company's growth. "For our first few sales, we operated in a reactive mode as customers came to us. With the CEG's help, we transitioned to a more proactive strategic planning approach to grow our company and position it for eventual sale," Gleason says. As the company grew and consumed more of its founders' time, Paulus and Gleason turned to another new commercialization tool offered by the Laboratory—part-time entrepreneurial leave. Through the program, ORNL employees can split their time between work at the Laboratory and efforts to build a new company, keeping partial pay along with medical, vacation and other benefits. Both say without that umbilical cord, they probably would not have taken a chance on ImTek.

Even with the $3.75 million sale of their company, Gleason and Paulus have not fully cut their ties to ORNL. Both are now on full-time entrepreneurial leave, allowing them the option to return to the Laboratory and keep their time-of-service—within a period of three years.

As Gleason and Paulus positioned ImTek for sale, with the help of the CEG, the founders approached CTI Molecular Imaging, a Knoxville-based developer of positron emission tomography (PET) technology. ImTek simultaneously was negotiating with Philips, then a sales partner.

The timing was perfect. CTI had already begun negotiations with Concorde Microsystems, a Knoxville-based leading manufacturer of laboratory animal PET scanners. The ImTek product line fit well with Concorde's

(continued on p. 10)

Inveon, an updated version of ORNL-born ImTek's early micro-CAT scanners that offers PET and single photon emission computed tomography (SPECT) components as well, is now being sold by Siemens.

Wireless Meter Systems

- **Company:** SmartSynch
- **Founded:** 1985, moved to Jackson, Miss., in 2000 and launched current business.
- **Headquarters:** Jackson, Miss.
- **Relationship to ORNL:** Received investment from Battelle Ventures, working with ORNL researchers to develop new products.
- **Product Description:** The company's core product, the SmartMeter System, monitors utility usage in real-time from electric meters using public wireless networks and the Internet. The system allows utility customers to better manage electricity use, saving them more than $9 billion.
- **Customers:** More than 50 major utility customers
- **On working with ORNL:** "We have an ongoing conversation with different research groups further back in the technology pipeline that are all working on technology relevant to electric transmission and distribution. We would like to commercialize technology that's not quite ready yet."—*Henry Jones, SmartSynch chief technology officer*

Henry Jones is director of research and development at SmartSynch, a Mississippi-based company working with the Laboratory on utility-related technologies.

(continued from p. 9)

products. In November 2004, ImTek sold to CTI. Four months later, CTI announced its own sale to Siemens for $1 billion.

Through the merger process, the CEG assisted ImTek, remaining involved through the final negotiations and signing of the deal with CTI. When ImTek sold, the company's founders were not the only ones smiling. Through earlier license negotiations, UT-Battelle had taken a 4 percent equity stake in the company. ORNL employs equity positions in addition to the typical up-front fees and royalty agreements as a way to bring additional revenues back into the laboratory.

"Any licensing organization has more flexibility in doing deals, especially with start-up companies, when equity can be accepted in lieu of cash," says Casey Porto, director of technology transfer for ORNL's Technology Transfer and Economic Development office. "The deal is often one of mutual benefit, since most start-up companies would also like to be able to point to an organization such as ORNL and claim them as a shareholder."

These tools, along with success stories like ImTek's, help create the "entrepreneurial spirit" UT-Battelle is hoping to foster at the Laboratory, says ORNL Director Jeff Wadsworth. "We have certainly encouraged that at the Laboratory," he says. Citing ImTek, he added, "People have taken entrepreneurial leave. We provide high visibility for technology transfer awards. We are trying to convince our staff that we value that piece of the Lab as much as we value any others." ®

A CAPITAL IDEA

Something start-up companies require besides great ideas and plenty of hard work is money—often, lots of it. Because in East Tennessee local sources of venture capital have historically been hard to come by, UT-Battelle officials identified seed funding as a critical ingredient needed to generate more business in the region.

When former Tennessee Economic Development Commissioner Alex Fischer joined Oak Ridge National Laboratory four years ago, "he recognized there is a piece of the Battelle strategy that should include venture funding," says ORNL Director Jeff Wadsworth. "At that time, Carl Kohrt, the newly appointed CEO of Battelle, had a similar vision. He brought the notion to the board and he suggested that Battelle should create a venture fund, not only for the company's own technologies but for any technologies in the domains of Battelle's interest."

As a result, Columbus, Ohio–based Battelle created Battelle Ventures, a $150 million, independent venture capital fund aimed at providing promising technology companies, in markets related to Battelle's missions, the equity dollars needed to commercialize their products. Included in the fund's scope is technology developed at ORNL and the four other national labs Battelle helps to manage.

Battelle Ventures has invested in 10 companies thus far, focusing on the information technology, homeland security, energy and nanotechnology markets. One company, New Jersey–based Mul-

TECHNOLOGY *spotlight*

Hybrid Solar Lighting

- **Company:** Sunlight Direct
- **Founded:** 2004
- **Headquarters:** Oak Ridge, Tenn.
- **Relationship to ORNL:** Licensee
- **Employee Founder:** Duncan Earl
- **Product Description:** Using optical fibers and a solar rooftop collector, sunlight is piped into commercial buildings and integrates with artificial light for energy savings and improved lighting quality.
- **Customers:** Beta testers include Wal-Mart, BP, Aveda, the Naval Exchange shopping complex in Hawaii. First commercial product to be introduced in 2007.
- **On starting a company:** "As hybrid solar lighting moved toward commercialization, we were trying to license the technology to other companies, but it wasn't yet ready for the mass market. There wasn't an outside company ready to take the technology from prototype to product, so I did it myself. I've since hired a CEO, and we're rolling out beta tests across the country."—*Duncan Earl, Sunlight Direct chief technology officer*

Knoxville-based Sunlight Direct's technology is made up of a satellite-guided rooftop solar collector and fiber optic bundles, pictured, that deliver sunlight directly into a building.

tispectral Imaging, replaced its original infrared camera detection technology with infrared-sensing microcantilever arrays licensed from ORNL. (See sidebar on p. 12.)

Fischer says Battelle Ventures has modified the fund's approach to investing since its inception in 2003. While promising, many technologies at ORNL and other labs are simply too early in development to warrant traditional venture dollars, he says. "There has been a shift in approach from not just simply starting up companies out of the labs but going to what we call a technology injection model. This model takes established companies and injects lab technologies as a differentiator for those companies in which Battelle Ventures is investing."

Such an example is SmartSynch, one of Battelle Ventures' early investments. The company produces wireless smart meter systems for utility customers and has been working with ORNL researchers to develop technologies the company could then license. (See Technology Spotlight on p. 9.)

Henry Jones, director of research and development at Jackson, Miss.–based SmartSynch, followed the advice of the Laboratory's tech transfer office when it came to gleaning technologies from ORNL. "They said, yes, you can come in, you can see if we have an answer to a particular problem that you're having. If those are your expectations, you might be disappointed. But if you are really trying to develop a relationship with the Lab to work on future products then you can definitely get that at Oak Ridge," Jones says.

The debut of Battelle Ventures has served to expand the availability of local venture capital. In 2005, a group of Knoxville business leaders created a $35 million fund, Innovation Valley Venture Partners, to co-invest with Battelle Ventures, including investments prior to IVP's creation. Within the last three years, Technology 2020—which operates UT-Battelle's Center for Entrepreneurial Growth—has raised private money and secured federal matching dollars to create two funds, the Southern Appalachian Fund and Meritus Ventures, that bring more than $40 million in start-up capital to underserved areas of the Southeast.

"What we have done with Battelle Ventures and Innovation Valley Partners will have a lasting impact," Fischer says. With other funds coming on line, he adds, "you see all that effort beginning to take root in the region."

ANOTHER TOOL IN THE TOOLBOX

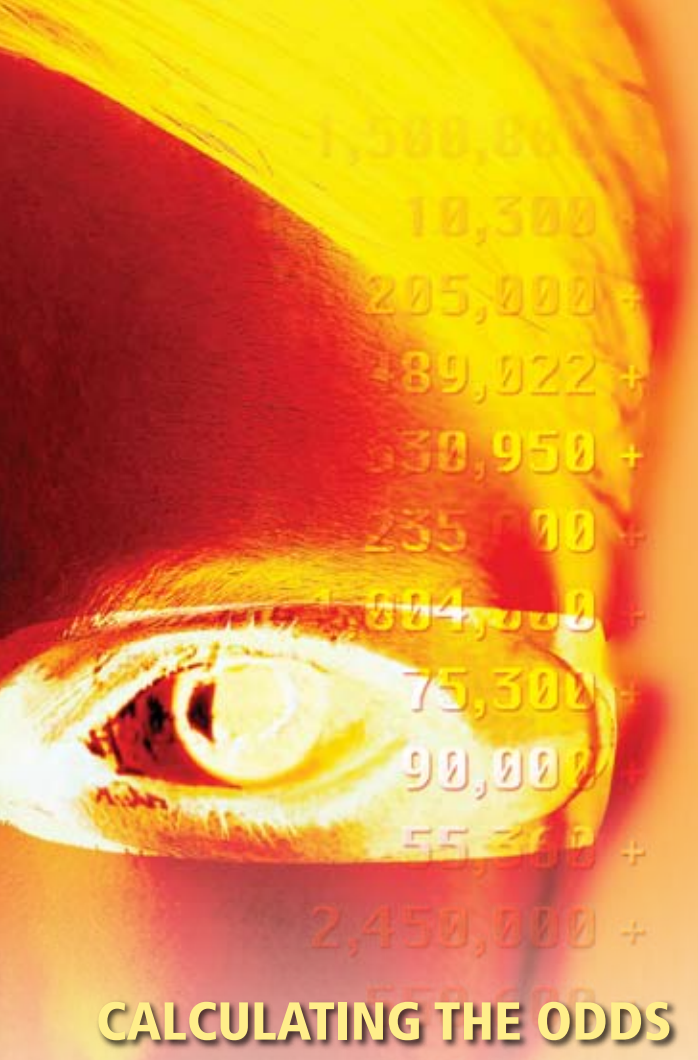
However compelling the technology, a gap often exists between government-funded research and its transfer to the marketplace. As a research project nears completion, federal dollars often dry up before an invention has progressed enough to spin out as a commercial product. Enter technology maturation funds, the means by which many promising technologies make needed advances toward becoming a commercial product.

Two sources of tech maturation funding are available to researchers: One is government dollars, generated by revenues Oak Ridge National Laboratory receives from previously licensed technologies, including royalties. The second source is "privately funded technology transfer," (PFTT) funded by UT-Battelle, which receives the returns from a technology after it is licensed. These private funds can be supplemented by Battelle corporate dollars and matching investments from the University of Tennessee.

In the case of government funded tech maturation, researchers apply for grants through an annual process, reviewed by the Laboratory's invention disclosure review committee, which selects the recipients. Awards typically average about $50,000. Privately funded maturation funds are available on an open-call basis, with an invention undergoing a business analysis to determine market potential before a final determination is made whether to supply private funding. UT, Battelle and, finally, the Department of Energy, must formally approve the arrangement before funding is provided. In addition, PFTT pays for patent and marketing costs as the technology progresses.

As part of last year's contract renegotiation with the Department of Energy, UT-Battelle agreed to invest $3.5 million between 2005 and 2010 in the Laboratory's PFTT program. Battelle can contribute separately to that pot. Likewise, the University of Tennessee has the option to put funding into PFTT projects. UT recently committed to match dollar for dollar the PFTT projects in which the university chooses to participate.

Of the returns from PFTT, 51 percent goes back into ORNL operations, while 49 percent can be used by UT-Battelle at other facilities for scientific R&D or education. "Having PFTT maturation resources at our disposal lets us take a strategic perspective in building portfolios of PFTT technologies," says Brett Bosley, commercialization manager in the Laboratory's Technology Transfer and Economic Development office. "This approach can build on the scientific research to deliver great commercialization outcomes," he says, noting how the private money also expands the Laboratory's total pool of dollars available to prepare new technologies for market. With private funding now available, "we have another tool in the toolbox," he says.



CALCULATING THE ODDS

A licensee of ORNL technology receives a venture capital investment.

Battelle Ventures has already placed a bet on ORNL technology. The $150 million venture capital fund launched in 2003 by Battelle Memorial Institute of Columbus, Ohio, has invested in ORNL licensee Multispectral Imaging, Inc., of Parsippany, N.J. MII's mission is to build high-sensitivity, low-cost infrared camera detectors that enable soldiers and firefighters to "see" objects at night or in smoky areas.

The detector will incorporate ORNL's infrared-sensing microcantilever array technology invented by Thomas Thundat, Eric Wachter and Bruce Warmack. MII's engineering team designed and fabricated a capacitive sensing readout chip integrated with the MII-designed microcantilever sensor array. ORNL's Panos Datskos helped optimize and test prototype microcantilever sensor arrays.

A somewhat surprising aspect of the investment is that MII, a 2003 startup, received venture capital funding even though the managers had just changed technology horses mid-stream.

"The company had the courage to abandon the original infrared sensing technology with the blessing of its investors and switch to ORNL technology," says Russ Miller, commercialization manager in ORNL's Technology Transfer and Economic Development office. "Battelle Ventures and the company's original investors had confidence in MII's new direction."

In an array of 160 × 120 silicon microcantilevers, each 50-micron-long microcantilever, which represents a pixel, bends in proportion to the intensity of the infrared radiation striking it. Every object gives off infrared light; the hotter the object, the greater the number of infrared photons emitted. Competing infrared sensing technologies can be either cooled to cryogenic temperatures or operated at near room temperatures. The "uncooled" ORNL microcantilever technology operates at room temperature, and because this technology requires no cooling, it uses less energy than most competitors, lowering the cost. MII's capacitively sensed microcantilever array offers high resolution, low noise and impressive dynamic range, allowing users of the future camera to take finely detailed pictures of objects with high sensitivity in both brightly lit and dark, smoky rooms.

MII first licensed ORNL's microcantilever technology and then licensed two related inventions by Datskos and Slobodan Rajic. Later the company entered a work-for-others agreement with ORNL to get help in characterizing the sensitivity of MII's test devices and measuring how much a cantilever bends with changes in infrared light intensity.

ORNL's microcantilever technology patents previously had been licensed to Sarcon Microsystems, an East Tennessee company that closed in 2004. Sarcon had not solved significant engineering problems with the readout circuitry before the company's operating funds were exhausted.

"UT-Battelle recovered the rights to the microcantilever technology after terminating the Sarcon license," Russ Miller says. "Soon thereafter we re-licensed the patented microcantilever technology to Multispectral Imaging."

Matt Miller, MII's founder and chief executive officer, learned about the ORNL technologies when he met former Sarcon managers, including Scott Hunter. Hunter worked at ORNL in the 1980s, learned about ORNL's microcantilever sensors as a Consultec Scientific employee, cofounded Sarcon Microsystems to commercialize the ORNL technology and became Sarcon's chief technology officer.

Miller was a senior executive for NextWave Communications, Viacom, Perkin-Elmer Corp. and General Instruments. He began his career at RCA Laboratories, now the Sarnoff Corp., a company based in Princeton, N.J., that was a founding shareholder in Sarcon. Miller holds a Ph.D. in engineering from Princeton University. Princeton is the home of Battelle Ventures.

Miller encouraged his engineering team to take a fresh look at the ORNL technology. Hunter shared with MII the technology's potential and Sarcon's engineering problems. Hired as CTO, Hunter guided his MII team on the redesign.

Incredibly, in one year, the MII engineering team made arrays of uniformly released microcantilever sensor structures that have up to five times the responsivity of Sarcon's devices. The microcantilevers bend out of the sensor plane, avoiding sticking problems that Sarcon encountered. MII redesigned and fabricated the electronics to eliminate readout problems that caused low sensitivity.

The ability of this ingenious team to quickly solve difficult technical problems probably added to the investors' confidence in Matt Miller, making Multispectral Imaging seem like a good bet for Battelle Ventures. ®

SIDE BY SIDE

A new research park at ORNL will increase access to technology.

The scene is surreal. Researchers from Oak Ridge National Laboratory and engineers from Fortune 500 companies huddled over cups of coffee to discuss their latest cooperative research. Modern office towers and green space where toxic waste sites and 1940s-era Quonset huts once stood. A casual mix of jeans and backpacks, khakis and polos, suits and ties.

This is the vision for a new Oak Ridge National Laboratory Innovation Valley Science and Technology Park.

Unveiled in May 2006, with construction on the first facility set to begin this fall, the S&T Park is the latest chapter in ORNL's modernization efforts. The park provides space where companies doing research at ORNL, partner universities, start-ups built around Laboratory technologies and ORNL contractors can do business within a short distance of Laboratory researchers and Department of Energy user facilities such as the Spallation Neutron Source, the Center for Nanophase Materials Sciences and the High Flux Isotope Reactor.

Partners in the project include UT-Battelle–Oak Ridge National Laboratory; the Community Reuse Organization of East Tennessee, an economic development organization to which the park property has been leased; the University of Tennessee, which will co-locate in the park; Technology 2020 and its Center for Entrepreneurial Growth, which is funded by UT-Battelle and will also likely locate onsite, and the Innovation Valley Nano Initiative, a regional initiative to create a nanotechnology business hub in East Tennessee.

Two local companies, Pro2Serve and Holrob Investments, have agreed to construct the park's first two $15 million, 100,000-square foot buildings onsite. Pro2Serve is an Oak Ridge firm that contracts engineering services to the Laboratory and other DOE customers—work that includes commercialization of ORNL-developed, national security-related technologies. Holrob Investments is a private development company that will lease out the space. Plans call for a total of 40 acres to be transferred by DOE to the Community Reuse Organization of East Tennessee and developed for the technology park and associated green space.

ORNL anticipates the park's future occupants could include groups from ORNL partner universities, research and development satellite offices for industrial partners of the Laboratory, start-up companies founded by ORNL researchers or licensees and a nanotechnology research center under development by Technology 2020 as part of the Nano Initiative. The research center would offer low-cost access to dedicated micro/nanofabrication facilities and shared access to higher-end, state-of-the-art fabrication facilities at ORNL. The center also would serve as a link between basic research being done at the Spallation Neutron Source and nanocenter and the business community. ORNL's Technology Transfer and Economic Development offices would also likely relocate to space in the park.

A member of the Association of University Research Parks, the technology park marks a first for national laboratories across the country by bringing companies inside the fence. The model is one begun by universities noted for success in technology transfer, whose track record UT-Battelle is working to emulate.

"We are the first lab to have a research park in a secure area," says Tom Ballard, director of economic development and partnerships in ORNL's Technology Transfer and Economic Development office. "The park is a statement that we really do value commercialization of our research. The park's location also says we want to see things done locally when they can be."

Some question whether private firms will want to locate on a federal government site, given the accompanying security and restrictions. On the other hand, higher security requirements can be a selling point for certain businesses, says Alex Fischer, director of ORNL's Technology Transfer and Economic Development office. "For some types of companies, a location behind the fence is ideal," he notes. "Requiring visitors to provide identification and sign in to get a visitor's pass is commonplace in the business world. In today's climate, it is a positive thing for R&D and national security companies to work in a setting that has a higher level of security." ®

A KEY MISSION

Assisting industry helps both the Laboratory and U.S. competitiveness.

The Department of Energy's national laboratories contain some of the world's most advanced technologies. In recent years, DOE's mission has placed a renewed focus on supporting America's economic competitiveness by making these technologies more accessible to industry. Oak Ridge National Laboratory's strategy in pursuit of this mission has two distinct components. One strives to identify and promote technologies that can form the basis of new companies. The second, and equally valuable, activity, uses the Laboratory's vast capabilities to solve technological problems and offer new opportunities for existing industry.

By assisting industry, ORNL also helps itself. Dozens of companies have sponsored important research at ORNL, resulting in new scientific discoveries and inventions. ORNL researchers also have published scientific papers and received patents and awards as a result of their work supported by industry. Industry, in turn, has transformed some of these new ORNL-developed technologies into commercial processes and products that are marketed for a profit. UT-Battelle, which manages ORNL for the Department of Energy, licenses these patented technologies to industry in exchange for licensing fees and royalties, which represent a percentage of companies' sales.

The scope of industrial partnerships is impressive. ORNL will help industry become more energy efficient through the incorporation of wireless sensors and high-temperature superconductors. ORNL and computer manufacturers are developing the world's most powerful supercomputer for open scientific research. In one of the most significant endeavors, Laboratory researchers are helping lay the groundwork for the emerging fuel cell industry.

Fuel cells are viewed by many as the power sources of the future because of their ability to generate pollution-free, climate-friendly electricity for buildings and vehicles. Barriers to widespread use of fuel cells have been high manufacturing costs and performance issues related to materials used to make the device.

Under a work-for-others agreement, ORNL researchers led by Tim Armstrong and Rod Judkins are conducting research for Worldwide Energy, Inc., that may help topple the barriers. "We have developed a porous-metal-supported solid oxide fuel cell, an electricity-generating device based on ORNL's inorganic membrane technology," Armstrong says. "Solid oxide fuel cells operate at high temperature and achieve high fuel efficiency. Thus, they are ideally suited for stationary distributed power generation for commercial and military uses."

The fuel-cell element consists of a tubular metallic support structure with interior layers of a conventional nickel-yttria-stabilized zirconia anode, an yttria-stabilized zirconia electrolyte, and a selection of possible cathodes. The novel design enables these fuel-cell elements to be manufactured at significantly lower costs than conventional flat-plate or planar designs. The robust structure of the porous-metal-supported SOFC element ensures long performance life.

Solid oxide fuel cells produce electricity through electrochemical reactions involving fuel, such as methane or hydrogen, at the anode and oxygen at the cathode. Because the ORNL–Worldwide Energy device can be operated at high temperature, the fuel cell can be integrated into a number of combined heat and power applications with overall efficiency in excess of 80 percent. A hybrid configuration in which electrochemical cycles are combined with Brayton-cycle turbine technology to convert at least 60 percent of the fuel's chemical energy into electricity is also possible.

Several of the concept's innovative features made possible by ORNL-developed fabrication methods minimize cracking, deterioration and the possibility of leaks in the fuel-cell assembly. The ORNL technology has been licensed to Worldwide Energy, which has determined that several fuel-cell configurations are feasible and commercially viable.

Portals into the Lab

The work-for-others agreement is one of three primary mechanisms by which industry can take advantage of ORNL's unique expertise and equipment to solve an industrial research problem. The other two are the cooperative research and development agreement (CRADA) and the user agreement.

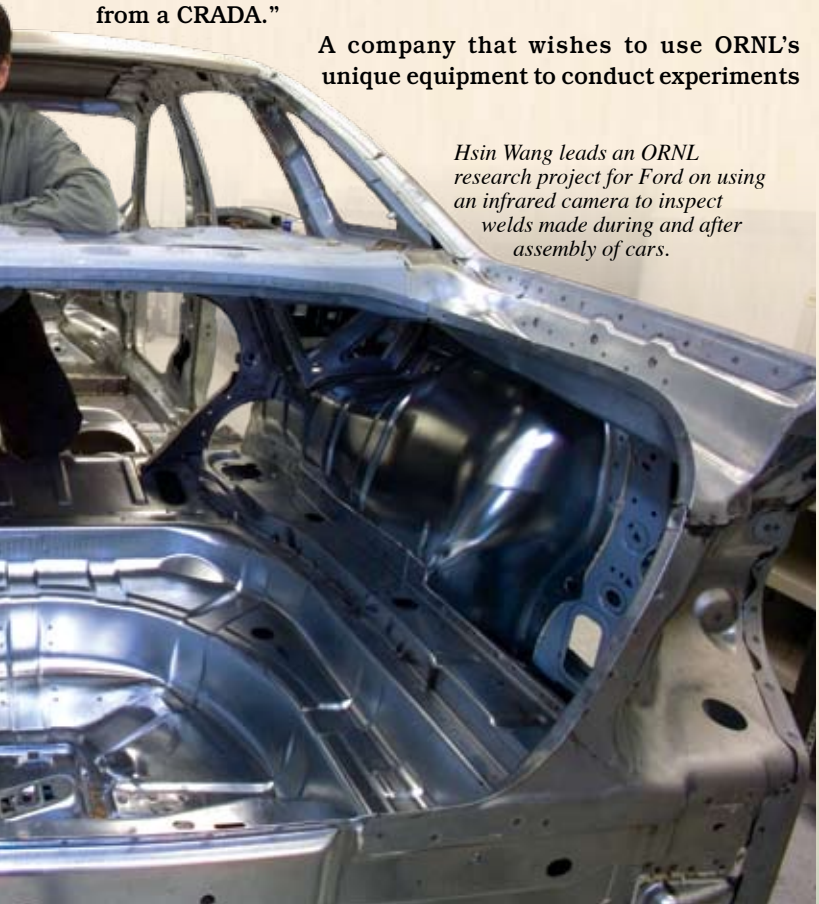
Tom Ballard, head of partnerships and economic development in ORNL's Technology Transfer and Economic Development office, puts it simply, "I ask a potential industrial customer three questions. 'Do you want us to do work for you, do you want to work with our researchers, or do you want to work in our facilities?'" Pending agreement by the research manager, if the customer wants to pay ORNL to solve some problems, as in the example above, then the preferred mechanism is likely a work-for-others agreement.

or characterize a material would utilize a user agreement as the portal of entry to the Laboratory. Under a user agreement, a company can send its own staff to conduct research in one of DOE's designated user facilities at the Laboratory. ORNL personnel provide support to complete all essential elements of an experiment or do routine maintenance and repairs.

Alex Fischer, director of the Technology Transfer and Economic Development office, says, "In a user facility agreement we show the company's researchers how to use unique instruments. So long as the company's researchers publish their findings in the open literature, the company is not required to pay a fee for use of the government facility at ORNL provided that the facility has a base of funding support. Should the company wish to keep the research results proprietary, the company pays a fee negotiated in the contract." CRADAs and work-for-others agreements can lead to licenses in which a company, for purposes of profit, obtains the right to use patented technologies developed by ORNL researchers.

"If an industrial firm seeks to conduct research in collaboration with ORNL researchers and share the costs of the joint research, sometimes with DOE, then a CRADA is probably the preferred mechanism of interaction," says Frank Damiano, team leader for sponsored research in TTED. "The purpose of a CRADA is to collaborate on a research problem and pool the R&D results to bring a specific technology to the marketplace. Scientific papers, patents and licenses may arise from a CRADA."

A company that wishes to use ORNL's unique equipment to conduct experiments



Hsin Wang leads an ORNL research project for Ford on using an infrared camera to inspect welds made during and after assembly of cars.

High-tech Energy

The largest ORNL-industry agreement is the $28 million CRADA with the United States Enrichment Corporation. ORNL researchers led by Wayne Manges are helping USEC researchers develop what they hope will be the world's most efficient method of producing a fuel enriched in fissionable uranium for nuclear power plants, which provide 20% of America's electricity. The ORNL-USEC team pursues a mission of creating economically attractive, high-speed gas centrifuge machines and processes for enriching uranium hexafluoride gas in normally scarce, fissionable uranium-235. Gas centrifuges use one-tenth the electrical power required by gaseous diffusion, the traditional method used in the United States for 60 years for uranium enrichment. ORNL research teams have improved centrifuge technology by using carbon-fiber composites for centrifuge components, smaller motors operated by power electronics, and a centrifuge design optimized by ORNL's state-of-the-art measurement technology and modeling and simulations using high-performance computing. The centrifuge machines are being built at a Boeing facility in Oak Ridge and are being tested on five improved testing stands located at East Tennessee Technology Park, where gas centrifuge technology was first tested decades ago.

One of DOE's energy missions encourages the development of a domestic industry for the manufacture of high-temperature superconducting (HTS) wire and devices. HTS wire enables underground cables, transformers, motors and generators to carry more current

with no resistive losses, allowing these technologies to be more compact. ORNL has been supporting the DOE project for years, partly through CRADAs between industry and the Laboratory's High-Temperature Superconductivity Program. Acting program manager Dominic Lee says, "We are currently working on eight CRADAs, including work with domestic HTS wire manufacturers such as American Superconductor Corporation and SuperPower Inc. We also conduct cable, motor and transformer demonstration projects with companies such as Southwire, Rockwell Automation and Waukesha Electric Systems."

The licensure of ORNL technologies and use of Oak Ridge research findings have positioned American Superconductor to sell second-generation, high-temperature superconducting (2G HTS) wire for demonstration projects in several countries. This wire is made in part by using ORNL's rolling assisted biaxially textured substrates (RABiTS) technology.

ORNL has two CRADAs with SuperPower, which uses different deposition techniques to lay down its textured magnesium oxide (MgO) template and the high-quality, yttrium-barium-copper oxide (YBCO) superconductor layer, which sandwich an ORNL-developed buffer layer Lee's group was proud that SuperPower recently beat their Japanese competitor in ampmeter wire performance, a key superconducting figure of merit for long wires. SuperPower announced this world record as a result of creating a wire 322 meters long that can carry 219 amperes per centimeter-width.

Lee's group is also working with Southwire Company in a test of a 200-meter HTS cable. Southwire, one of the largest cable and building wire manufacturers in the world, holds a substantial share of the global transmission and distribution cable market. The Columbus cable project—a partnership of Ultera (a joint venture of Southwire and NKT Cable of Denmark), American Electric Power, ORNL, American Superconductor and Praxair—uses a triaxial cable design, jointly invented by ORNL and Southwire. Because of the cable's compact design, the amount and cost of HTS wire are reduced by half, making this HTS cable project the least expensive in the world.

"Part of DOE's energy security mission is to keep the HTS industry domestic rather than offshore," Lee says, adding that ORNL is helping DOE develop superconducting motors, cables, transformers and fault current limiters. "The Navy needs HTS motors that are smaller and weigh less for the integrated propulsion systems envisioned for an All-Electric Navy. Superconducting cables, transformers and fault current limiters working together would make a more secure and reliable national electric grid."

Automotive Partners

Residing in a key state for automotive parts manufacturing, ORNL works closely with the automotive industry, often through CRADAs and user agreements at the Laboratory's user facilities. A number of companies, including first and second tier automotive suppliers, conduct or fund automotive research at ORNL's High Temperature Materials Laboratory and the National Transportation Research Center. The two facilities contain an assortment of unique equipment for characterizing materials and testing devices.

According to Arvid Pasto, HTML director, "Industrial firms such as Caterpillar, Cummins Engine and Detroit Diesel have been using the HTML to find ways to control emissions of particulates and nitrogen oxides to meet new Environmental Protection Agency limits. Under a user agreement, an industrial firm has 10 days to use HTML to solve a problem. We have a CRADA with Cummins Engine to help the company improve the longevity of a catalyst needed for emission control."

The research is diverse. The Ford Motor Company has been working with HTML researchers to determine if an infrared camera can be installed on Ford's assembly line to assess the quality of welds while being made on each car.

Daimler-Chrysler came to HTML because of a mystery: a small percentage of one automotive component continued to fail unexpectedly. None of the standard characterization techniques yielded an answer. But when a specimen was placed in HTML's Auger spectroscopy instrument, a Daimler-Chrysler researcher discovered a thin layer of phosphorus, which embrittles metal parts. The component's manufacturer later discovered that an incorrect atmosphere in the furnace used to heat-treat the components had prevented uniform dispersion of phosphorus throughout each part.

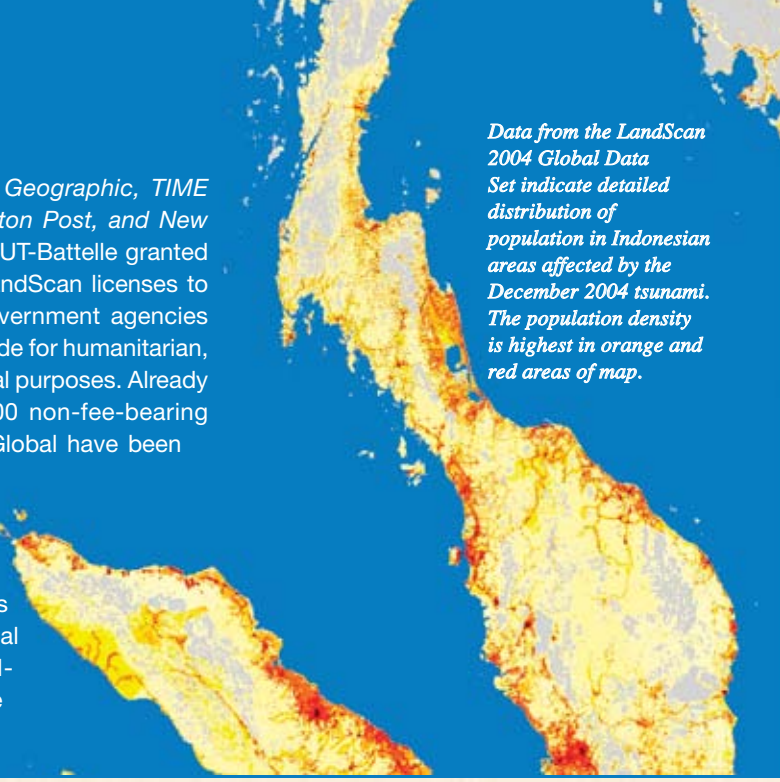
Closer to home, ORNL helped solve a problem for Industrial Ceramics Solutions, a small company in nearby Knoxville that manufactures diesel soot filters. Starting in 2007 EPA will require all American diesel-powered trucks to control soot emissions, and some manufacturers will use the filters to reduce particulate releases to the air. The company's owner learned that his filter product occasionally cracks and lets the soot escape, undermining filter performance.

"We helped him understand what happens to the filter to make it crack," Pasto says. "Our insights allowed him to come up with a better fabrication process that makes the filters last longer."

For ORNL and its industrial partners, the legal mechanisms for interactions—work-for-others agreements, CRADAs and user agreements—are designed to benefit both parties. As a result, industries throughout Tennessee and the United States have benefited in multiple ways, boosting America's scientific and economic competitiveness. ®

HUNDREDS OF LICENSES

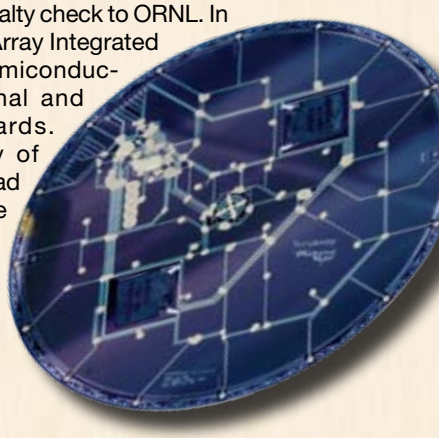
After the Indian Ocean tsunami of December 2004, ORNL's LandScan "High Resolution Global Population Data Set" had a huge impact. This award-winning population distribution database helped government agencies estimate how many people were potentially affected and where to send emergency supplies. LandScan, which refines the best available census data using geographic information system and remote sensing technologies, has emerged as an international community standard for disaster response, humanitarian relief, sustainable development and environmental protection. Today LandScan is one of the most licensed of ORNL technologies. In fiscal-year 2005, numerous organizations obtained commercial, revenue-generating licenses from ORNL. High-profile users include *National Geographic, TIME magazine, the Washington Post, and New York Times.* In FY2005, UT-Battelle granted 123 non-commercial LandScan licenses to the United Nations, government agencies and universities worldwide for humanitarian, research and educational purposes. Already this year more than 100 non-fee-bearing licenses to LandScan Global have been issued. Research using LandScan has resulted in publications on subjects of interest to policy decision makers such as predicted effects of global climate change. LandScan truly has a positive human influence.



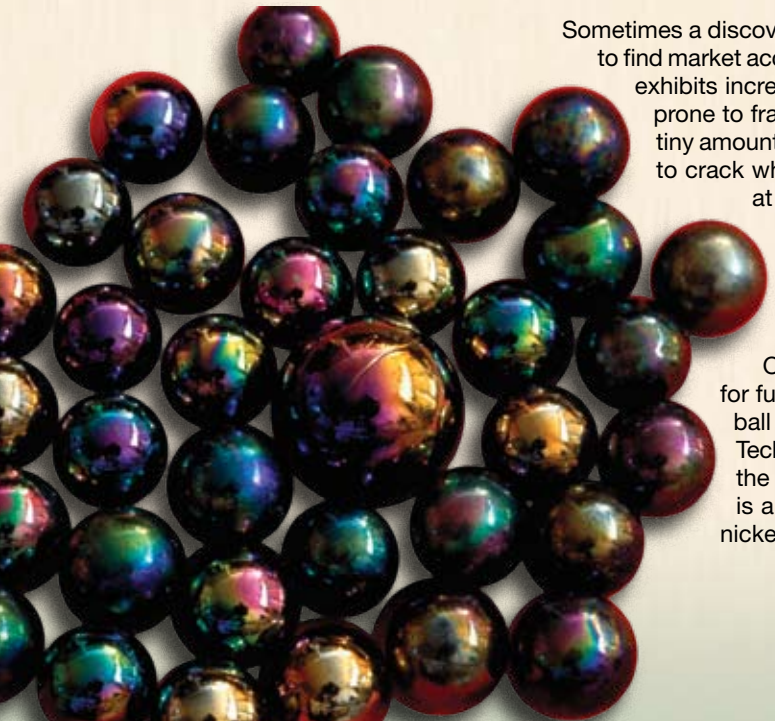
Data from the LandScan 2004 Global Data Set indicate detailed distribution of population in Indonesian areas affected by the December 2004 tsunami. The population density is highest in orange and red areas of map.

A MARKETABLE SOLUTION

In mid-1994 Bob Lauf and Don Bible attended a SEMATECH workshop in Austin, Texas, hoping to promote their variable microwave furnace technology—previously licensed to Lambda Technologies—for future semiconductor wafer fabrication. In a technical session they learned interesting facts about SensArray's tool used by semiconductor manufacturers to determine whether silicon computer chips on wafers are being heated at a uniform temperature. They saw that the tool was dotted with sensors whose wires merge into a "cat's tail" plugged into a temperature measurement device. They heard that the physical connection limits wafer movement and that the wires could alter the temperature measurement. At the Austin airport, Lauf and Bible sketched a wireless wafer concept. Back in Oak Ridge, they wrote an invention disclosure along with Carl Sohns, who built a breadboard prototype of a wireless wafer. Tiny temperature sensors on this breadboard are wired to a control chip, which could wirelessly transmit temperature readings to a base station linked to the wafer furnace control system. A patent was issued in 1999. "This patent surfaced two years later when wireless technology blossomed and SensArray inquired about our technology," Lauf says. In 2001 SensArray licensed the ORNL patent and in 2004 sent the first royalty check to ORNL. In 2005 the SensArray Integrated Wafer won Semiconductor International and R&D 100 awards. By then many of these devices had been sold to the world's leading semiconductor manufacturers.



TAKING THE LONG VIEW



Sometimes a discovery with superior technical traits can take as long as two decades to find market acceptance. Since the 1930s metallurgists knew that nickel aluminide exhibits increased strength with rising temperature. But the alloy is brittle and prone to fracture. In 1982 an ORNL group led by C. T. Liu found that adding tiny amounts of boron to nickel aluminide made the alloy ductile and less likely to crack when formed into shapes. The alloy recipes were further improved at ORNL by adding trace amounts of chromium, molybdenum and zirconium. After 20 years ORNL's alloy finally found a market. Tests showed that modified nickel aluminides last longer than steel as furnace rolls to carry steel plates for bridges, for example, into metallurgical furnaces. As a result, the steel industry uses less energy, avoids plant shutdowns and makes a better product. ORNL's nickel aluminide lasts twice as long as chromium-nickel steel for furnace furniture—trays and fixtures on which automotive valves, ball bearings and gears are heat-treated in a furnace. Duraloy Technologies, BAE Systems and Alcon Industries, Inc. licensed the DOE-funded technology. Delphi Automotive Systems is a loyal customer. With extraordinary persistence, nickel aluminides have found their niche.

AN IMPRESSIVE PATENT PORTFOLIO

Amit Goyal holds 50 patents, giving ORNL dominance over a key element in commercial high-temperature superconducting wire.

As a graduate of the distinguished Indian Institutes of Technology, the only university in the world to which *Business Week* devoted a special issue, ORNL researcher Amit Goyal sometimes wonders if he chose the wrong business. "I read that, during the dotcom boom, 40 percent of all dotcom companies started in the Silicon Valley were founded by IIT graduates," says Goyal. "Some of these graduates have a materials science degree like me."

Goyal still has a strong chance to realize the same kind of financial reward as his fellow IIT alumni. He is one of ORNL's most prolific inventors. He holds 50 issued patents in his portfolio with many more pending.

American Superconductor Corporation owns the rights to at least 16 of Goyal's patents. American Superconductor is the world's largest company focused on manufacturing second-generation (2G), high-temperature superconducting (HTS) wire for transmission cables, transformers, motors, generators, electromagnets, fault current limiters and levitating fast trains.

A recent news release stated that the company has sold more than 2.7 kilometers of HTS wire to customers working on demonstration projects in eight countries. The wire is fabricated in part using ORNL's patented technique for making the "roadbed" for the superconductor. If any of the possible applications for American Superconductor wire are adopted worldwide, Goyal and ORNL stand to reap significant revenues in the form of royalties. The accompanying publicity for the Laboratory, while not measured in dollars, would be equally valuable.

"Having such a prolific inventor on our staff certainly enhances ORNL's reputation within the scientific community," says Casey Porto, director of technology transfer at the Laboratory. She notes that Goyal is a UT-Battelle Distinguished Inventor who represented ORNL last year at Battelle's awards ceremony for inventors from the five Department of Energy national laboratories that Battelle helps to manage.

In the early 1990s Goyal led the development at ORNL of rolling assisted biaxially textured substrates (RABiTS). These metallic templates, working through appropriate buffer layers, align the deposited crystals of yttrium, barium, and copper oxides (YBCO) so they act as high-temperature superconducting films. RABiTS, an acronym invented by Goyal, is the approach adopted by American Superconductor for the manufacture of 2G HTS wire. In January 2006 American Superconductor announced a focus on the manufacture of 2G wire, followed in May by a news release stating the company would no longer make first-generation HTS wire.

Seeking Protection

The breadth of Goyal's 50 patents is impressive. "The original patent dealt with one way of making biaxially textured flexible substrates," he says. "Then, to make our patent portfolio impenetrable, we decided to find other ways of making these substrates that were not covered in our original patent."

Goyal was concerned that researchers in other companies and countries would seek a way around the ORNL patents. He imagines an inventor saying, "I like what you have done, and it's fascinating. But I can make the same thing you do in a different way that's not covered in your patent."

As the work progressed, Goyal and his colleagues recognized the need for substrates with different physical properties. They forged stronger substrates including those that exhibit no magnetism when a current runs through the coated conductor. Goyal sought patent protection for these materials. Most of the patented substrates are made of alloys that can be textured when properly processed. American Superconductor uses nickel-tungsten alloy, which is less magnetic than the other substrates.

"Our original substrates were polycrystalline substrates where the three axes of all the grains were fairly well aligned and the substrate resembled a crystal with a large mosaic," Goyal says. "We later found several ways of making single-crystal substrates containing only a single grain that may have applications beyond superconductivity. We subsequently obtained patents on different kinds of buffer layers of interest and of value to the application. We have additional patents on other device layers that can be deposited on epitaxial buffer layers over RABiTS substrates."

Buffer layers shield the YBCO layer from harmful interactions with the substrate. At the same time buffer layers transfer the substrate texture to the YBCO layer, aligning the film's crystalline grains sufficiently to carry current without resistance.

Goyal's patent portfolio covers all aspects of the substrates, buffer layers and superconductor that can be used for 2G HTS wire. "The portfolio includes various ways of making these layers that someone else could conceive of so they would not necessarily have to license our technology if they want to make HTS wire," he says. "We wished to protect our technology from people who could get similar results coming from a different angle."

Amit Goyal in the "clean room," where nickel-tungsten substrates are rolled to make a "roadbed" for high-temperature superconducting wire

RABiTS Riches

The patents for the superconducting wire technology competing with RABiTS are owned by a variety of people and organizations in Japan, Germany and the United States, particularly Lawrence Berkeley National Laboratory, Stanford University and Los Alamos National Laboratory. Because ORNL has dominance over the RABiTS patent portfolio, companies desiring to make products using 2G HTS wire will find licensing ORNL's superconducting wire technology to be simpler, faster and cheaper.

Goyal claims he has "20 to 30 invention disclosures in other areas," such as diamond films, electronic materials and chemical vapor deposition, that have no patent protection. These inventions fall in areas in which ORNL lacks major programs, so UT-Battelle at present has little incentive to pay for patenting these innovations. If UT-Battelle declines to file for a patent on a particular invention, the Department of Energy has the option to apply for a patent on the related ORNL technology. If DOE also declines, the inventor has the option to file a patent application if willing to invest the required money and time. Goyal says he may eventually file for some patents on his own.

"I appreciated the need for a patent portfolio that provided ORNL with broad patent coverage but I had a hard time selling my idea internally," Goyal says. He eventually succeeded. The ultimate winners could be not only the inventor but also ORNL and UT-Battelle. ®

SUPERCONDUCTOR CURE

The Achilles' heel of high-temperature superconducting wire in transmission cables, motors and generators lies in the wire's self-generated magnetic field. ORNL researchers recently showed that nanotechnology could offer a cure, rescuing superconductors in electrical equipment from the threat to their touted ability to conduct large currents with no resistance.

Amit Goyal and a team that included postdoctoral researcher Sukill Kang demonstrated enhancement of electrical performance in two-centimeter-long segments of high-temperature superconducting wire. They introduced defects into the superconducting film made of yttrium, barium and copper oxides (YBCO). Their method, which will likely be patented, is described in a paper entitled "High-Performance High-T_c Superconducting Wires," which appears in the March 31, 2006, issue of *Science* magazine. The technology received a Nano 50 Award from *Nanotech Briefs*, a digital magazine for design engineers.

Goyal knew that IBM researchers ten years ago reported massive enhancement of the current in single-crystal YBCO after bombarding the film with heavy-ion radiation. The radiation produced nanoscale defects that pinned the magnetic field lines when the field is aligned along the defects. But radiation is not practical and would cause the superconductor's metal template to become radioactive. Goyal's goal was to find a practical source of nanoscale defects.

The ORNL researchers mixed nano-sized barium zirconate ($BaZrO_3$, or BZO) powder with YBCO powder to form a target. Using pulsed laser ablation, Kang heated up the YBCO target with a laser beam and deposited the oxides as a 3-micron-thick YBCO film on a flexible metal substrate. The product was a superconducting film in which the YBCO is interlaced with columns of aligned nanodots of BZO.

"Our measurements showed massive enhancement of the film's current-carrying properties," Goyal says. "We studied cross sections of the film using transmission electron microscopy. We found self-aligned nanodots arranged into separate columns. We believe each epitaxial BZO nanodot prefers to line up with the previous dot because that allows the film to be at its lowest energy state."

Goyal plans to help companies learn how to cure superconductors' greatest deficiency using these and other nanoscale defects.

REINVESTING ROYALTIES

Supporting a robust program of technology transfer often requires a number of revenue streams. UT-Battelle funds a portion of technology transfer activities using annual royalties derived from the sale of commercial products developed from ORNL patents.

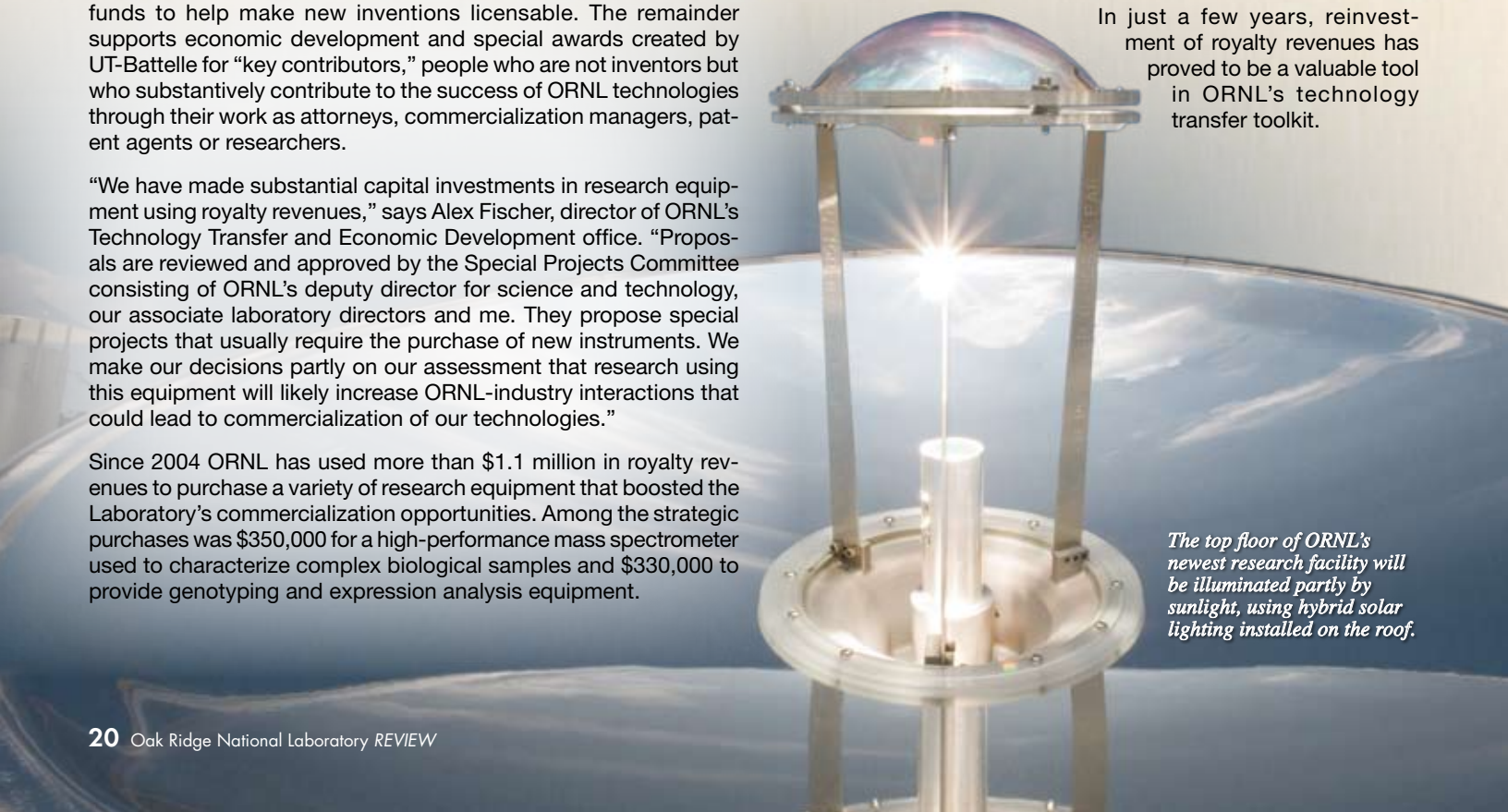
UT-Battelle allocates 20 percent of royalty revenues to the purchase of equipment and the support for special projects and initiatives that promote technology transfer. In addition, approximately 15 percent goes to staff inventors and 35 percent to technology maturation funds to help make new inventions licensable. The remainder supports economic development and special awards created by UT-Battelle for "key contributors," people who are not inventors but who substantively contribute to the success of ORNL technologies through their work as attorneys, commercialization managers, patent agents or researchers.

"We have made substantial capital investments in research equipment using royalty revenues," says Alex Fischer, director of ORNL's Technology Transfer and Economic Development office. "Proposals are reviewed and approved by the Special Projects Committee consisting of ORNL's deputy director for science and technology, our associate laboratory directors and me. They propose special projects that usually require the purchase of new instruments. We make our decisions partly on our assessment that research using this equipment will likely increase ORNL-industry interactions that could lead to commercialization of our technologies."

Since 2004 ORNL has used more than $1.1 million in royalty revenues to purchase a variety of research equipment that boosted the Laboratory's commercialization opportunities. Among the strategic purchases was $350,000 for a high-performance mass spectrometer used to characterize complex biological samples and $330,000 to provide genotyping and expression analysis equipment.

One of ORNL's most promising inventions is hybrid solar lighting, which can reduce utility costs by capturing sunlight and providing high-quality lighting for commercial facilities. With an investment of $120,000 in royalty fees, hybrid solar lighting technology will be installed on the roof of the Laboratory's newest research facility. A computer-controlled combination of natural and artificial lighting will be provided to the offices on the top floor. If successful, the project should stimulate commercial interest in the ORNL technology.

In just a few years, reinvestment of royalty revenues has proved to be a valuable tool in ORNL's technology transfer toolkit.



The top floor of ORNL's newest research facility will be illuminated partly by sunlight, using hybrid solar lighting installed on the roof.

A LONG-TERM INVESTMENT

UT students become a part of ORNL's technology transfer organization.

ORNL's technology transfer strategy has added a creative new element. In addition to investments in conventional technology commercialization efforts, ORNL also is making similar long-term investments in the development of "human capital" needed to sustain a successful technology transfer program. University of Tennessee graduate students in business and engineering work part-time nudging ORNL inventions closer to commercialization. The students are recruited and mentored by Pat Richardson, a former vice president at Motorola and director of strategy and business development for ORNL's Technology Transfer and Economic Development office.

Recently, Richardson delivered a lecture about the invention process and how inventions reach the marketplace as part of a course on consulting. "I told the UT students about the iPod, the popular portable media player designed and marketed by Apple Computer," Richardson says. "A consultant proposed the business concept to Apple's CEO. Steve Jobs liked the idea, which resulted in a patent for the iPod with Steve as one of the inventors."

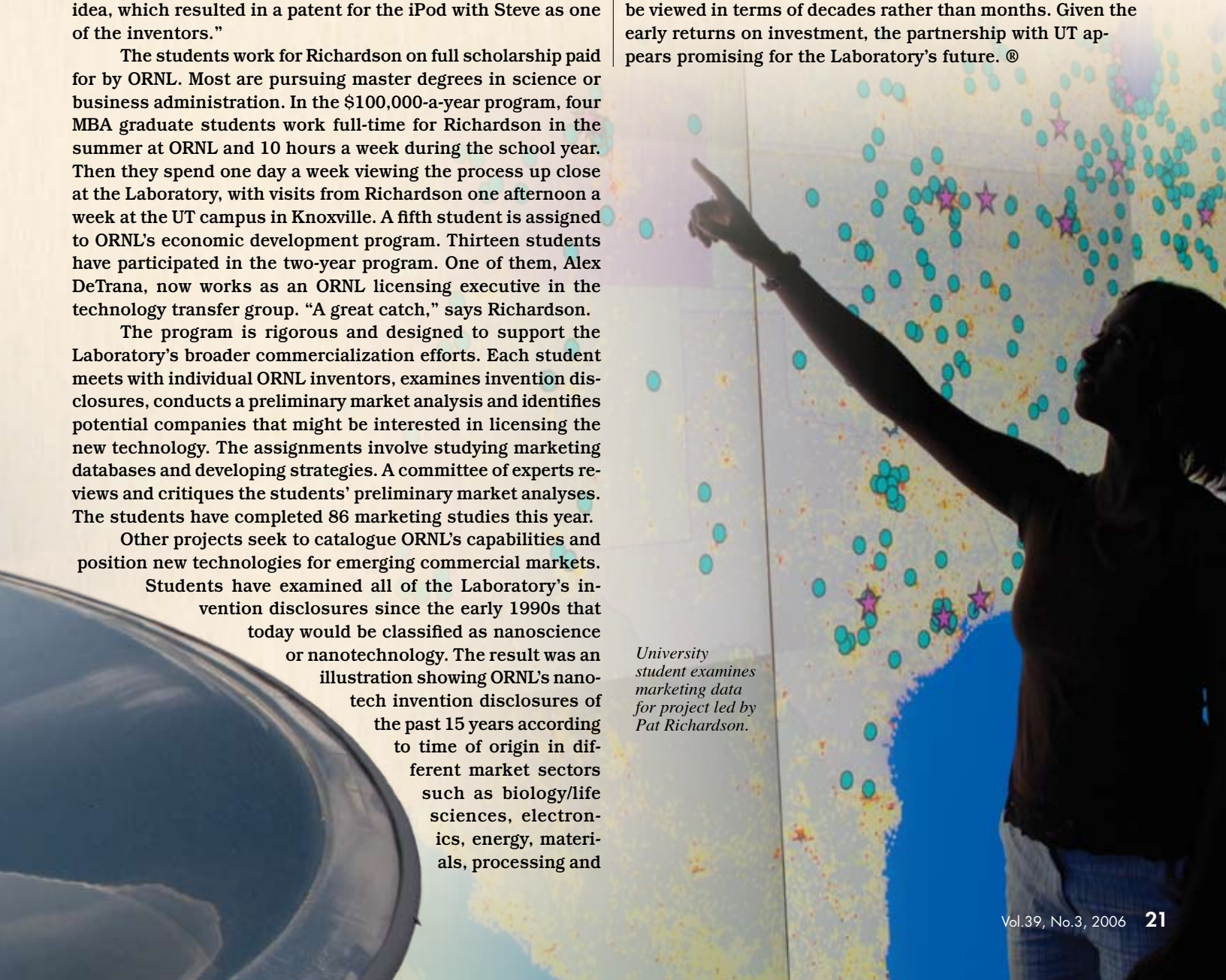
The students work for Richardson on full scholarship paid for by ORNL. Most are pursuing master degrees in science or business administration. In the $100,000-a-year program, four MBA graduate students work full-time for Richardson in the summer at ORNL and 10 hours a week during the school year. Then they spend one day a week viewing the process up close at the Laboratory, with visits from Richardson one afternoon a week at the UT campus in Knoxville. A fifth student is assigned to ORNL's economic development program. Thirteen students have participated in the two-year program. One of them, Alex DeTrana, now works as an ORNL licensing executive in the technology transfer group. "A great catch," says Richardson.

The program is rigorous and designed to support the Laboratory's broader commercialization efforts. Each student meets with individual ORNL inventors, examines invention disclosures, conducts a preliminary market analysis and identifies potential companies that might be interested in licensing the new technology. The assignments involve studying marketing databases and developing strategies. A committee of experts reviews and critiques the students' preliminary market analyses. The students have completed 86 marketing studies this year.

Other projects seek to catalogue ORNL's capabilities and position new technologies for emerging commercial markets. Students have examined all of the Laboratory's invention disclosures since the early 1990s that today would be classified as nanoscience or nanotechnology. The result was an illustration showing ORNL's nanotech invention disclosures of the past 15 years according to time of origin in different market sectors such as biology/life sciences, electronics, energy, materials, processing and sensors and analytical tools. "Equipped with this information, we then looked at projects at ORNL's new Center for Nanophase Materials Sciences to see how many fit into each market sector," Richardson says.

Richardson sees value in students working together in teams to solve problems, conduct research and update reports on licensees in which ORNL holds shares of stock. "I want them to have the team experience," he says. "I encourage them to build partnerships with other team members. I also try to give them a chance to exercise their leadership skills.

The decision to incorporate students into ORNL's technology transfer program reflects the growing partnership between the Laboratory and the University of Tennessee, a partnership in this instance made easier by the fact that ORNL's two senior technology transfer staff are UT graduates. The program also signals a belief that developing and sustaining a culture of commercialization at the Laboratory is an endeavor that must be viewed in terms of decades rather than months. Given the early returns on investment, the partnership with UT appears promising for the Laboratory's future. ®



University student examines marketing data for project led by Pat Richardson.

PROFILE

GERALD BOYD: The Next Frontier

Since January 2003 Gerald Boyd has been manager of the Department of Energy's Oak Ridge Office. In this role, he is often the primary liaison between DOE and Oak Ridge National Laboratory's programs, including technology transfer. Boyd's tenure in Oak Ridge has been characterized by a willingness to work with DOE contractors on a variety of unconventional approaches to operational challenges. He has been a champion of environmental remediation on the Oak Ridge Reservation and of innovative technology transfer efforts at ORNL, including a new technology park located adjacent to the Laboratory. His personal commitment to partnership with both DOE contractors and local civic groups, including a successful effort to renovate Oak Ridge High School, has generated renewed support for DOE within the Oak Ridge community. A native of Tennessee, Boyd came to Oak Ridge after previously serving as Deputy Assistant Secretary for Science and Technology in the Office of Environmental Management and as Associate Deputy Assistant Secretary for Science and Technology. Boyd received a bachelor's degree in biology and chemistry from the University of Mississippi and a master's degree in education and administration from Florida State University.

Q. Why is technology transfer important to the Department of Energy's mission?

First, we are required by law to have a tech transfer program. Aside from that, I personally believe if the taxpayers' money is going to be spent on research, logically that scientific information and the resulting technologies should be transferred into the market, when possible, in a way that results in economic benefit to the nation.

Q. Does promoting technology transfer detract from the Laboratory's basic research mission?

I think that technology transfer and basic research—the core mission of the Laboratory—can be mutually supportive. Without good, solid, basic scientific research, we cannot create technological advantage for America's economy. Conversely, commercial application identifies and shapes basic research, because real-world problems quite often have to be addressed in the basic research phase.

Q: Why have federal laboratories seemingly been slower to embrace technology transfer than other institutions, such as universities?

There has been a cautious effort on the part of the Department to ensure that national laboratories do not unfairly compete with the private sector. What these laboratories do best is take on big problems that are too costly or too complex for the private sector to address. National laboratories should not develop a widget that is 5% better than the old widget. Rather, their focus should be on helping society deal with major problems. In this context, we are

now allowing laboratory contractors such as UT-Battelle to come forward with innovative approaches to technology transfer—ideas that maybe we were not interested in before because we were cautious of playing the wrong role. I think UT-Battelle in particular has been exceptionally good at bringing creative new approaches to this field.

Q: Speaking of innovative approaches, one of several new initiatives you have supported at Oak Ridge National Laboratory is privately funded technology transfer. What do you see as the role of this initiative?

Because the Laboratory's core mission is basic research, there is often a need for additional funding to ensure that we have pushed tech transfer through commercialization to the extent possible. Privately funded tech transfer is a complement to government-funded tech transfer, which often is not adequate to commercialize technology fully.

"Technology transfer is the next big frontier that the Lab is pursuing."

Q: Another ambitious technology transfer initiative is the Science and Technology Park to be located on the ORNL campus. How would you like to see the park develop?

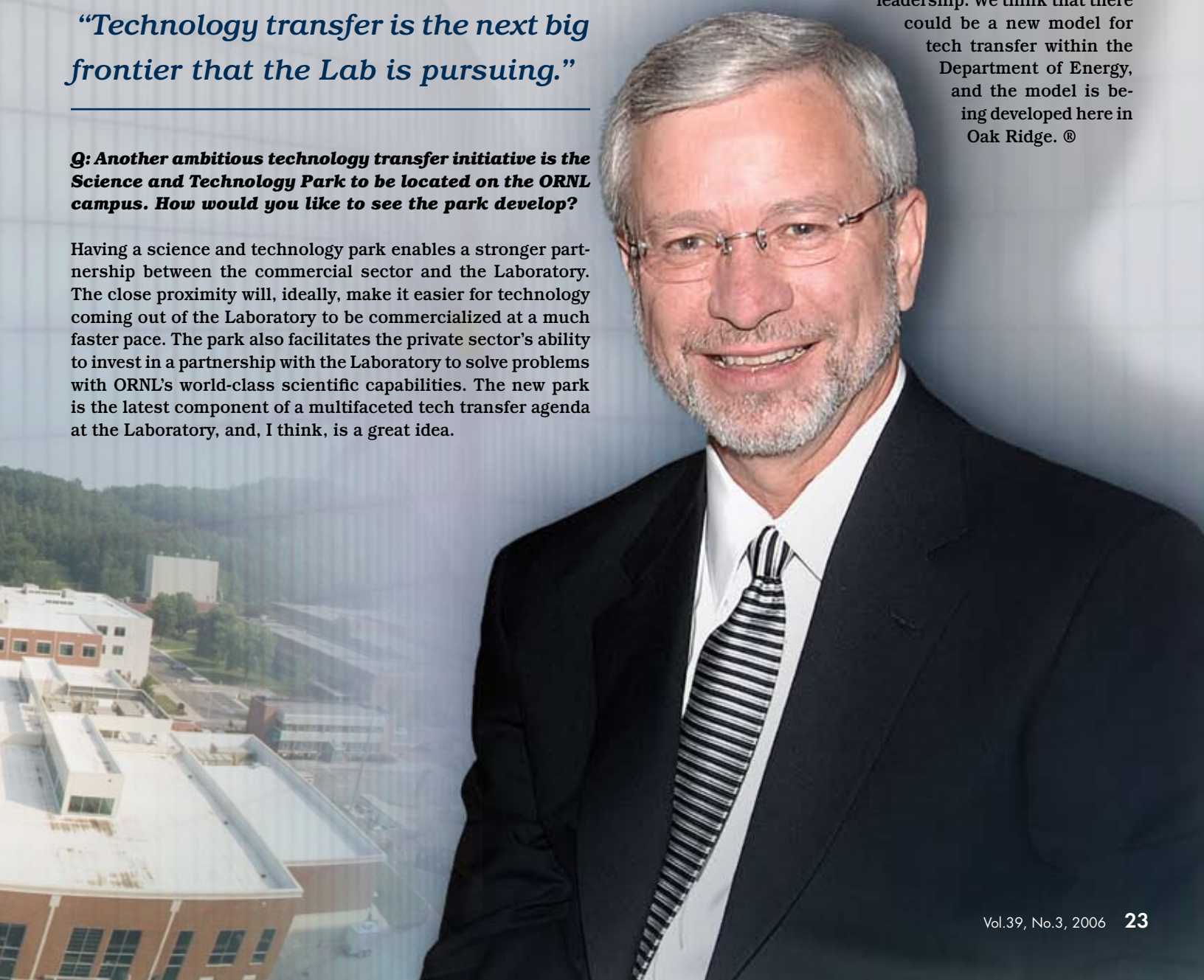
Having a science and technology park enables a stronger partnership between the commercial sector and the Laboratory. The close proximity will, ideally, make it easier for technology coming out of the Laboratory to be commercialized at a much faster pace. The park also facilitates the private sector's ability to invest in a partnership with the Laboratory to solve problems with ORNL's world-class scientific capabilities. The new park is the latest component of a multifaceted tech transfer agenda at the Laboratory, and, I think, is a great idea.

Q: What do you view as the single most important thing a lab can do to encourage technology transfer?

The single most important role for a laboratory in licensing and commercialization of technology is private investment. That includes forming strategic partnerships with large, established businesses and helping small start-up companies seek partnerships and venture capital to mature technologies and bring them to the marketplace.

Q: How does tech transfer fit into ORNL's broader agenda?

ORNL has concentrated heavily on modernization, including construction of new research facilities, upgrading old buildings and bringing new capabilities online so that the research agenda can truly be fulfilled. Technology transfer is the next big frontier that the Lab is pursuing. I think there is a greater emphasis on commercialization now at ORNL because of a new culture and management strategy put in place by the Laboratory's leadership. We think that there could be a new model for tech transfer within the Department of Energy, and the model is being developed here in Oak Ridge. ®



DETECTING SKIN CANCER

An optical solution may detect melanoma without a biopsy.

As a native of Nigeria, ORNL biomedical engineer Justin Baba never gets sunburned and has no significant risk of contracting melanoma, the fatal skin cancer. But he is passionately committed to helping light-skinned people by developing an accurate, portable, noninvasive technique for detecting melanoma.

Aided by ORNL's Philip Boudreaux and Nance Ericson and an optical company, Baba has built the first clinical automated instrument with no moving parts for using polarized light to image subsurface features of moles. The instrument has been tested on nine melanoma suspects at M. D. Anderson Cancer Center in Houston, Texas. "The preliminary results are encouraging," he says. While noting that the instrument shows promise in distinguishing between cancerous and non-malignant moles, he cautions that a much larger patient sample size is needed.

"I am really excited about this technology," says Baba, a staff researcher in the Monolithic Systems Development Group of ORNL's Engineering Science and Technology Division. "M. D. Anderson researchers like our optical biopsy instrument but they want us to get funding to miniaturize it." What physicians would like, he explains, is a Star Trek-like wand they can wave over patients to spot tumors in their early, curable stage.

Melanoma is the most fatal of skin cancers. However, if detected early, this skin cancer almost always can be cured by surgical removal of the melanoma, a dark-pigmented, malignant tumor that arises from a melanocyte—an epidermal cell that synthesizes melanin, the dark pigment found in skin and hair.

"Melanocytes are located deep in the skin's bloodless epidermal layer," Baba says. "But right below that layer is the dermal layer, which contains blood vessels. As the melanoma grows, it stretches down into the blood vessels. Once in the blood the cancer spreads like wildfire. In just a few months, the patient can develop lesions in the kidney and liver and eventually die."

Today, if a patient is concerned about a mole, the physician assesses whether a more intensive examination is required by visually inspecting the suspect mole, taking into account size, shape, color and the rate and nature of its growth. Suspect lesions are biopsied—a piece of mole is excised and examined for cancer. This process is invasive, painful, expensive and time-consuming but increasingly necessary for liability reasons. Madeline Duvic, an M. D. Anderson clinician and one of Baba's collaborators, claims that in her clinical practice typically only two of about 200 skin biopsies she performs yearly test positive for melanoma.

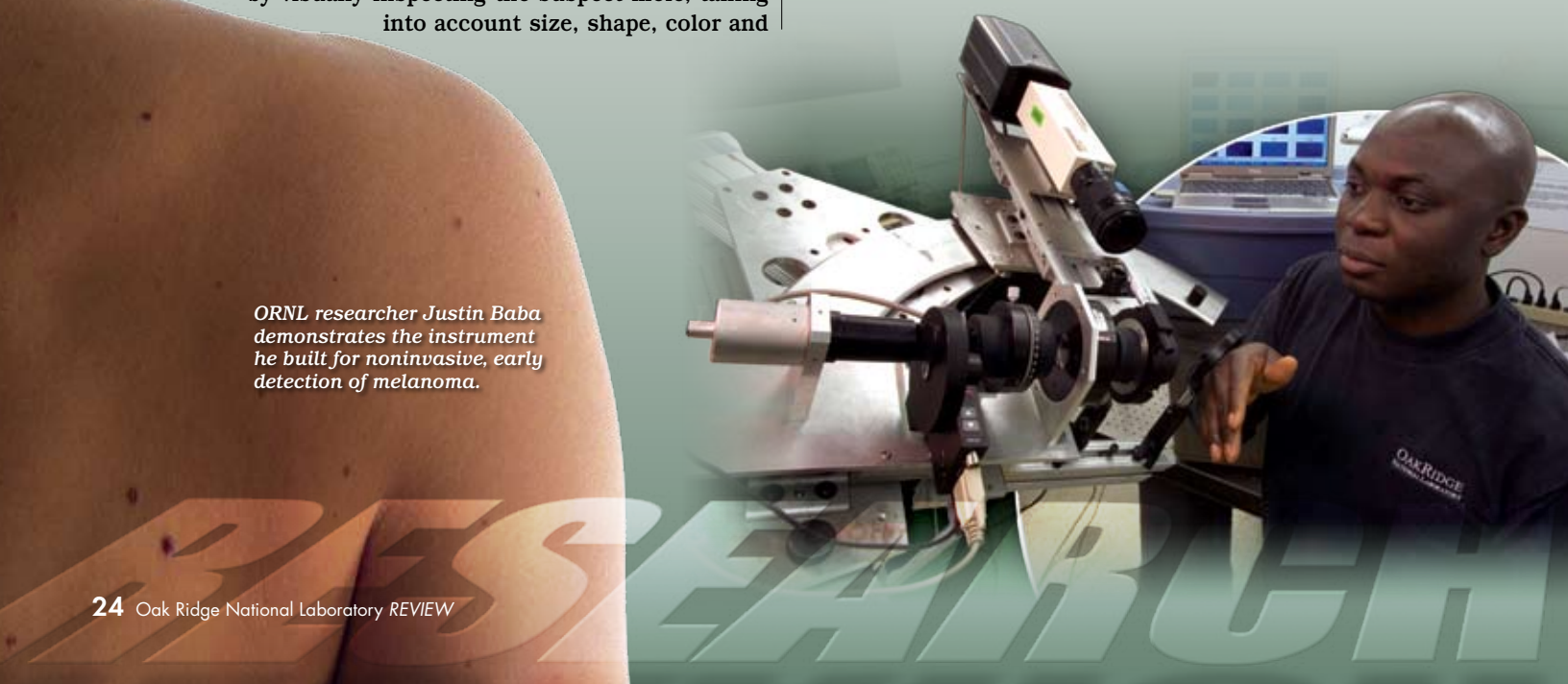
What physicians need is a noninvasive, highly accurate technology to screen people at high risk of getting melanoma, such as blondes with fair complexions and redheads with freckles who are exposed to sunlight, have been sunburned, and do not always wear sunscreen. "If physicians can detect and treat melanoma in its early stages, they can save lives," Baba says.

Baba and Gerard Coté, his Texas A&M University Ph.D. adviser, advocate the use of polarized light for noninvasive biopsies of suspect moles. Polarized light photons passing through the skin are scattered from fibrous proteins, or collagen, in the dermal cells. Collagen fluoresces when exposed to blue polarized light. A camera images the mole's underlying structural features, including melanoma-induced disruptions in collagen.

Compared with normal cells, cancer cells are larger, possess denser nuclei, require more blood flow to provide nutrients needed by fast-growing tumors and scatter light differently. Multi-colored polarized-light images reveal details that indicate these differences.

"Our potential solution to skin cancer detection is an automated Mueller Matrix polarization imaging system," Baba says. "The Mueller Matrix algorithm is a powerful tool for analyzing the images by taking into account changes in the linear and circular components acquired by polarized light scattered from moles. Thirty-six images are combined into 16 images that reveal differences between cancerous moles and normal ones."

In time, Justin Baba could have a significant answer to skin cancer. ®



ORNL researcher Justin Baba demonstrates the instrument he built for noninvasive, early detection of melanoma.

A BIOLOGICAL SOLUTION

Researchers harness bacteria to produce uniformly sized magnetic nanoparticles.

Magnetic nanoparticles for refrigerator magnets and computer memory are still being made the old-fashioned way. The mining, milling and grinding technologies of the 1920s continue to be applied to iron to produce magnetic particles ranging in size between 10 and 100 nanometers, or 1/500th the width of a human hair.

A strain of bacteria identified nearly 15 years ago by ORNL's Tommy Phelps can churn out a high yield of zinc-doped, iron oxide nanoparticles in the size range of 20 to 30 nm. By altering the chemical environment in which the bacteria are grown in a bioreactor and by feeding the microorganisms the correct energy source, researchers can induce the biological production of nanoparticles with a uniform size and desirable magnetic properties.

"We can produce zinc-doped, magnetite nanoparticles in large, scalable batches," Phelps says. "These magnetic powders can be used for coatings, stronger magnets, hand-held battery drills with direct-current motors, and magnetic media for data storage for computers."

Customers who want zinc-doped, magnetite nanoparticles in the size range of 20 to 30 nm may be surprised to learn that the powder is up to 100 times less expensive if produced by ORNL's NanoFermentation™ process instead of the conventional method. Conversely, those content with powders of various sizes in the range of 50 to 100 nm will find the milled and ground particles more economical. Internally funded ORNL research is directed at improving the economics of NanoFermentation™.

Other potential applications of NanoFermentation™ powders are ferrofluids, which can be used for brakes to securely hold suspended airplanes on aircraft carriers; catalytic iron nanoparticles, which offer an extremely high surface area and, therefore, more chemical reactivity; and water treatment in which specially coated magnetic particles theoretically attract contaminants and the loaded particles are recovered by a magnetic field.

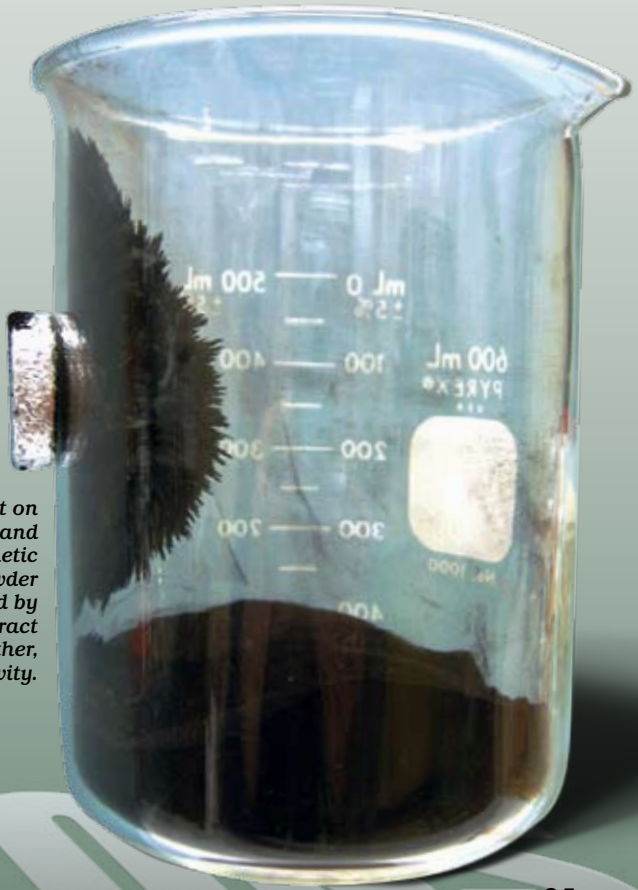
In 1992, while examining core samples obtained from a depth of 10,000 feet by a natural-gas drilling project in Virginia, Phelps discovered a new strain of the thermophile *Thermoanaerobacter ethanolicus*. This species of bacteria, which thrives at temperatures of 60 to 70°C, was first discovered in the 1970s at Yellowstone National Park in Wyoming and later in 1994 at the Piceance Basin in Colorado. The three strains of the same species exhibit slight metabolic differences. For example, the Oak Ridge strain cannot use hydrogen as an energy source, but hydrogen can be fed to the Piceance Basin strain.

Thermoanaerobacter ethanolicus produces ethanol and acetic acid as waste products. Phelps believes an excess of these products is toxic to the species, so the bacteria limit their waste production by donating electrons to iron or other metals in their environment, forming nanoparticles of iron compounds.

Bob Lauf, a materials scientist and inventor, has collaborated with Phelps on the biological production of iron oxide (Fe_3O_4) doped with eight different metals, including chromium, cobalt, manganese, nickel, lanthanides (rare earths) and zinc. By growing the bacteria in a solution containing zinc, the microorganisms incorporate the metal into the magnetite structure, changing its chemical formula. Some of the iron atoms bonded to oxygen atoms are replaced by zinc atoms. ORNL researchers Bryan Chakoumakas and Claudia Rawn used neutron scattering to verify that zinc atoms are part of the magnetite structure rather than on the particle surface, as some people believe.

ORNL's Lonnie Love and Adam Rondinone measured the changes in magnetization manifested by nanoparticles doped with different metals. The researchers found different techniques for changing the size and shape of magnetic nanoparticles. Several patent applications have been filed, and at least 15 scientific papers on the bacteria and their products have been published.

Compared with mining, milling and grinding, Phelps sees NanoFermentation™, which received *R&D* magazine's inaugural MICRO/NANO 25 award and an R&D 100 Award in 2006, as a "green" process that does not harm the environment and uses much less labor and energy and fewer hazardous solvents. He envisions this new way of fashioning nanoparticles as a 21st century nanomanufacturing technology. ®



Magnet on beaker and magnetic powder produced by bacteria attract each other, defying gravity.

DANCING PROTEINS

Scientists use a light beam to separate proteins on a chip.

Researchers have demonstrated novel use of a beam of light to trap proteins and make them "dance," similar to Star Trek's imaginary "tractor beam" projected at something to pull it from one spot to another. The demonstration is described in a paper that appears in a recent issue of the *Proceedings of the National Academy of Sciences Early Edition*.

The technique—developed by a team from ORNL, California Institute of Technology and Protein Discovery—is more than just a novelty that turns science fiction into science. The discovery is useful for separating, concentrating and analyzing proteins rapidly with high sensitivity and selectivity.

"With this technique, we can steer DNA, proteins and other biomolecules for transport in three dimensions," says Chuck Witkowski, a co-author and president and chief executive officer of Protein Discovery, a Knoxville startup company. "We can also separate biomolecules according to their size and isoelectric point. The ability to perform these functions with high efficiency and precision has applications for diagnosing disease and making new medical discoveries."

The technique, called photoelectrophoretic localization and transport (PELT), involves shining a focused beam of light on semiconductor material to move the proteins. Force-field traps are created by the localized photocurrent, which produces electric fields that induce protein motion. In contrast to traditional gel electrophoresis, which uses high voltage, this approach permits researchers to change dynamically characteristics of the electric field in three dimensions in real time using computer-controlled software and low voltage.

PELT is extremely versatile and offers several advantages over methods that use conventional electrophoresis, according to co-author Thomas Thundat, a group leader in ORNL's Life Sciences Division. "This technique provides an easier way to separate proteins and other biomolecules. In addition to applications for diagnostics, this discovery tool allows researchers to investigate photo-induced effects of a semiconductor-liquid interface."

The new method also overcomes limitations of conventional optical trapping techniques, commonly called optical tweezers. Although versatile, optical tweezers are unable to transport objects much smaller than the wavelength of light, such as DNA fragments, oligonucleotides, proteins and peptides. Instead, such small molecules must first be attached to larger particles, called handles. This and other techniques have significant limitations, according to authors of the paper.

PELT both separates and concentrates proteins. When light from a laser diode shines on a gel-coated semiconductor chip placed under a positive electric potential, charge carriers are produced inside the semiconductor where the light is falling. Negatively charged carriers rush to the semiconductor-liquid interface, which then attracts the positively charged proteins. The smaller the activated spot, the more concentrated the accumulated proteins are. When the light is scanned across the surface of a gel containing a sieving medium, the smaller proteins skip along faster than the heavier ones chasing the light, resulting in separation.

Researchers can assess how much two different molecules, such as a disease protein and potential drug, interact at the illuminated spot by measuring changes in the photocurrent level. The approach might be useful for drug discovery.

Although photoelectrophoretic localization and transport holds tremendous promise, Witkowski says that much work remains to commercialize the technology. In time, however, he envisions a significant commercial role for this technology in the medical field, specifically for disease diagnostics.

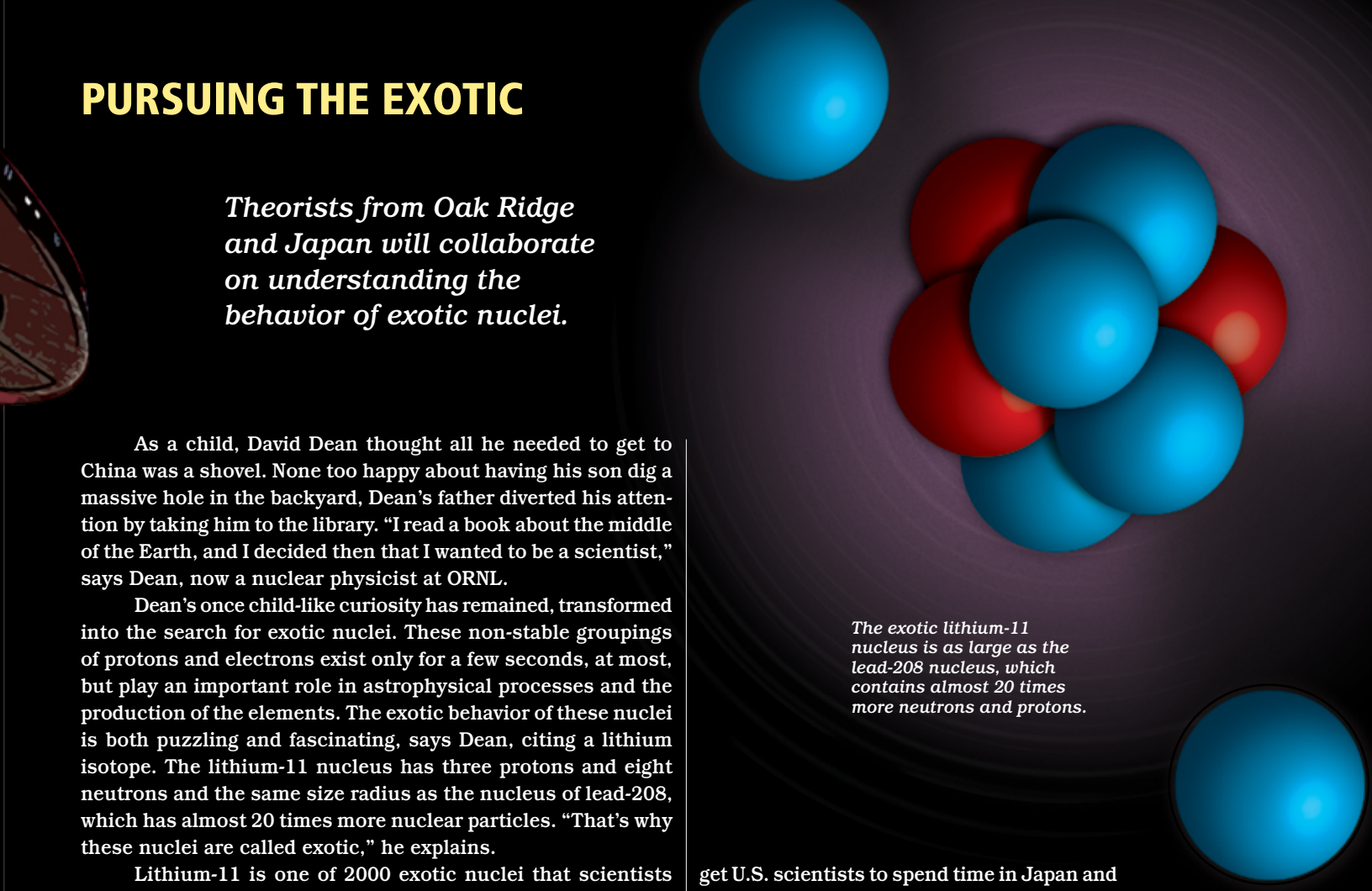
Other authors of the paper are Nathan Lewis, professor at the California Institute of Technology; Dean Hafeman and James Harkins IV, both of Protein Discovery; Bruce Warmack of ORNL's Engineering Science and Technology Division, and Gil Brown of ORNL's Chemical Sciences Division. The paper will appear in an upcoming issue of *Applied Physical Sciences, Biophysics*, published by the National Academy of Sciences.

Funding for this research was provided in part by the Department of Energy's Office of Biological and Environmental Research. Protein Discovery is a privately held life sciences company that is developing solutions for molecular research, drug discovery and development and medical diagnostics using high-throughput mass spectrometry. ®

RESEARCH

PURSUING THE EXOTIC

Theorists from Oak Ridge and Japan will collaborate on understanding the behavior of exotic nuclei.



The exotic lithium-11 nucleus is as large as the lead-208 nucleus, which contains almost 20 times more neutrons and protons.

As a child, David Dean thought all he needed to get to China was a shovel. None too happy about having his son dig a massive hole in the backyard, Dean's father diverted his attention by taking him to the library. "I read a book about the middle of the Earth, and I decided then that I wanted to be a scientist," says Dean, now a nuclear physicist at ORNL.

Dean's once child-like curiosity has remained, transformed into the search for exotic nuclei. These non-stable groupings of protons and electrons exist only for a few seconds, at most, but play an important role in astrophysical processes and the production of the elements. The exotic behavior of these nuclei is both puzzling and fascinating, says Dean, citing a lithium isotope. The lithium-11 nucleus has three protons and eight neutrons and the same size radius as the nucleus of lead-208, which has almost 20 times more nuclear particles. "That's why these nuclei are called exotic," he explains.

Lithium-11 is one of 2000 exotic nuclei that scientists have recorded at facilities such as Holifield Radioactive Ion Beam Facility in ORNL's Physics Division. Of the roughly 6000 nuclei known to exist, Dean says only 300 are stable. "We know very little about the nuclei that lie beyond the stable ones," he notes, adding that many of the nuclei scientists could uncover are too elusive even for facilities like Holifield.

New experimental facilities worldwide, including two in Japan, are making the next step toward understanding nuclei. Theoretical centers at the University of Tokyo and Rikagaku Kenkyusho, RIKEN: the Institute of Chemical and Physical Sciences of Japan will support a newly funded Japan-U.S. Theory Institute for Physics with Exotic Nuclei, known as JUSTIPEN. In March the U.S. Department of Energy announced funding for JUSTIPEN, which resides at RIKEN.

In 2008 RIKEN will open the Rare Isotope Beam Facility, placing nuclear theorists and experimentalists side by side at one of the world's most powerful nuclear research facilities. The new facility will accelerate a beam of normal nuclei to high energy to smash into a target, creating exotic nuclei. RIKEN's RadioIsotope Beam Factory will allow scientists to study exotic nuclei that exist for only milliseconds, enabling a qualitative leap in our understanding of nuclear properties.

David Dean's focus lies in the theory institute. He was in Japan on July 10 when the institute opened, assuming the position of JUSTIPEN's associate director. "We want to establish international collaboration among theorists. We are trying to get U.S. scientists to spend time in Japan and have Japanese scientists come to Oak Ridge. I think in time such an exchange will enhance our understanding of nuclei."

Dean began working on collaboration plans for the institute two years ago when he was chair of the Rare Isotope Accelerator Theory Group Executive Committee. He and his ORNL colleagues, including Witold Nazarewicz, a professor of physics at the University of Tennessee, wanted to submit a proposal for the theory institute's recruitment of American scientists. The proposal called for JUSTIPEN to host American scientists in Japan each year to do their research alongside Japanese theorists. The institute hopes to host 12 visitors in 2006 for one to four weeks. In the future, the theory institute hopes to double that number and encourage long-term stays.

If Japanese theorists win funding, they will visit the United States. Oak Ridge will host many of them at the Joint Institute for Heavy Ion Research, which supports collaborative nuclear research at Holifield.

The collaborators hope to help each other better understand features of exotic nuclei that will be studied experimentally, and to provide a unified, predictive theory for those nuclei and nuclear properties that are difficult or impossible to measure. If they can obtain a better idea about the behavior of these elusive proton-neutron clusters and their fate as they interact with the environment, the scientists will be able to help pin down how nuclei are created in the universe. ®

...and the WINNERS are...

Accomplishments of Distinction at Oak Ridge National Laboratory

ORNL researchers won six R&D 100 Awards in 2006 from *R&D* Magazine in recognition of the year's most significant technological innovations. With 128 of these prestigious awards, ORNL leads DOE national labs and is second to General Electric. The winning entries and developers are: ***Hybrid Solar Lighting System***, an energy-efficient method of delivering sunlight to top-floor rooms while controlling electric light levels to provide quality illumination, developed by **Jeff Muhs, David Beshears, Art Clemons, Duncan Earl**, **Curt Maxey, John Jordan, Melissa Lapsa, Randall Lind, Christina Ward, R. Wes Wysor** and Sunlight Direct of Oak Ridge; ***LandScan Global Population Database***, a global population distribution model that has 25 times the resolution of the next best global population database and is useful for disaster response, humanitarian relief, sustainable development and environmental protection, developed by **Eddie Bright, Phil Coleman, Amy King, Budhendra Bhaduri** and **Ed Tinnel**; ***Metal Infusion Surface Treatment*** (MIST), a process for infusing elements into metallic surfaces that dramatically increases the lifetime of metalworking tools and the performance of catalytic devices, developed by researchers from C3 International, assisted by staff from **ORNL's Materials Science and Technology Division; *TMA 6301 and TMA 4701***, heat-resistant cast austenitic stainless steels with improved durability and lifespan at higher maximum operating temperatures, developed for industrial equipment using a computer-aided design methodology by **Govindarajan Muralidharan, Vinod Sikka, Phil Maziasz, Neal Evans, Michael Santella**, **Christopher Stevens,** Duraloy Technologies and Nucor Sheet Mill Group; ***Trane CDQ***, an air conditioning–dehumidification device that controls temperature and humidity of building interiors, developed by **Jim Sand** in collaboration with the Trane Company; and ***NanoFermentation***, use of a bacterial strain to produce uniform, nanocrystalline, magnetic powders for magnetic media, ferrofluids and other applications, developed by **Tommy Joe Phelps, Lonnie Love, Adam Rondinone, Bob Lauf, Yul Roh, Chuanlun Zhang** and **Ji-Won Moon**. NanoFermentation also received one of *R&D* Magazine's inaugural ***MICRO/NANO 25 awards***.

ORNL's high-temperature superconducting wire technology, referred to as "HTS Wires Enabled via 3D Self-Assembly of Insulating Nanodots," received a ***Nano 50 Award*** from *Nanotech Briefs*, a digital magazine for design engineers.

John Hsu, **Stephen Smith** and **Arthur Moorhead** were recently recognized as "distinguished inventors" by Battelle for receiving 14 or more patents during their research careers at ORNL.

Ian Wright and **Hua-Tay Lin** have been elected ***fellows of ASM International***; **Cam Hubbard** has been elected a ***fellow of the American Ceramic Society***, and **Steve Sims** has been elected a ***fellow of the Health Physics Society.***

Brian H. Davison received the ***Charles D. Scott Award*** (named after a retired ORNL corporate fellow) at the 28th Symposium on Biotechnology for Fuels and Chemicals in recognition of his innovations and insights in biotechnology and bioprocessing.

ORNL has received its third consecutive ***Pollution Prevention Best-In-Class award*** from DOE. ®

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Bioenergy

OAK RIDGE NATIONAL LABORATORY REVIEW
P.O. Box 2008, Oak Ridge, Tennessee 37831- 6266

ORNL *Review*

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www.ornl.gov/ORNLReview/

The *Review* is printed in the United States of America and is also available from the National Technical Information Service, U.S. Department of Commerce, 5285 Port Royal Road, Springfield, VA 22161

Oak Ridge National Laboratory is managed by UT-Battelle, LLC, for the U.S. Department of Energy under contract DE-AC05-00OR22725

ISSN 0048-1262

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