Oak Ridge National Laboratory
REVIEW
• MANAGED BY UT-BATTELLE FOR THE DEPARTMENT OF ENERGY •

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new
pathways
to research

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Features

NEW PATHWAYS TO RESEARCH

RESEARCH HORIZONS

AWARDS

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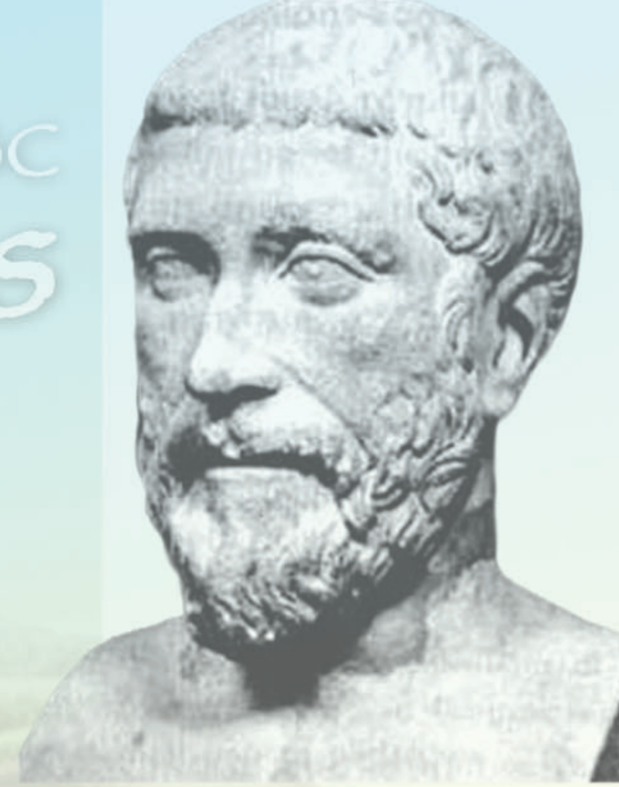
Pythagoras



New Pathways to Research

This edition of the ORNL *Review* could appropriately be dedicated to Pythagoras, a Greek mathematician who, to the best of our knowledge, left no written record of his life and work in the 6th century B.C. Although most middle school students are familiar with his theorem of the right triangle, Pythagoras had a far more profound impact on scientific discovery than his belief that the entire cosmos can be expressed in mathematical formulas.

For those of us at Oak Ridge National Laboratory, the enduring legacy of Pythagoras and his followers was the ability to adapt their thinking to new conditions and new ideas. Translated into the modern vernacular, they were able to abandon conventional wisdom and think "out of the box" in ways that reshaped fundamental notions of how the universe works. From mathematics to astronomy to music, their capacity to think independently produced a creative energy that 25 centuries later fuels our scientific agenda.

As they did for Pythagoras, evolving technologies have combined with world events in ways that make it necessary for us to revisit our strategies and scientific priorities at ORNL. The past three years were a period in which we developed distinctly new strategies in pursuit of our mission on behalf of the Department of Energy. The strategies are designed to support our staff as they challenge long-held assumptions and blaze bold scientific trails in areas such as fusion energy and high-performance computing. Our Laboratory agenda includes new management techniques that make it possible to dedicate extensive resources to the emerging fields of nanoscale materials and functional genomics. A commitment to broaden the Laboratory's core competencies has enabled ORNL to emerge rapidly as a leading center for national security technologies. Each of these initiatives has attracted funding that will strengthen ORNL's place at the forefront of international research and result in lasting contributions to America's quality of life.

Significantly, some of our boldest new approaches at ORNL include the way in which we make scientific inquiry possible. More often than not, cutting-edge research is the product of world-class scientists working on some of our most complex problems in world-class facilities. An important part of our story at ORNL is a creative strategy designed to transform an aging and expensive infrastructure into one of the world's most modern research centers. This part of our strategy includes new funding sources and new partnerships that are changing in a lasting way how we support scientific research.

This edition of the *Review* features some of the new pathways we are taking for scientific programs and operational strategies at ORNL. Our readers will note that these changes include the *Review* itself, which for decades has been a chronicle of the discoveries and new technologies taking place at the Laboratory. Reflecting ORNL's new image, the *Review* is updating its style and format. Each issue of the *Review* will examine in depth one aspect of the Laboratory agenda, accompanied by articles on recent research and a section on ORNL staff who have received national recognition for their discoveries.

I hope these articles capture the enthusiasm we have at ORNL for the Laboratory's future. With a new campus and new partners, our research program is robust and growing. Like Pythagoras, we are gazing over the horizon, with our minds open to the opportunities and possibilities that await us.

Bill Madia, Director

The standing-room-only crowd assembled in Wigner Auditorium grew quiet as Energy Secretary Spencer Abraham picked up his pen. The gathered dignitaries, including a U.S. senator and two congressmen, sensed along with Oak Ridge National Laboratory staff the significance of the moment. With a simple signature on a deed, the Secretary would enable ORNL to undertake the boldest initiative since the Laboratory's construction in 1943.

Breaking the MOLD to Build a NEW LABORATORY

A DAUNTING TASK

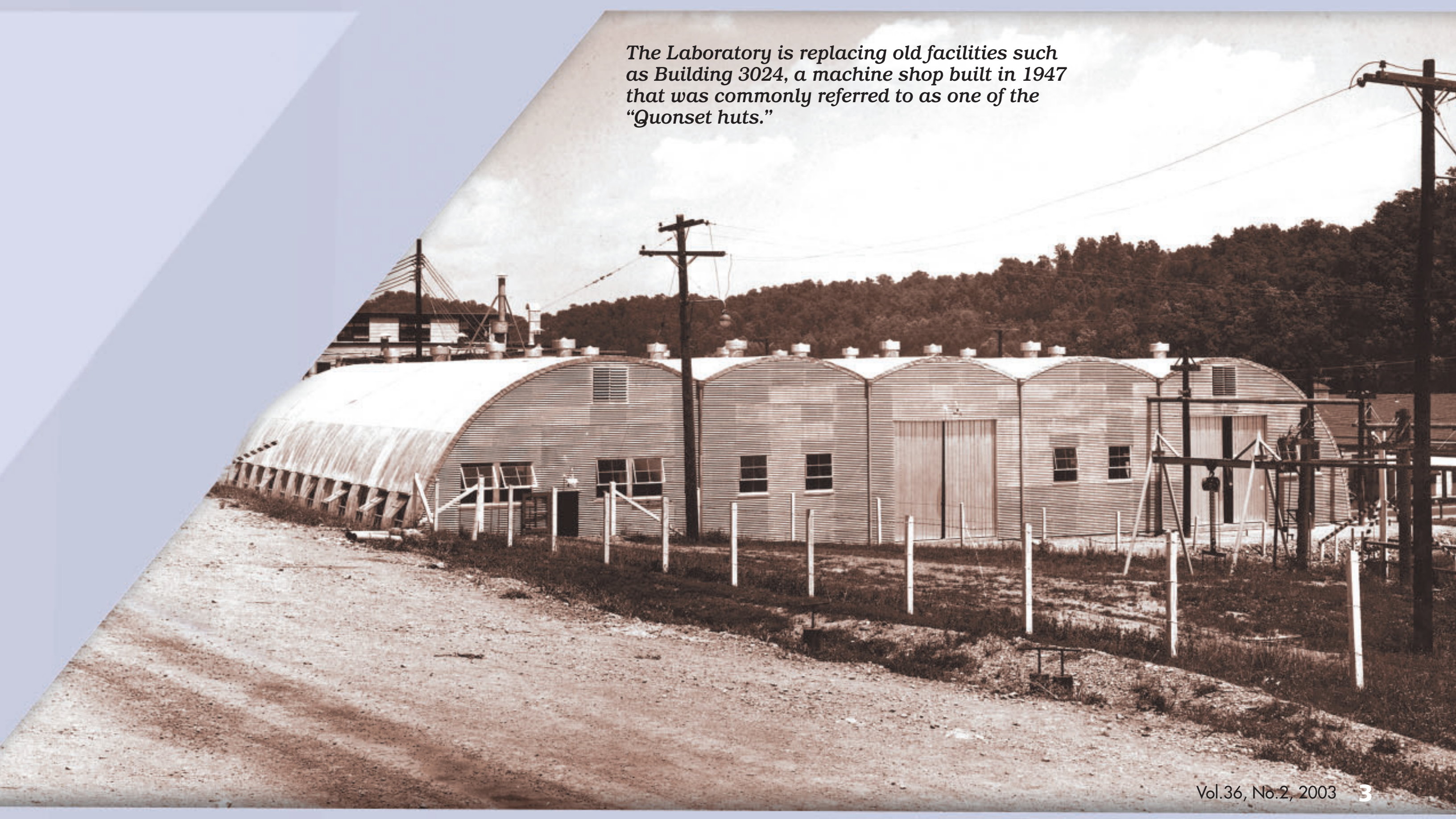
When the new team members from the University of Tennessee and Battelle assumed the management contract for the Department of Energy's Oak Ridge National Laboratory in April 2000, most were "stunned" at the condition of the Laboratory's infrastructure. Approximately one-half of ORNL's buildings were more than 40 years old, and some two-thirds needed replacement or extensive renovation. The Laboratory had experienced decades of insufficient capital investment for new buildings and deferred maintenance for older ones. The result was an outdated research complex that was increasingly expensive to operate, impairing the Laboratory's ability to produce good science. Utility costs, for example, averaged more than $3000 per occupant at ORNL, nearly four times the average for comparable facilities.

The impact of the aging infrastructure was felt in areas besides cost. Expensive facilities handicapped ORNL staff in the competition for research funding. Program managers found it difficult to recruit world-class staff to what some referred to as "third-world" laboratories. Conditions were so bad in ORNL's mouse genomics research facility, or "mouse house," that management gave up altogether on recruiting new staff.

The most disturbing fact facing ORNL management was the likelihood that the problem would only get worse. Congress and the Department of Energy gave no indication that sufficient funding would be available even to stabilize the decline of existing facilities. Given that other DOE laboratories had similar infrastructure needs, the notion that ORNL could secure congressional funding adequate to replace deficient buildings and modernize the Laboratory in five to six years was clearly beyond the realm of political possibility.

BREAKING THE MOLD

Officials at both ORNL and the Department of Energy realized that an unconventional strategy would be required to fund large-scale modernization of the Laboratory. In May 2000 the Laboratory presented DOE with a novel proposal: UT-Battelle first would secure a funding commitment of $26 million from the state of Tennessee for four new facilities on the ORNL campus. The state com-



The Laboratory is replacing old facilities such as Building 3024, a machine shop built in 1947 that was commonly referred to as one of the "Quonset huts."

mitment would be accompanied by a pledge from Battelle to obtain approximately $72 million in private funding for three additional buildings. Finally, the state and private commitments would be used to leverage about $225 million in funding from DOE for the renovation of the Laboratory's largest existing facility and the construction of six new buildings.

The proposal was as delicate as it was novel. Each facet of the funding plan was contingent upon the success of the others. Viewing ORNL as an untapped potential for the state's economic development and the University of Tennessee's research program, Governor Don Sundquist joined the speakers of the Tennessee House and Senate in pledging $26 million to ORNL as the state's share of the package and appropriating an initial sum of $8 million to fund a new facility for computational sciences, called the Joint Institute for Computational Sciences. The commitment by state government to fund facilities at ORNL provided momentum for another unprecedented initiative. To obtain private financing, UT-Battelle would have to convince DOE to transfer to private ownership a six-acre parcel located literally in the middle of the ORNL campus. Such a transfer would have to overcome, in addition to decades of institutionalized government policy, serious reservations about how facilities on private property would be constructed and managed, as well as how they could be expected to support DOE's mission on an ongoing basis. Absent a willingness by DOE to break the mold, ORNL's modernization plan had little chance of success.

A turning point came in September 2000 when Energy Secretary Bill Richardson traveled to Oak Ridge and endorsed ORNL's modernization plan. Standing beside Governor Sundquist and Laboratory Director Bill Madia, Richardson unveiled a drawing of the ORNL campus as envisioned in 2006, complete with federal, state, and private facilities. The Secretary's endorsement provided critical momentum to the modernization effort. To support what was no longer exclusively a federal project, state government made available resources to help complete environmental assessments and monitor construction of private and state-funded buildings. DOE attorneys joined in drafting stacks of legal documents needed to transfer the property and finalize the lease agreement.

Significantly, the transition from a Democratic to a Republican administration after the November 2000 elections did not slow modernization plans. DOE's new leadership embraced ORNL's efforts to use creative approaches to funding and constructing facilities in support of DOE's mission. In June 2001, Secretary Spencer Abraham came to Oak Ridge to sign personally the deed transferring DOE property to the newly created UT-Battelle Development Corporation. Several hurdles remained, but for the first time even skeptics began to believe that UT-Battelle's plan might actually become a reality.

OVERCOMING THE UNEXPECTED

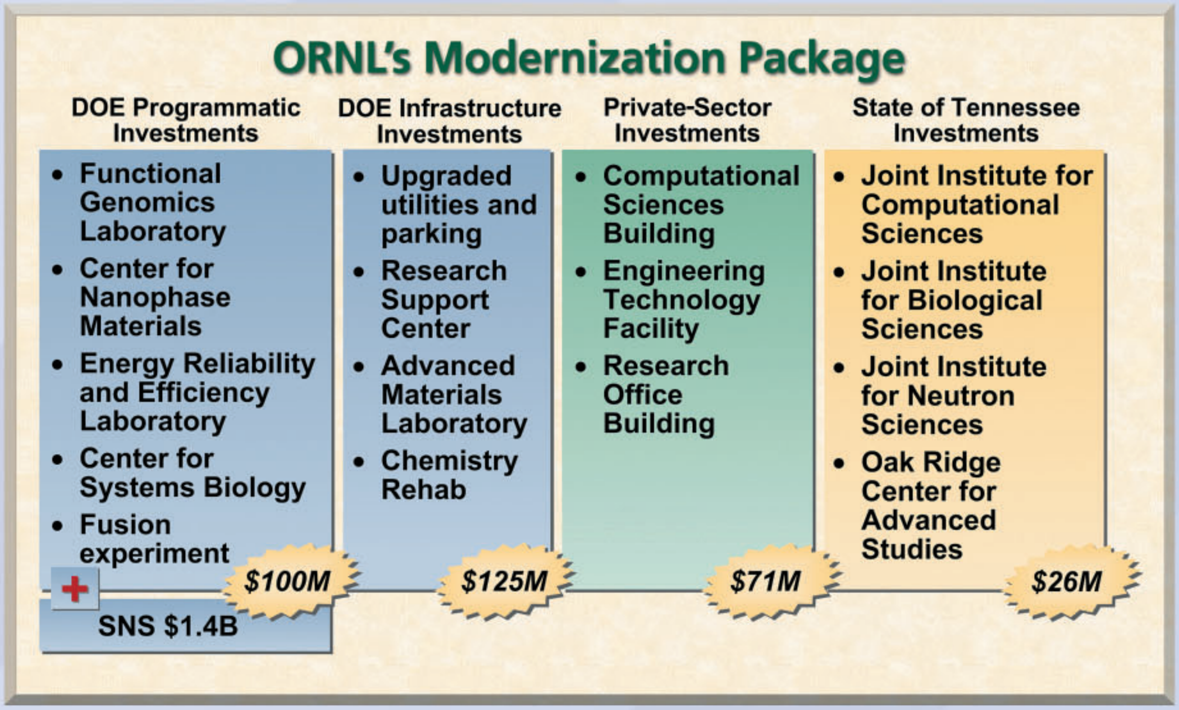
Implementation of the modernization plan accelerated throughout the summer. Working for the first time outside the

Transforming the Laboratory

In June 2003, only 16 months after breaking ground, ORNL celebrated completion of the first of 12 new facilities in the Laboratory's ambitious modernization program. The new buildings represent an unprecedented partnership among the federal, state, and private sectors. Together, they will transform the Department of Energy's oldest laboratory into one of America's most modern centers for cutting-edge research. Shown at right are new facilities that will be completed in 2003.

PRIVATE SECTOR

Research Support—Privately funded on land deeded by the Department of Energy to UT-Battelle Development Corporation, the 350,000-sq.-ft research facility consolidates three buildings that house research programs in energy and computational sciences. The facility is occupied by 33 engineering technology laboratories, including clean rooms and high-bay space. More than 40,000 sq. ft of raised computer flooring combine with office space and network support to give ORNL's Center for Computational Sciences one of the world's most modern computer laboratories.



government's conventional process for procurement and construction, ORNL management, through the UT-Battelle Development Corporation, modified and fast-tracked the process of selecting a firm to design and build the three privately funded facilities. Just as in the private sector, the flexibility gave ORNL the opportunity to solicit comprehensive proposals for design, funding, scheduling, and construction based on the concept of "best value."

The new approach attracted seven proposals, each with distinctly unique architectural and financing components. The project's new-found flexibility was reflected in the winning proposal, which urged ORNL to reduce construction and operating costs by combining the three facilities into one, begin design work prior to the bond closing, and accelerate construction by starting when 30% of the design was completed. In a conventional process, such changes might have taken months or even years to gain necessary DOE approval. Instead, UT-Battelle Development Corporation quickly approved the changes and in August 2001 selected Colliers Keenan, a developer in Columbia, South Carolina, to move forward with the project.

DEPARTMENT OF ENERGY

Advanced Materials Characterization Laboratory—The new 12,000-sq.-ft facility will house three of the world's most powerful electron microscopes, capable of examining the structure of materials at the atomic level. The microscopes will be shared with universities and industrial firms across the United States.

William L. and Liane B. Russell Center for Comparative and Functional Genomics—Home to the Mouse Genetics Research program, the facility replaces the "Mouse House," one of ORNL's oldest and most outdated laboratories. The state-of-the-art facility, also known as the "Vivarium," will support the Laboratory's distinctive expertise in complex biological systems.

STATE OF TENNESSEE

Joint Institute for Computational Sciences—Managed jointly by ORNL and the University of Tennessee, the 50,000-sq.-ft facility will support collaborative research in the adjacent Center for Computational Sciences. The building also will house the Oak Ridge Center for Advanced Studies, designed to attract visiting faculty and researchers to address some of the world's most challenging scientific issues.

Less than three weeks after the selection, ORNL's modernization plan was threatened by the kind of challenge that no one could have anticipated. The September 11 attack on the World Trade Center sent a shock wave through the nation's financial markets. Indeed, the anticipated bond insurer for ORNL's construction project suffered extensive human and financial losses in the attack and had to withdraw from the deal. Overnight, multi-million dollar bond ventures such as ORNL's were viewed with a greatly heightened sense of caution. The unconventional nature of ORNL's project, which involved a private developer building and leasing a large research facility, occupancy by a third party, and funding contingent upon annual appropriations from the federal government, served only to intensify the reservations of the bond market.

Unfortunately for ORNL, the repercussions from the terrorist attacks were followed in late 2001 by another unforeseen series of events that further clouded efforts to finance the project. A succession of corporate scandals, many of which involved deceptive accounting and financing schemes, served to make bond analysts even more skeptical of proposals that included unusual elements. ORNL managers found themselves pitching one of the most unique and complex proposals in the history of government construction at the very moment investors were seeking simplicity and a minimum of risk.

Discussions with potential investors throughout the winter made evident that the bonds would have to be sold at a higher cost if the project was to survive. Finally, on March 4, 2002, Banc of America Securities closed a $72-million bond sale that provided the needed funding. Unexpected events had delayed the project about three months. But within two weeks of the bond sale, workers began tearing up parking lots and digging foundations for the largest construction effort in Oak Ridge since the Manhattan Project of World War II. Sailing into the wind, the Laboratory was taking a distinctly new pathway to research.

New Directions for a 60-Year Partnership

ORNL and the University of Tennessee

Tucked away in Governor Phil Bredesen's first proposed budget to Tennessee's General Assembly in March 2003 was $400,000 in planning funds for the Joint Institute for Biological Sciences at Oak Ridge National Laboratory. The fact that the funds were part of a budget that contained substantial cuts in state spending was an extraordinary statement about the importance of the maturing relationship between Oak Ridge National Laboratory and the University of Tennessee.

Since the Laboratory's beginning in 1943, ORNL staff have taught science and engineering in an adjunct capacity at UT, while university faculty have served as consultants and research participants at ORNL. The relationship expanded in 1984 with the creation of the Science Alliance, a state-funded program that promotes joint research and educational collaboration between the Laboratory and university. Both institutions have strengthened their research agendas through the Distinguished Scientist program, which attracts world-class researchers who split their time and cost between ORNL and UT.

The relationship took a new direction in 1999 when UT sought to be not just a partner but also a manager of the Laboratory. Joining with Battelle, UT presented Tennessee's governor and legislative leadership with an unprecedented contract proposal: UT-Battelle would commit to commercializing ORNL's extensive portfolio of technologies partly through creation of at least ten new companies a year. In return, the state would commit to building four facilities on the ORNL campus that would be used and managed jointly by UT and the Laboratory. The state's investment, in effect, would bring a "three-for-one" benefit. State funds would leverage federal and private funds for ORNL's modernization initiative; UT would see its research program strengthened by greater access to ORNL resources and by new facilities for biological, computational, and neutron sciences; and ORNL would make its portfolio of technologies available for the creation of new jobs.

ORNL's modernization plan includes the elimination of approximately 1.4 million sq. ft of outdated facilities.

The state of Tennessee's financial support of ORNL and UT's new management role have redefined and strengthened the partnership between the Laboratory and the university. The new joint institutes are a critical part of ORNL's efforts to compete for funding from new Department of Energy programs in genomics, nanophase materials, and high-performance computing. Simultaneously, UT's strengthened partnership with ORNL will enable the university to expand its research agenda. The 60-year relationship can now be viewed from a new perspective, broadening the horizons of both institutions.

New Benefits from the Partnership

From the earliest discussions in the spring of 2000, ORNL officials were determined to adopt a new approach to the planning of the Laboratory's modernization initiative. Since 1942, dozens of large and small facilities had been constructed, largely on an ad hoc basis, with little thought given to the relationship of individual buildings either to the existing campus or to future construction. The result was an inevitable hodgepodge of mismatched buildings and unsightly parking lots that left ORNL looking more like an aging industry than a modern research campus.

The presence of the University of Tennessee as a new managing partner of ORNL afforded the unique chance to develop a long-term master plan for the Laboratory's modernization. The effort was led by UT College of Architecture Professor Jon Coddington, whose resumé includes the design of Nashville's Bicentennial Mall. Employing the talents of UT faculty and graduate students, Coddington worked closely with ORNL staff to develop a modernization plan that seeks in a number of ways to transform how staff and visitors view the Laboratory.

The UT plan was sweeping in scope. A former parking lot became the new center of the Laboratory, with five new facilities located around a grass lawn, much like a college campus. Both the interior and exterior elements of the new buildings were designed as components of a larger architectural theme. Construction materials incorporated rigorous environmental standards for energy and recycling. Signage was standardized, including large stone signs that introduced visitors to ORNL's major research facilities. Planners modified the Laboratory entrance and added a new street lined with trees and closed to vehicles. The new cafeteria was designed with glass walls overlooking a pond with swans and falling water.

ORNL's modernization efforts will replace an aging infrastructure with state-of-the-art research facilities. Thanks to a growing partnership with the University of Tennessee, these facilities will also reflect a new spirit of time and place at ORNL.

National Security: a new Priority for the Lab Agenda

In April 2000 UT-Battelle's modification of Oak Ridge National Laboratory's scientific agenda added a major new category to the list of research capabilities. World events, including the dissolution of the Soviet Union and the increased risk that nuclear materials would be sought by America's adversaries, created new challenges to the nation's security and the need for new scientific approaches to meet these challenges. ORNL's capabilities in a suite of emerging technologies provided a potential match for several of these challenges. Together, these technologies form the basis of ORNL's new National Security Directorate.

Today, national-security-related projects represent about 15% of ORNL's research portfolio. The terrorist attacks of September 11, 2001, intensified the Laboratory's emphasis on identifying and modifying technologies in support of the efforts of the new Department of Homeland Security (DHS). ORNL's associate laboratory director for national security is Frank Akers, a retired Army Brigadier General whose job is twofold. In Washington, he informs DHS and other federal agencies about ORNL's research capabilities. At home, he focuses on educating ORNL staff researchers about the needs of a major new customer, the DHS.

"The Department of Energy and the Department of Defense have invested heavily in the development of new technologies at ORNL and other labs that the DHS could harvest for pennies on the dollar," Akers says. "The DOD and DHS have retired military and national security personnel who can readily determine how to apply ORNL technologies to critical situations."

Frank Akers

A NEW MISSION FOR ORNL

The new Department of Homeland Security embraces 22 former agencies and 170,000 employees and has an annual budget of $38 billion. The creation of the department marked the largest reorganization of the federal government since the formation of the Department of Defense in 1947.

The new department, headed by Secretary Tom Ridge, includes the Secret Service, Coast Guard, and the Transportation Security Administration, which is responsible for providing security for all transportation regulated by the Department of Transportation. ORNL's capabilities at the National Transportation Research Center and earlier research conducted for the Department of Transportation and the Federal Highway Administration exemplify how the Laboratory is positioned to assist the new agency in a variety of tasks to strengthen transportation security.

Matching the Laboratory's resources with its opportunities is one of the jobs of ORNL's Mike Kuliasha, a member of the National Security Directorate. Asked to evaluate a broad and complex array of threats, Kuliasha seeks a practical approach that produces economic as well as security benefits. "If we improve our infrastructure to prevent an attack, we can create a secondary return on our investment. We would have a more responsive public health system. We would have a more robust economy if we keep better track of imported products because they will be distributed more efficiently. We would have better equipped and trained emergency responders who can respond faster and more effectively to a natural disaster, such as a tornado. We can justify the costs of better protection against terrorists in terms of additional social benefits."

Still, Kuliasha is realistic about the need to make hard choices. "We can't stop every suicide bomber entering a grocery store or mall," Kuliasha says. "We must think about how to stop terrorists to protect against mass casualties, such as 9/11, in which more than 3000 people were killed. We must also prevent events of high consequences, such as the anthrax attacks on the mail in 2001 in which 5 people died, 22 were infected, 30,000 were given an antibiotic, and millions were terrorized. As a result of the dispersal of a few grams of weaponized anthrax in the mail, 23 sites were contaminated, 30 tons of wastes have been disposed of, and more than half a billion dollars has been spent on building decontamination."

The government is concerned about terrorists taking out a key infrastructure. "We can't guard all places," Kuliasha notes, "So the highest-risk areas, such as the Golden Gate Bridge, are targeted for special protection during alerts."

One goal of DHS's Emergency Preparedness and Response personnel is crisis management, which focuses on ensuring that first responders have the equipment and communications they need. Another goal is consequence management. For example, Kuliasha says, after the September 11, 2001, attack on the World Trade Center, federal officials immediately had to manage consequences that included the shutdown of the stock market, the partial destruction of the New York City subway, and the need to aid the injured and families of the victims and to clean up the debris. "This office is also concerned with developing a plan for monitoring the U.S. infrastructure before it is attacked and maintaining it after an attack," he says.

Another DHS program, the Information Analysis and Infrastructure

An Instant Response to the Terrorist Threat

Shortly after the 9/11 terrorist attack, Ron Brown, director at Nashville's FlashTechnology, which manufactures, installs, and remotely monitors aviation strobe lighting on cell-phone towers, had an idea. He had read about ORNL's work for the U.S. Army to develop the Block II Chemical Biological Mass Spectrometer (CBMS) for detecting chemical and biological warfare agents. Why not put such detectors at cell towers, which are located near population centers and are equipped with communication technologies?

Brown's idea found its way to Jim Kulesz in ORNL's Computational Sciences and Engineering Division. Kulesz who had just proposed combining CBMS with ORNL's Hazard Prediction and Assessment Capability (HPAC) and LandScan software. If given wind speed and direction and the threat agent's concentration, HPAC can predict where the agent will migrate and how many people nearby could be exposed unless they evacuate or take cover in safe facilities.

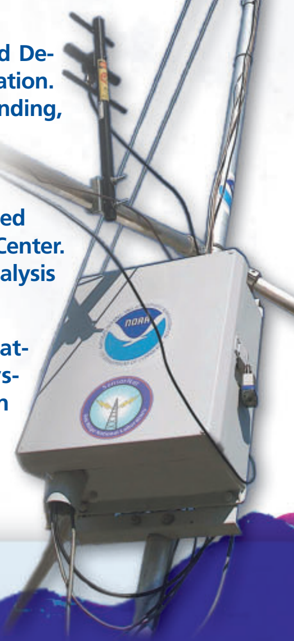
After hearing Brown's proposal, Kulesz conceived of SensorNet, a combination of sensor and communication technologies at cell towers and other national infrastructures to detect radiological, biological, and chemical threats and provide immediate threat information to emergency response command centers. These command centers could then convey timely and meaningful information to emergency responders, health-care centers, and affected populations.

SensorNet is now designed to maximize participation by the government and private sectors. SensorNet will use "best in class," commercially ready, radiation detectors and sensors of chemical and biological threats combined with the best modeling tools, such as HPAC and LandScan software, to provide threat information over a secure data network to local, regional, and national command centers. The threat detectors, computers, and communication technologies would be located at many of the existing 145,000 private-sector cellular sites and other national infrastructure components at an estimated cost of $2 billion.

The SensorNet concept was successfully field tested in March 2002 in Tennessee using three mass spectrometers to detect airborne chemical and biological warfare simulants in Chattanooga, Knoxville, and Nashville. All sensors were networked to a command center at the state's Office of Homeland Security in Nashville. In just 96 seconds, the command center detected and identified simulants and developed a plume model for each city.

The SensorNet team includes the departments of Energy and Defense and the National Oceanic and Atmospheric Administration. SensorNet, which has received $3 million in initial federal funding, has experimental test beds in Washington, D.C., and East Tennessee, including a radiation interdiction node at a truck weigh station off Interstate 40 near Knoxville. A SensorNet Communications Center is being developed at the ORNL-UT National Transportation Research Center. The project's goal is to achieve detection and analysis nationwide in less than 5 minutes.

SensorNet cannot prevent a terrorist attack, but researchers believe the system could provide information fast enough to prevent a widespread tragedy.



Don't GO NEAR THE Water

Poison the waters. That's what a terrorist cell might want to do to people drinking from a municipal water supply, but a green plant cell could be the key to saving lives after such an attack. ORNL researchers have devised a fluorescence technique using naturally occurring algae in primary source drinking water to spot water that has become suddenly tainted, potentially detecting a terrorist attack.

Algae grow naturally on and near the surface of our surface-exposed drinking water sources by using the energy of sunlight and carbon dioxide in the air. Through photosynthesis, healthy algae absorb considerable light but "leak" a little bit of it, according to Eli Greenbaum, a researcher in ORNL's Chemical Sciences Division (CSD). Greenbaum and CSD research assistants Miguel Rodriguez and Charlene Sanders found that this light leakage gives healthy algae a fluorescence signature that can be measured by a standard fluorometer and recorded by a computer.

"If algae in drinking water are exposed to a poison such as potassium cyanide, methyl parathion, or the herbicides Diuron or Paraquat, the algae become unhealthy," says Greenbaum, who came up with the idea to use algae to detect water contamination. "These aquatic plants then leak more or less light than is usual."

In low concentrations, these chemicals can damage the kidneys, central nervous system, or respiratory system. In high concentrations they can kill people.

The researchers found that algae exposed to any of these poisons in drinking water give off a detectable fluorescence signature that is different from that of normal, healthy algae. They observed that differences between fluorescence signatures of algae in ambient water and those of algae in poisoned water could be determined by a fluorometer linked to a laptop computer.

"Our AquaSentinel℠ can detect a broad spectrum of poisons in water and send up a red flag," Greenbaum says. "It is not as sensitive as a gas chromatograph mass spectrometer system, but it is sensitive enough to trigger an alarm to indicate that a city's drinking water may be unsafe. AquaSentinel℠ uses no reagents and it can run continuously without being attended."

With funding from the Defense Advanced Research Projects Agency, the researchers have developed a field-deployable system. They are testing this prototype AquaSentinel℠ at a continuous pumping station on the Clinch River near ORNL's robotics research laboratory.

Further development of AquaSentinel℠ will be funded by United Defense, a U.S. government defense contractor headquartered in Arlington, Virginia. United Defense has an option to be the first company to license the AquaSentinel℠ technology.

David E. Hill of ORNL's Metals and Ceramics Division is helping the CSD researchers develop a database of a variety of algae signatures. They are also writing software to enable the computer to match detected and recorded signatures, to identify any poisonous substances added to the water. Hill is also developing Internet access to this database.

AquaSentinel℠ will be designed to warn municipal reservoir managers that the water supply may have been poisoned. They can then decide whether to shut off the water intake to protect the city's population from a possible terrorist threat.

Protection office, seeks to harness information technologies to identify which packages and containers coming into the country are most likely to pose a danger. "You might expect that packages shipped by Sony are okay, but what about an unlabeled package from Yemen? It's not feasible to check every container, so our front-end defense is information technology that can help workers separate the risky packages from the safe ones. The best approach is an inspection verification tracking system in which the container is inspected when it's loaded at another nation's seaport. This system would eliminate the need to inspect packages deemed to be safe and allow inspectors to focus on packages with a higher probability of containing a weapon of mass destruction. In all these efforts, ORNL technologies can be a part of the solution."

ORNL'S EMERGING ROLE

DHS may have as many as five Centers for Homeland Security. "We hope ORNL will have a center along with DOE's Pacific Northwest National Laboratory and the three defense labs—Sandia, Los Alamos, and Lawrence Livermore national laboratories," Kuliasha says. "ORNL and PNNL have the largest homeland security research and development portfolios among the DOE science labs.

"We're teaming with university medical schools and hope to become a National Institutes of Health (NIH) Regional Center of Excellence in Biodefense," he adds. The schools are Emory, Vanderbilt, Duke, University of Alabama at Birmingham, University of North Carolina at Chapel Hill, and University of Florida.

Kuliasha has presented several talks on homeland security technologies developed at the DOE national labs. His audiences have included Senator Bill Frist's Forum on Technology and Innovation, the Naval Research Advisory Committee, and the Army's U.S. Northern Command, as well as groups at DHS, DOD, the Center for Disease Control and Prevention, and NIH.

ORNL researchers have developed a number of technologies that have attracted national media attention. Three of the technologies were showcased in December 2002 on "ABC World News Tonight," resulting in inquiries from a number of companies interested in potential commercialization.

Two of the featured concepts were SensorNet, which is expected to receive $3 million in funding, and AquaSentinel℠ (see sidebars). A third showcased ORNL technology was the boarding pass analyzer, a mass spectrometer that detects trace explosives on boarding passes to screen for passengers that might have handled explosives. The $180,000 detector developed by Gary Van Berkel and others at ORNL is substantially faster and more accurate than the $60,000 ion mobility mass spectrometer currently used at airports.

"Ion mobility spectrometry gives a lot of false positives," Kuliasha says. "Shoe polish and banana peels set it off. By the time it indicates the presence of a possible terrorist, the suspect has already gotten through to the airplane."

ORNL's boarding pass analyzer is highly specific, sensitive, and fast, making it worth the extra $120,000, Kuliasha says. The mass spectrometer detects and identifies RDX and TNT and can tell whether a person testing positive has been around explosives or has merely packed nitroglycerin medicine for a heart condition.

The list of ORNL technologies of potential interest to DHS is growing. They include the Block II chemical biological mass spectrometer, the multifunctional biochip, and the "point-and-shoot" Raman integrated tunable sensor (RAMiTS), which can rapidly detect and identify chemical and biological warfare agents; frangible bullets that break up rather than ricochet off walls, preventing unwanted injuries to security forces and unwanted damage to strategically valuable property; composites to make baggage compartments in airplanes more resistant to damage from explosives; the "Hotspotter" hand-held monitor that detects and identifies radiation (developed in collaboration with Y-12 researchers); and graphite foam that conducts heat unusually well, making it potentially useful for increasing the comfort and productivity of suited-up first responders and for providing cooling that would enable next-generation computers to be faster and better able to intercept and decode communications between terrorist cells.

ORNL's information technologies such as VIPAR, which searches for and clusters similar information from disparate sources on the Internet, as well as from foreign newspapers, classified intelligence, and satellite images, could help the U.S. government better spot trends in buying and training patterns and other activities that might signal an imminent terrorist attack.

From information technologies to mass spectrometry to the detection of weapons of mass destruction, ORNL's national security portfolio is expected to continue its rapid growth. In the new environment, the challenge is to stay one step ahead of our adversaries.

KEEPING THE GENIE IN

A LABORATORY THAT HELPED DEVELOP THE FIRST NUCLEAR WEAPONS TODAY

As has been the case with most events that shaped world history, the collapse of the Soviet Union in 1991 presented both opportunities and challenges to the United States. The removal of an aggressive military superpower had a profound positive impact on America's security and its ability to channel resources toward domestic needs. Unfortunately, many Americans were unaware that the dissolution of the Soviet Union left behind some 1300 metric tons of weapons-usable nuclear material, much of it in the hands of fledgling nation states such as Ukraine and Kazakhstan. Beset with a multitude of problems associated with building a new government with new institutions, these former Soviet republics often lacked both the security resources and diplomatic sophistication required to manage their nuclear stockpiles.

In these new countries, as in the new Russian Federation, the economic chaos that accompanied political freedom presented a grave security threat to the nuclear weapons stored at various locations. Soldiers and scientists sometimes were not paid for months. Inadequate funds for basic operation and maintenance led to a serious deterioration of facilities and security procedures. The rapid rise in each of these countries of organized crime increased the likelihood that nuclear materials might be purchased or stolen and made available to the highest bidder on the world's underground black market.

The United States, working through the Department of Energy and the National Nuclear Security Administration (NNSA), is actively addressing the problem of preventing the proliferation of nuclear materials from the former Soviet Union. A multidisciplinary suite of technologies makes Oak Ridge National Laboratory ideally suited to help develop, coordinate, and implement domestic and international policies designed to prevent the illegal transfer of nuclear materials and to find ways of using those materials for peaceful purposes.

Securing Nuclear Materials

ORNL's efforts are led by Larry Satkowiak, deputy director for Nuclear Nonproliferation Programs. Satkowiak helps manage the Material Protection, Control & Accounting program, which works with 80 Russian facilities. The group's goals are to secure the weapons-usable nuclear materials, help improve safeguards and security systems, and improve accounting systems that make it possible to keep track of the nuclear materials.

"Our program is considered the 'first line of defense' in preventing Russian weapons and weapons-usable material from 'leaking' to rogue nations and terrorists," Satkowiak says. "In the 'second line of defense' program, ORNL is helping Russian customs officials detect nuclear materials being smuggled out of the country by providing them with radiation monitoring equipment and training."

After the Soviet Union collapsed, the Laboratory also focused on the stockpiles of weapons-usable nuclear material, mainly highly enriched uranium (HEU), which remained in the former republics under varying levels of protection. ORNL staff have helped recover and transport much of these materials to more secure locations for disposition.

In 1994 under Project Sapphire, an Oak Ridge team helped ensure that 600 kilograms of HEU were loaded safely and shipped securely from Kazakhstan to what is now the Oak Ridge Y-12 National Security Complex. A few years later, under Project Olympus, several hundred kilograms of HEU were transferred from the Republic of Georgia to a processing facility in the United Kingdom. In 2002, ORNL staff worked with experts from NNSA, the Department of State, and the International Atomic Energy Agency (IAEA) to safely remove and package 50 kilograms of HEU from the Vinca Institute reactor near Belgrade, Yugoslavia. The material was transported to Russia for conversion to reactor-grade fuel.

From Bombs to Kilowatts

ORNL researchers also are developing technology and providing systems to verify that HEU has been blended down inRussian Federation facilities for conversion to nuclear fuel. An ORNL-developed system monitors the down-blending of HEU to low-enriched uranium, which is then supplied to manu facturers of fuel for U.S. commercial power plants. A 20-person Oak Ridge team assists in nearly continuous "on-the-ground" monitoring of this blend-down activity.

ORNL is DOE's lead laboratory for developing nuclear-based technologies to enable the use of surplus plutonium in existing reactors in the United

THE BOTTLE

WORKS TO PREVENT THEIR SPREAD.

States, Russia, and possibly Canada. "Our aim is to reduce inventories of surplus weapons-usable materials worldwide in a safe, secure, transparent, and irreversible manner," Satkowiak says. ORNL's Domestic Plutonium Disposition program is managing a multi-site effort to fabricate, irradiate, and test mixed-oxide fuel containing plutonium and uranium for use in power plants. ORNL's Russian Plutonium Disposition program manages and conducts research with Russia aimed at developing the technology needed to fabricate mixed-oxide fuels for Russian reactors.

Preventing "Brain Drain"

ORNL partners with Y-12 in two efforts to help downsize the former Soviet Union weapons complex: the Initiatives for Proliferation Prevention (IPP) and the Nuclear Cities Initiative (NCI). IPP's goal is to provide meaningful, sustainable, non-weapons-related work for researchers formerly engaged in weapons work who now live in Russia, Belarus, Ukraine, and Kazakhstan. Several have started new businesses with help from ORNL. One successful business has developed a new method for recycling comingled metals, and another is producing and marketing an improved gas chromatograph. NCI focuses on the "closed cities" of the Russian weapons complex. One highly successful start-up is the ITECH security company within the city of Snezhinsk. ITECH is marketing label technologies it developed for tracking high-value goods and materials.

Tracking Them Down

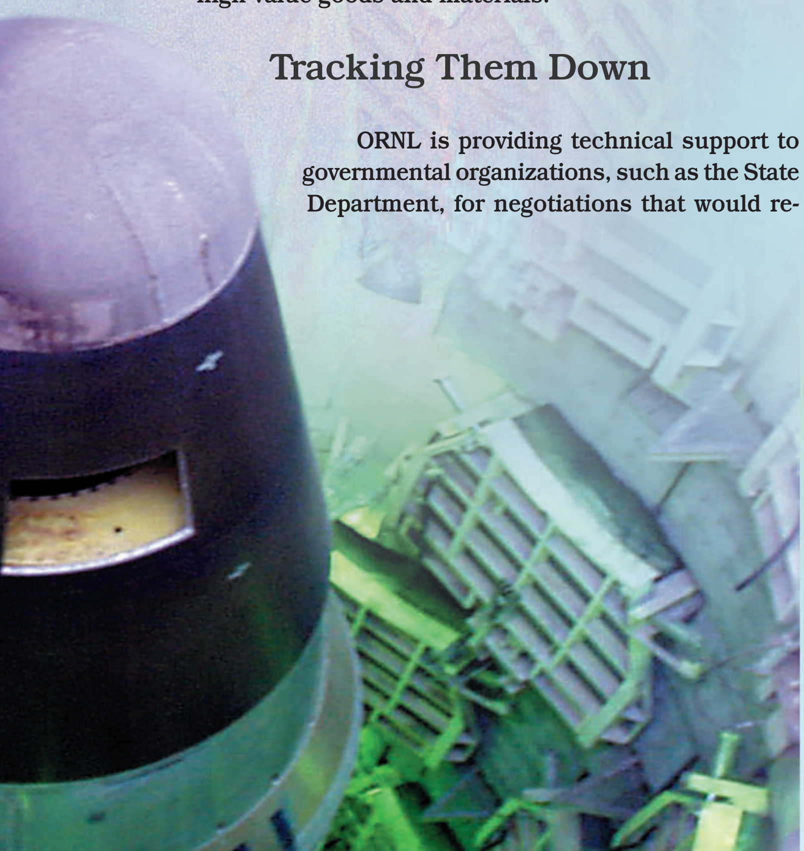
ORNL is providing technical support to governmental organizations, such as the State Department, for negotiations that would reduce deployed strategic nuclear warheads and provide options for bilateral monitoring of warhead subassembly dismantlement. One technology being considered for monitoring is ORNL's nuclear material identification system. This interrogating radiation detector can confirm the presence of a warhead without revealing sensitive design details.

A key component of America's non-proliferation policy is controlling nuclear material and devices exported from the United States and from other nations. ORNL researchers have been reviewing proposed exports of nuclear and nuclear dual-use equipment, materials, and technology. They have been assessing the risks that nuclear exports could be diverted to outlaw nations or terrorists and that exported reactors or materials could be used to make nuclear weapons.

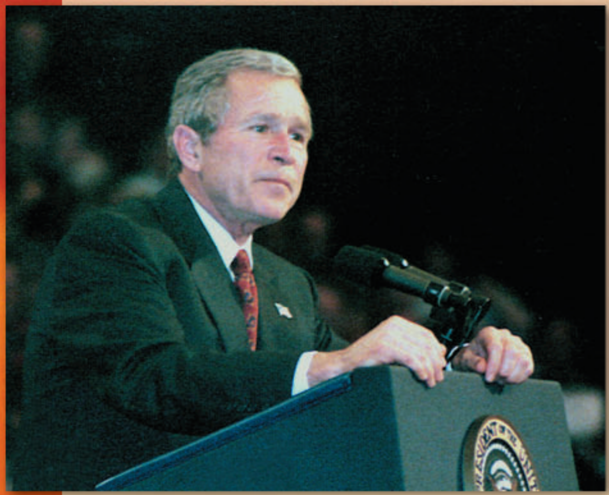
ORNL provides support to DOE's International Safeguards initiatives. These initiatives are designed to increase the IAEA's effectiveness and efficiency in independently assuring the international community that countries are complying with nonproliferation commitments. An ORNL group helps provide technical expertise to a DOE team that has been implementing international safeguards at Y-12 and other DOE facilities. ORNL helps DOE develop, test, and evaluate strengthened safeguards measures for IAEA to apply globally. These measures include ORNL-developed mass spectrometer methods of determining uranium and plutonium concentrations in environmental samples to detect "undeclared activities" at suspect sites.

To help prevent the smuggling of illegal nuclear materials and weapons into our country, customs officials need radiation detectors that are more sensitive and easier to use. Such detectors also would be useful to help monitor international compliance arms control treaties. ORNL researchers are developing greatly improved thin-film scintillators and other radiation-sensitive materials to increase sensitivity and enhance the use of radiation detectors.

To some, these technologies represent an ironic evolution of ORNL's mission and priorities. Oak Ridge National Laboratory was founded 60 years ago to end a war by helping develop a weapon of mass destruction. Today, ORNL is equally dedicated to the cause of avoiding future wars by preventing the use of those same weapons.



BETTING on the FUTURE



"Imagine a world in which our cars are driven by hydrogen and our homes are heated by electricity from a fusion power plant. It will be a totally different world than what we're used to....It's worth a look. Because the promise is so great."

—President George W. Bush, February 6, 2003

ORNL may soon be involved in an international partnership and become the site for a new fusion energy research device.

Fusion. The very word continues to stir excitement and ignite debate within the scientific community that at times seems as intense as the solar nuclear reaction it describes. For three decades, scientific and political enthusiasm for fusion energy research has ebbed and flowed. Soaring gasoline prices and threats to oil supplies have led periodically to calls for a renewed commitment to fusion research. Unlocking the secrets of fusion energy requires patience and sustained funding over several years. In a world that often demands a rapid return on investments, some believe that fusion research has never enjoyed the extended support needed to develop a lasting source of safe, clean, and abundant energy.

As the Department of Energy's largest energy research laboratory, Oak Ridge National Laboratory has chosen to make fusion energy a priority item of the Laboratory's research agenda. With this decision, the Laboratory has embarked upon a multi-year journey that will require a significant commitment of personnel and facilities. Those involved are aware that fusion's future may be as uncertain as its past, and that beyond the crest of the hill, the path ORNL has chosen is unmarked. They also believe, however, that the promise and potential of fusion energy are pointing us in the right direction.

"Bill Madia has played an instrumental, if not inspirational, role in revitalizing our program," Stan Milora, director of ORNL's Fusion Energy Division (FED), says of ORNL's director. "He believes our fusion research contributes strongly to both ORNL's science and energy missions. He recognized the importance of strengthening ORNL's partnership with the Princeton Plasma Physics Laboratory (PPPL) in developing compact stellarators."

ORNL fusion researchers have enjoyed a long-term relationship with PPPL in Princeton, New Jersey. In 1979 ORNL's neutral-beam technology achieved a record-high temperature in a PPPL fusion device. In the 1980s, under Milora's leadership, pellet fueling developed at ORNL was used for refueling PPPL devices. Today a jewel in PPPL's crown is the National Spherical Torus Experiment (NSTX), a research facility based on a promising plasma confinement approach conceived by ORNL physicist Martin Peng, who, as director of the NSTX Research Program, leads its scientific research program.

Most ORNL-PPPL collaborations have involved tokamaks, toroidal plasma confinement devices shaped like a doughnut. A plasma is an extremely hot state of matter consisting of charged heavy hydrogen nuclei (e.g., deuterium from seawater and tritium bred in the device) and free electrons swirling at very high velocities. Ideally, the plasma is confined not by the material walls but by magnetic fields, including the field produced by the plasma current. Confining plasma particles long enough at a sufficiently high density would allow sustained production of fusion reactions, which would provide the heat needed to generate electrical power. The energy produced would exceed the energy used to operate the device.

Among the PPPL projects involving ORNL researchers was the Tokamak Fusion Test Reactor (TFTR), which produced a world-record 10.7 megawatts of fusion power in 1994 using deuterium-tritium fuel. The focus of ORNL and PPPL toroidal research is now the NSTX, much smaller than the TFTR and shaped like a cored apple, giving it a more compact design, and the compact stellarator. The NSTX goal is to provide data for determining whether a next-generation spherical torus device could produce three times the fusion power of TFTR at a third of the cost. The compact stellarator goal is to combine the best features of the tokamak with those of the other major confinement approach, the stellarator.

NEW DEVICE FOR ORNL?

Tokamaks require a large current flowing in the plasma for their good confinement properties, but this current can cause a "disruptive" loss of the plasma energy that can damage the tokamak and would lead to lower efficiency in an eventual fusion power plant. The stellarator does not require a large current in the plasma, but this approach would lead to a very large reactor. Two experiments are proposed to study the two variants of the compact stellarator approach: the National Compact Stellarator Experiment (NCSX), under design for construction at PPPL, and the Quasi-Poloidal Stellarator (QPS), under design for construction at ORNL.

FED has major responsibilities for both experiments because of its expertise in designing innovative stellarator experiments, its experience operating a large stellarator experiment, and its strong stellarator theory program. ORNL is responsible for the engineering design of the NCSX stellarator in partnership with PPPL under the leadership of ORNL's Brad Nelson. ORNL's Steve Hirshman leads the multi-institutional group that developed the computational tools and initial design of the complex magnetic field coils required to create the NCSX plasma configuration.

PPPL and the University of Montana are collaborating under ORNL's leadership in developing the QPS concept. The complex magnetic field geometry of the QPS was developed by Hirshman's team, principally FED's Don Spong and CSED's Dennis Strickler, with the help of the IBM RS/6000 SP supercomputer at DOE's Center for Computational Sciences at ORNL. Brad Nelson's group, principally Dave Williamson and Mike Cole, are translating the demanding physics design into an engineering design for a practical device. The proposal is to construct QPS by 2008 in the new ORNL multipurpose facility that UT-Battelle plans to build near the robotics research building on the Clinch River.

Milora has other reasons to be optimistic about the future of fusion energy research at ORNL and in the United States. "Fusion is an attractive long-term energy option," he says. "Fusion energy will rely on unlimited, renewable fuel. Fuel from 50 cups of seawater equals 2 tons of coal.

"Fusion will be environmentally acceptable because it releases no water or air pollutants, including greenhouse gas emissions. Its small amounts of wastes will give off low-level radioactivity, but only for a short time, posing virtually no disposal problem."

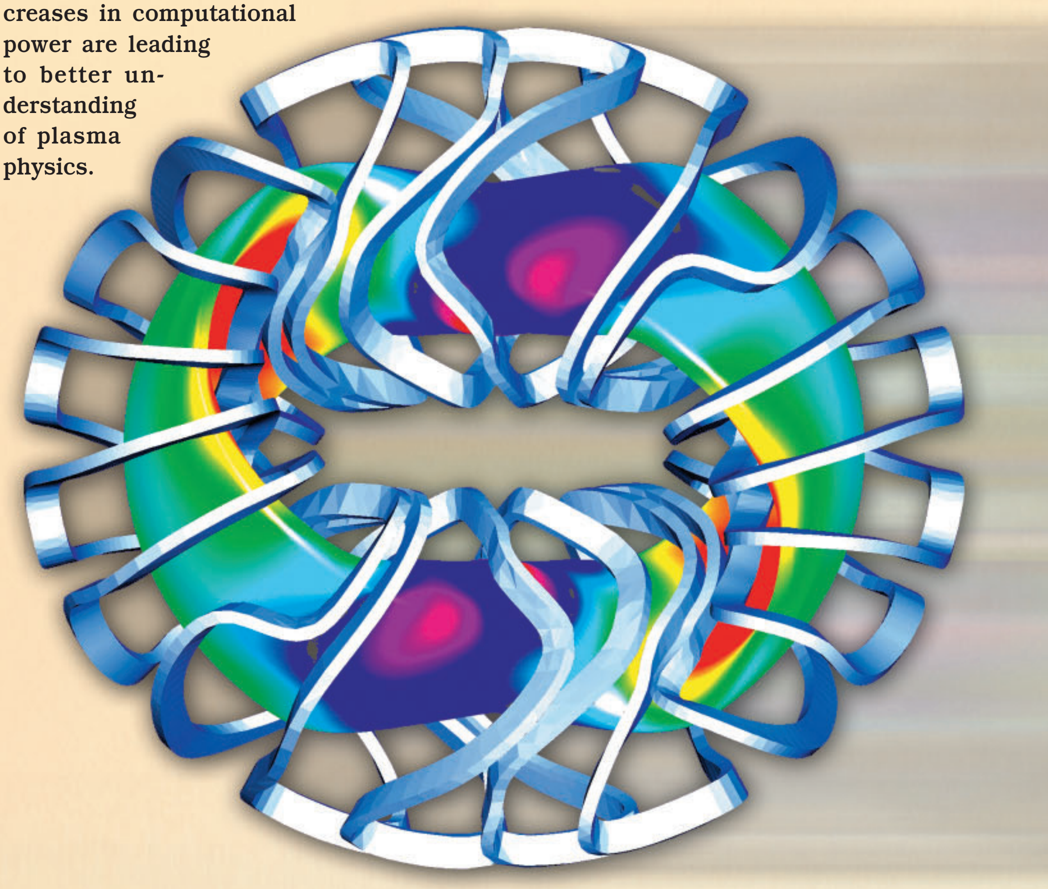
STEADY PROGRESS

In recent years, Milora notes, steady progress has been made in fusion research. Fusion power has increased by eight orders of magnitude, and sustained plasma time has increased 100 times. New methods have quelled turbulence in high-temperature plasmas, resulting in dramatic improvements in the ability to hold plasma heat within magnetic "bottles." Increases in computational power are leading to better understanding of plasma physics.

Because President Bush supports the development of technologies to stabilize atmospheric carbon dioxide to avert undesirable climate changes, it is believed that carbon-free energy production technologies should be in place by the middle of the century. Milora notes that the May 2001 report of the National Energy Policy Development Group headed by Vice President Dick Cheney "recommends that the President direct the Secretary of Energy to develop next-generation technology—including hydrogen and fusion."

Recently, Ray Orbach, director of DOE's Office of Science, requested that the Fusion Energy Sciences Advisory Committee (FESAC) develop a plan for the commercialization of fusion energy on the President's time frame. The plan, prepared by a FESAC panel chaired by PPPL's Director Rob Goldston, outlines the steps and resources required for the operation of a demonstration fusion electric power plant (Demo) in about 35 years.

The magnetic field strength of the flux surface and magnet coils of the Quasi-Poloidal Stellarator is shown by color coding.



Friendly Materials for FUSION

To design a commercial fusion power plant that could compete economically and environmentally with fossil and fission power plants, improved materials are needed for the vessel and other structural components. Such a material must withstand the heat and radiation of a fusion plant operating at temperatures up to 1000°C for maximum efficiency. Also, a few years after the fusion plant is shut down, the new material should be no more radioactive than a pile of coal ash from a coal-fired power plant. Thus, components made of this material could be disposed of legally by shallow land burial or eventual recycling.

During the early 1980s, austenitic stainless steel was considered the leading candidate structural material for fusion reactors. Studies predicted that, after fusion neutrons bombarded this steel, it would emit high levels of decay heat and hazardous radioactivity long after the plant closed. Such a "high-activation" material requires special disposal.

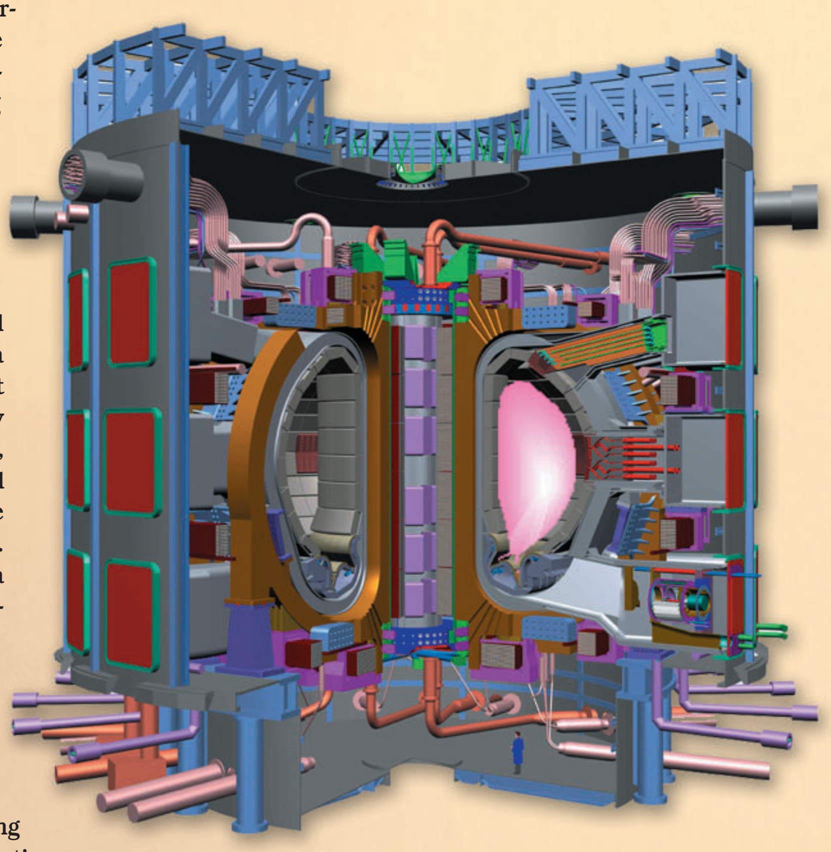
In the mid-1980s it was decided that fusion plants, which will not produce climate-altering carbon dioxide or health-altering sulfur and nitrogen oxides, could be made even more environmentally attractive. One key was to identify "low-activation" materials that give off very low decay heat and radioactivity after a short time.

NEXT STEP

So, what are the next steps to get our nation to a power-producing fusion reactor? FED's Nermin Uckan, editor of the journal *Fusion Science and Technology*, says fusion researchers believe that now is the time to build a burning plasma experiment.

One such experiment being planned is the International Thermonuclear Experimental Reactor (ITER) partnership involving Europe, Canada, Japan, Russia and China. Recently, the United States rejoined international negotiations on ITER, suggesting that ORNL may someday play a role again in this important venture. ITER is designed to demonstrate essential fusion energy technologies in a system that integrates physics and technology and will test key elements required to use fusion as a practical energy source for electricity production. ITER's engineering design, completed in July 2001, incorporates U.S. innovations and takes advantage of recent physics developments that have increased confidence that the project will meet its goals. ITER will be the first device to produce a burning plasma and to operate at a high fusion power level for such long-duration experiments.

"Assuming successful international negotiations, in about a decade, an international coalition will bring the ITER online," Uckan says. "ITER is capable of producing at least 500 megawatts of fusion power in a steady flow up to an hour long. ITER plasma of high temperature and density will be confined by superconducting magnets, producing magnetic fields 100,000 times stronger than the earth's magnetic field." Should ITER not move forward, she adds, the U.S. plan calls for construction of a modest domestic burning plasma experiment called the Fusion Ignition Research Experiment (FIRE).

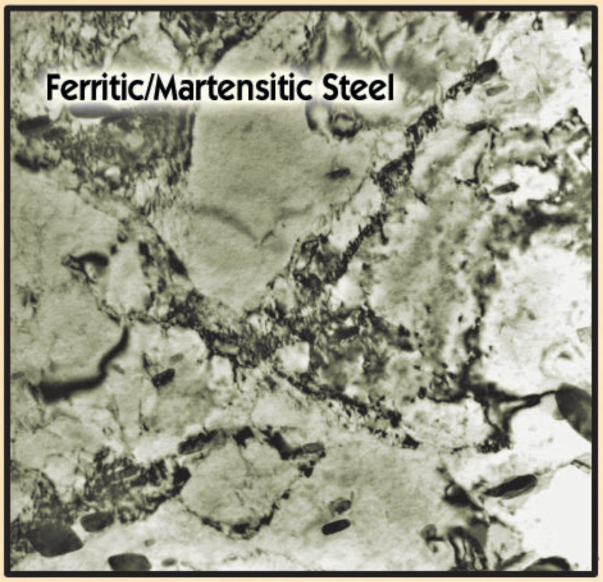


Schematic of the proposed International Thermonuclear Experimental Reactor.

Since the mid-1980s ORNL researchers have sought high-performance, reduced-activation, radiation-resistant structural materials. Steve Zinkle, leader of the Nuclear Materials Science and Technology Group in ORNL's Metals and Ceramics Division, and his colleagues have been irradiating alloy and ceramic samples with neutrons from the Laboratory's High Flux Isotope Reactor (HFIR) and evaluating their performance.

They found that the most promising low-activation fusion materials are an ORNL-formulated ferritic steel, a vanadium alloy, and a silicon carbide (SiC) composite developed by collaborators from ceramic companies and ORNL's High Temperature Materials Laboratory. The ferritic steel and vanadium alloy have superior mechanical properties and irradiation resistance compared with commercial alloys. Unlike commercially produced SiC ceramic composites that become substantially weaker during neutron irradiation, the ORNL fusion-formulated composite, according to experiments at HFIR, actually becomes 5 to 10% stronger after irradiation.

"Some 50 to 100 years after a fusion plant is dismantled, our reduced activation ferritic steel would have a radioactivity level only about twice that of coal ash," Zinkle says. "The vanadium alloy would decay to the coal ash level after 10 years. The SiC composite would decay to the same level after one year."



ORNL is involved in both the ITER and FIRE studies. "ORNL members, along with other U.S. institutions, are assessing the new ITER design and its procurement packages," she says. "ORNL was a major contributor to ITER physics and plasma technologies during the early phases of the project, and ORNL involvement will continue again in physics analysis, pellet fueling, and radiofrequency heating."

Milora serves on the U.S. Burning Plasma Program Advisory Committee, and Uckan serves as an international editor in compiling the Tokamak Physics Basis for ITER. Several ORNL researchers participate in and chair International Tokamak Physics Activity groups that provide physics input to ITER. Other participating institutions include PPPL; General Atomics; DOE's Lawrence Livermore, Los Alamos, and Sandia national laboratories; and several universities.

Fusion researchers in Europe, Japan, Russia, and the United States have called for the construction of an International Fusion Materials Irradiation Facility to test the properties of structural and other materials to determine which ones should be used in future plants. (See sidebar.) U.S. researchers also propose the construction of a Component Test Facility to test engineering structures to guide the design of future devices. Both facilities, if built, could be operating between 2015 and 2020.

"After the burning plasma experiment completes its operational life, the United States will need a demonstration reactor to show that new structural materials will hold up and that heat can be extracted from burning plasma to generate power," Milora says.

"In the DOE system," he adds, "ORNL is unique because of its variety of fusion-related capabilities. Our research embraces theory, computational simulation, experimental plasma physics, advanced materials, measurements of atomic physics processes that occur when the plasma interacts with the vessel wall, robotics, nuclear database maintenance, technologies for energy production, and enabling technologies such as radiofrequency heating and pellet refueling."

"Since the 1950s ORNL has helped advance fusion's steady progress," Uckan says. "It takes a long time because, in this business, you have to learn to crawl and then walk before you can run."

Editor's note: Exploring the life sciences has been a mission at Oak Ridge National Laboratory since the early 1950s, when researchers sought to understand the relationship of radiation to the human body. More than a half-century later, that early mission has embarked on a new course. The destination is a far bolder one: understanding life itself.

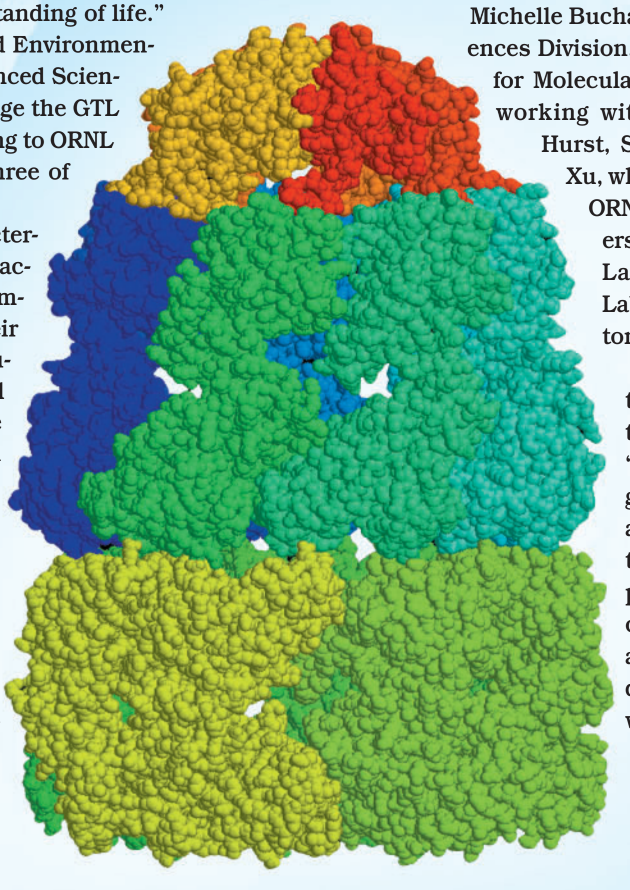
Sailing Into Uncharted Waters

A researcher scooped up some "clean" water containing bacteria and transferred the "bugs" to water with a known contaminant. Now comes the difficult part: Predicting how large groups of bacterial proteins, the workhorses in and around each one-celled organism, will respond to chemical "signals" from the contaminant.

Identifying and characterizing the molecular machines of life—the multi-protein complexes that execute cellular functions and govern cell form—is one of four ambitious goals of a new program started in 2001 by the Department of Energy's Office of Science. The Genomes to Life (GTL) program seeks to "achieve the most far-reaching of all biological goals—a fundamental, comprehensive, and systematic understanding of life."

DOE's Office of Biological and Environmental Research and the Office of Advanced Scientific Computing Research will manage the GTL program jointly. Both provide funding to ORNL researchers, who are involved in three of five GTL projects.

Other GTL goals are to characterize gene regulatory networks, characterize the functional repertoire of complex microbial communities in their natural environments at the molecular level, and develop computational methods and capabilities to advance understanding of complex biological systems and predict their behavior.



BIOLOGY IN THE POST-GENOME ERA

The GTL program follows DOE's Human Genome Program, which contributed to a revolutionary scientific achievement in 2000 with completion of the draft sequence of the human genome. Draft sequences of the genomes of several bacteria, the mouse, and other organisms also have been published. They show the order of chemical bases making up every gene in each organism.

Related to the Human Genome Program is the Microbial Genome Program, started in 1994. The program's purpose is to apply knowledge about microorganisms to help DOE achieve the agency's missions of developing clean energy sources and protecting the environment. These programs revolutionized biological research and provided what are now common tools used in forensics, pharmaceutical design, and disease diagnosis. Knowing the gene sequence, however, is only a first step in fully understanding how an organism works.

The long-term goal of the GTL program is to understand, at the molecular level, how genes, proteins, and other cellular molecules interact to carry out life's process within and between cells. Meeting this challenge will require teams of biological, chemical, physical, and computational scientists. Central to the program's success is the development of new analytical and computational tools.

Michelle Buchanan, director of ORNL's Chemical Sciences Division, is scientific director for GTL's Center for Molecular and Cellular Systems. Task leaders working with her include Mitch Doktycz, Greg Hurst, Steve Kennel, Mike Ramsey, and Ying Xu, who coordinate contributions from other ORNL staff. They collaborate with researchers from DOE's Pacific Northwest National Laboratory (PNNL), Argonne National Laboratory, and Sandia National Laboratories (SNL), as well as two universities.

"The program initially will identify and analyze protein complexes in two types of bacteria," Buchanan says. "Protein complexes enable cellular growth, metabolism, replication, repair, and responses to intracellular and extracellular signals, like molecules from pollutants. They are responsible for a cascade of molecular processes within and between cells. The complexes also dictate how a cell or organism interacts with its environment."

Bob Hettich prepares to study bacterial proteins using a high-performance Fourier transform ion cyclotron resonance mass spectrometer.

Buchanan's project will begin by focusing on the application of analytical tools to the identification and characterization of protein complexes to better understand the function of cells in two microbes. They are the *Shewanella oneidensis* (which can reduce oxidized metals in solid deposits in soils) and *Rhodopseudomonas palustris* (which can fix carbon monoxide or use organic molecules as a carbon source for basic metabolism).

"We plan to set up a high-throughput system to characterize the protein complexes in these microbes," Buchanan says. "We will use instruments such as mass spectrometers, the lab-on-a-chip device developed at ORNL, and imaging tools.

"Our data will help our computer scientists develop models so we can take shortcuts in identifying and describing protein complexes in different microbes. Our eventual goal is to do a bug a day."

Researchers working with the center will develop new capabilities to prepare and culture bacterial samples, do complex separations of components of protein complexes, identify proteins at the molecular level using mass spectrometry, characterize protein complexes in living cells by imaging, and apply bioinformatics and computational tools to collect and interpret data and form databases and tools for sharing by the biological community.

Ed Uberbacher, leader of the Computational Biology Group in ORNL's Life Sciences Division, says analytical tools and algorithms will be needed to determine how proteins interact, stimulate chemical reactions, and move materials inside and out of cells under different conditions.

"Proteins turn genes on and off, regulating their activities," he says. "When a bacterial cell is moved from clean to polluted water, proteins capture environmental signals and turn on genes that make proteins enabling the cell to adapt to its new environment. We want to characterize this cascade of changes."

For example, in a cell exposed to a pollutant, a phosphokinase enzyme may attach a phosphate to a protein to activate it. Mass spectrometry can confirm whether a protein is linked to a phosphate.

NEW CENTER FOR ORNL?

ORNL is a potential site for one of four GTL research centers planned by the Office of Science. The center, called the Characterization and Imaging of Molecular Machines, would be anchored to the project led by ORNL.

Oak Ridge's chances of hosting one of the new GTL centers are improved by a robust array of supporting programs and facilities. ORNL's Center for Computational Sciences would provide one of the world's largest supercomputers capable of processing, for example, the vast amounts of data involved with protein folding. The program also would be supported by two new facilities, the Center for Functional Genomics, funded by the Office of Science, and the Joint Institute for Biological Sciences, funded by the state of Tennessee.

"If DOE awards Oak Ridge a GTL facility, it could be operating in the next four to six years," Buchanan says. "The complex would have offices for visiting scientists, students, and staff; biopreparation and culture labs; analytical instruments; robots; imaging instruments; clusters of computers; data visualization; and networked links to supercomputers."

Synechococcus Sp cyanobacteria take up carbon dioxide from the atmosphere and store it in the ocean. But what limits the ability of these bacteria to fix carbon in many areas of the ocean? To answer these and other questions, another GTL project will combine experimental and computational simulation tools for high-throughput characterization of protein complexes. The researchers also will try to identify proteins in regulatory pathways and determine how they interact using gene microarray data.

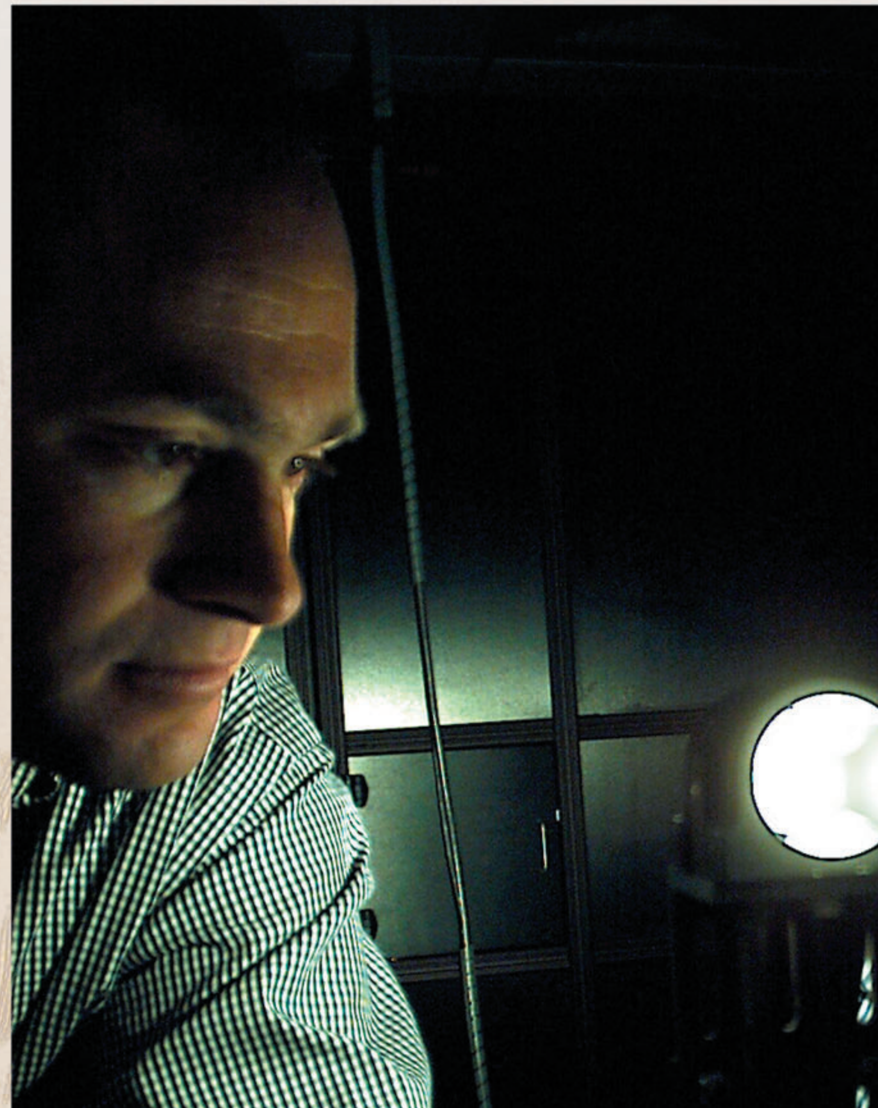
The leaders of the project, which involves collaborators from DOE national labs, universities, and research institutes, are Grant Heffelfinger of SNL and Al Geist of ORNL's Computer Science and Mathematics Division. Collaborating computer scientists from ORNL include Phil Locascio, Victor Olman, Nagiza Samatova, Manesh Shah, and Dong Xu.

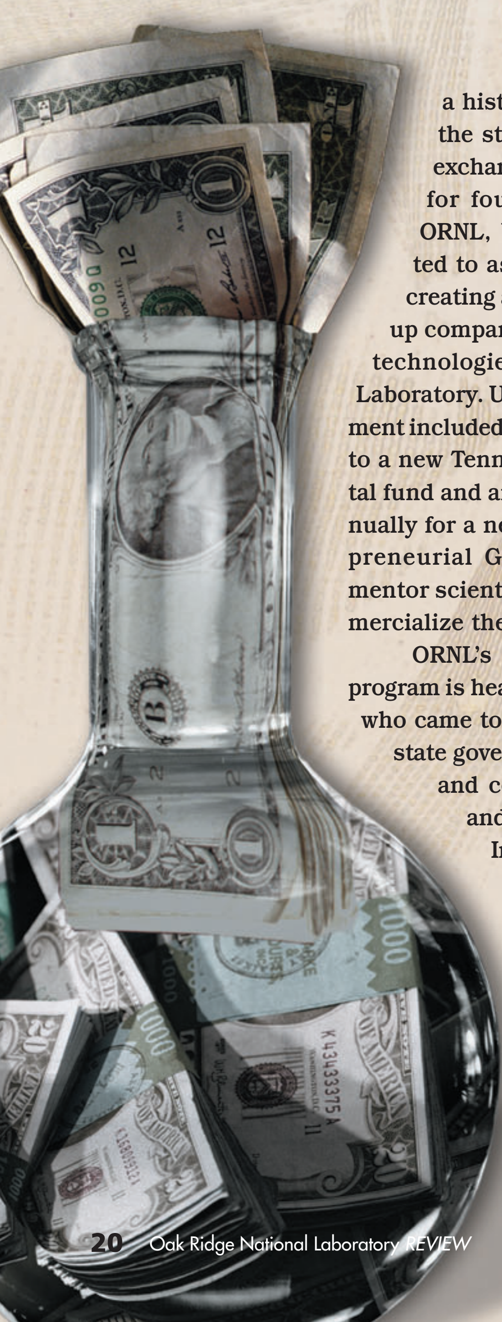
How do gene regulatory networks behave in microbes in response to waste sites contaminated with metals and radionuclides? This question will be tackled by another GTL project involving ORNL. DOE's Lawrence Berkeley National Laboratory leads this project, which also has collaborators from three universities and a corporation. Jizhong Zhou of ORNL's Environmental Sciences Division is using microarrays to help provide data on changes in gene expression under differing environmental conditions for use in computer models. The goal is to rapidly predict gene and protein changes in microbes as they encounter various stresses.

Like the Portuguese explorers of the 16th century, ORNL researchers are sailing into uncharted waters, excited by the discoveries that surely lie ahead.

A New Engine for ECONOMIC GROWTH

ORNL has added a new priority to the Laboratory agenda: Moving technology from the benchtop to the marketplace.





In April 2000, ORNL entered into a historic agreement with the state of Tennessee. In exchange for state funding for four new facilities at ORNL, UT-Battelle committed to assisting the state in creating at least 10 new start-up companies each year using technologies developed at the Laboratory. UT-Battelle's commitment included providing $1 million to a new TenneSeed venture capital fund and another $100,000 annually for a new Center for Entrepreneurial Growth designed to mentor scientists wishing to commercialize their research.

ORNL's technology transfer program is headed by Alex Fischer, who came to Oak Ridge after serving in state government as deputy governor and commissioner of Economic and Community Development. In an interview with the *Review*, Fischer reflected on how and why ORNL is allocating substantial resources to technology transfer through its Office of Technology Transfer and Economic Development.

Q: ***UT-Battelle has helped spur the creation of 30 new companies in the past three years. What are the drivers behind this effort?***

A: The federal government has made significant investments in Oak Ridge for national purposes. We have an opportunity to leverage those investments as an important economic driver for our region and, in fact, our country. Creating new companies based on ORNL technologies and transferring these technologies to companies are encouraged and supported by DOE, and are a key part of the UT-Battelle culture and philosophy. It also makes great business sense for the Lab's research and development agenda.

"I want to ensure that we deploy world-class market analysis. That should enhance our chances for success in commercializing ORNL technologies." —Alex Fischer

(with Jeff Muhs, left, developer of hybrid solar lighting, which ORNL seeks to commercialize).

Q: ***How does technology transfer help the Lab?***

A: It helps us bring more work into the Laboratory, and income created through the licensing of ORNL technologies is reinvested in R&D activities. Much of our commercialization work has a direct relationship to cooperative research and development agreements (CRADAs) and work-for-others projects. In the history of tech transfer at ORNL, almost $1.4 billion has been brought in through CRADAs and work-for-others contract mechanisms—that's a huge economic driver.

Q: ***How are technology transfer efforts affected by ORNL's relationship with the Battelle Memorial Institute in Columbus, Ohio, and the University of Tennessee?***

A: Battelle was set up as a nonprofit charitable trust by Gordon Battelle to "further mankind through science and technology." It has a strong commercialization legacy, including the development and licensing of the office copier and compact disc technologies. By combining Battelle with the state's flagship land-grant institution, we have created an organization with a culture very different from that of previous ORNL contractors. Previous contractors did technology transfer because it was in the contract. UT-Battelle does it because we feel it's the right thing to do, offering a tremendous opportunity for growing the Laboratory. It's part of the Battelle legacy, and it's increasingly part of the UT mindset. Dr. John Shumaker, UT's new president, is creating a private research foundation that will aggressively take advantage of the university's technology portfolio. The UT-Battelle combination creates a great environment for tech transfer at the Lab.

Q: ***Do Battelle and UT benefit financially from ORNL inventions?***

A: Not individually, but I hope that the 50/50 partnership of UT-Battelle, LLC, does. Profit is a good word, and I hope we make lots of it. When we do, *all* profits are reinvested back into furthering the Laboratory agenda. That's good for the Lab, DOE, UT, Battelle and the economy—everyone wins. We need to think more like a business and not be afraid to say profit. Profit isn't a dirty word.

Q: ***How is this money used?***

A: Some of it is put into a technology maturation fund. We have a great opportunity to plow money back into the further development of ORNL technologies that we believe have the best chance of being commercialized. Targeted reinvestments could get these technologies to the marketplace more quickly and further the Lab's R&D agenda. We're currently designing a process to prioritize our activities and investment in these areas.

Q: ***Does this mean your office influences ORNL's R&D agenda?***

A: We never should drive the research agenda at the Lab. That's not our job. ORNL's managers and funding sources, sponsors, and customers direct the research. We do, however, want to share information with researchers about our market analysis that provides good information on what the private marketplace says about the alignment between customer needs and our R&D. Our research community deserves to know how much demand exists for different technologies. Our scientists and engineers certainly are smart enough to know what to do with that information.

Q: ***How does your office do market analysis?***

A: My goal is to improve our market analysis capabilities. Our staff has been reorganized to put a heavier emphasis on business analysis. We have a new partnership with UT's master of business administration program. We will sponsor four MBA students each year to do early-stage market analysis of invention disclosures that come to our office. I have asked Mark Reeves and Margaret Spurlin to head an in-house intelligence team devoted to market analysis. They will supervise our MBA teams. When we need more sophisticated analysis, we will look to outside consultants. We have a great resource at Battelle in Columbus, where staff have years of expertise in this area. We need to tap our partners' capabilities to further our work in Oak Ridge. We will share this market intelligence with our researchers as an additional data point.

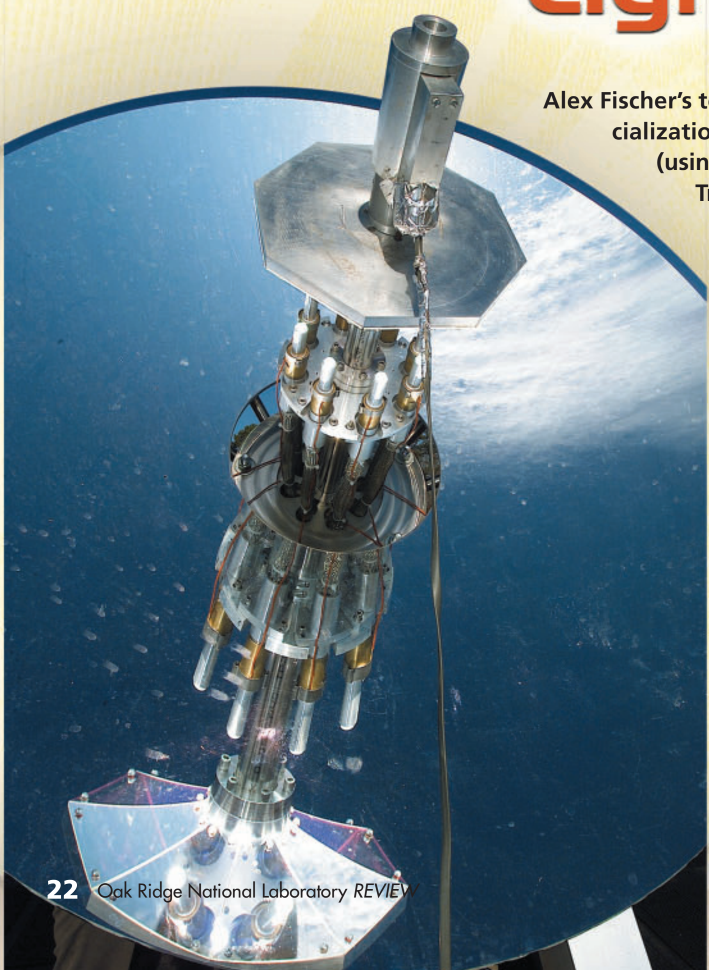
Q: ***How can you do market analysis in a faltering economy?***

A: If ever there was a time to do it, now is that time. I think our economy is poised for a great rebound and I want ORNL to be part of it. Innovation historically drives great gains in the economy. As we deploy world-class technology, and ORNL technology is world-class and second to none, I want to ensure that we deploy world-class market analysis. That should enhance our chances for success in commercializing ORNL technologies.

Q: ***How are the 30 companies faring in today's economy?***

A: Our companies are doing remarkably well. What a tough time for UT-Battelle to come in three years ago. Around that time, the dot-com and technology bubbles burst and venture capital evaporated. The national and local economies in the past three

Lighting the Way



Alex Fischer's technology transfer program is aggressively developing a commercialization plan for the licensing of ORNL's hybrid solar lighting technology (using device shown at left), now being demonstrated at the National Transportation Research Center. The hybrid lighting process, developed under the leadership of Jeff Muhs of the Engineering Science and Technology Division, allows the sun's rays to light a room directly by using optical fibers to bring sunlight inside, and in the future, indirectly by harnessing the remaining portion of sunlight (mainly infrared energy) to generate electricity that can power the room's light bulbs. ORNL and 10 companies have formed the Hybrid Lighting Partnership to develop hybrid solar lighting systems. Fischer would like to see an integrated system commercialized for use in schools, offices, and major retail outlets where studies show that natural sunlight has an advantage over traditional lighting. "Electric lighting is the single largest consumer of electricity in commercial buildings," Muhs says. "If we can replace electricity with energy from the sun as efficiently as possible using hybrid lighting, our nation will be less dependent on imported energy sources, we'll have cleaner air, and businesses will have better lighting and save money."

years have not been favorable for technology companies. But we made a commitment to create 10 companies a year to promote local and regional economic development. We have created 30 in three years, and the success rate has been good despite the economy. This year we are graduating a couple of companies from the Center for Entrepreneurial Growth, which is part of Tech 2020 located in Commerce Park in Oak Ridge. Through our partnership with the CEG, we create the right environment and infrastructure and pool a variety of resources—advice, business planning, counseling, funding, and physical space—to help each company succeed. The challenge is not just to create a company but to help it grow and mature. If investors think it is smart to support an ORNL technology-based spin-off company, there is access through Tech 2020 to more than $60 million in capital through the TenneSeed family of funds. We must use this great asset at ORNL for the economic benefit of the region.

Q: ***What are your office's other activities?***

A: We try to have a diversified portfolio. We don't just do small start-ups. We are working to license our technologies to mid-size companies and Fortune 500 companies like GM. Recent examples are the lab-on-a-chip device licensed to Caliper Technologies and graphite foam licensed to Poco Graphite. We also are involved in protection of our intellectual property, which includes invention disclosures and patented, copyrighted, and trademarked technologies. Historically, our patent attorneys and agents have done a good job on the legal analysis and protection of our intellectual property. For the future we are looking at "bundling" technologies—offering a company a suite of patents covering similar technologies from ORNL, UT, Battelle, and any of our core universities. Another concept being pursued is *contractor-funded technology transfer* in which UT-Battelle funds technology transfer efforts in exchange for certain rights to the intellectual property.

WINNING THE CHIP RACE:
A Technology Transfer Success Story

A picture is worth a thousand words, but a thousand pictures that look alike can make a semiconductor yield engineer say one word—"Eureka."

Ken Tobin, Regina Ferrell, Shaun Gleason, and Tom Karnowski, all of ORNL's Engineering Science and Technology Division, have developed an automated image search engine that reduces the time yield engineers spend sifting through numerous microscope images looking for the source of a manufacturing problem. This award-winning automated image retrieval (AIR) system helps engineers quickly find images showing defects similar in size, color, texture, or shape in layers of computer and cell-phone chips during their manufacture. One such defect could be a short or break in a transistor wire caused by particles accidentally released by a robot handler or scanning electron microscope.

AIR helps engineers learn more quickly how to ramp up yield so their companies can ship a higher percentage of their chips to customers, increasing their profits and reducing waste. A yield improvement of only 0.1% can save the industry $150 million annually.

"We demonstrated in a manufacturing environment that we can search 80,000 images and find 128 similar defect images in 7 seconds," Tobin says. "Our engine should retrieve similar images in less than 20 seconds from a database of one million images."

AIR started as an ORNL seed money project proposed by Tobin's team in 1998. In 1999 the team applied for two patents on AIR. In 2000, the first tests of AIR were performed on semiconductor image data at two leading semiconductor companies through a contract with International SEMATECH in Austin, Texas.

Applied Materials, Inc., of Santa Clara, California, which makes chip manufacturing and inspection equipment, entered into a multi-year cooperative research and development agreement with Tobin's group. After a successful proof of concept, the AIR technology was licensed to Applied Materials. The ORNL software product was integrated into the company's Defect Source Identifier product (DSI™-AIR).

The DSI™ -AIR product received an R&D 100 Award from *R&D* magazine in 2002 as one of the 100 top innovations of the year. For this work, Tobin's team also received the ORNL Director's Award, and in 2003, a Federal Laboratory Consortium Southeast Region and National award.

The AIR project has brought to ORNL $2.6 million from International SEMATECH and Applied Materials. Negotiations are under way with several companies interested in licensing AIR. The royalty stream to ORNL for AIR could exceed $1.5 million.

Ken Tobin shows images of similar chip defects captured by scanning electron microscopes and retrieved by the AIR software engine for yield analysis.

Tower power

In cooperation with 3M and TVA, ORNL has helped develop advanced power transmission cables that could improve the nation's electricity distribution.

Advanced overhead cables strung between transmission towers making up the U.S. power grid could carry up to three times the electrical current of today's power lines. What's more, they will not sag like conventional conductors when heated by excess current loads on hot days, as happened in the major power outage in August 1996 in the northwestern United States.

Advanced transmission lines will be needed because the U.S. demand for power is expected to rise by 25% in the next 10 years, when environmental and aesthetic concerns may delay further construction of towers and transmission right of ways (ROWs). Using available technology to build new ROWs and tower systems will cost well over $1 million per mile. Upgrading lines in today's ROWs with advanced conductors will significantly reduce the overloaded electrical infrastructure at a fraction of the cost.

ORNL and the Tennessee Valley Authority are working together to test advanced cables, developed jointly by 3M and ORNL, that could replace conventional aluminum-conductor, steel-reinforced (ACSR) power lines. A memorandum of understanding between ORNL, the Department of Energy, and TVA was signed at the March 25, 2003, dedication of the National Transmission Technology Research Center at ORNL. This facility will test advanced power lines strung between TVA poles along Old Bethel Valley Road, as well as other advanced transmission technologies at ORNL and East Tennessee Technology Park.

At the dedication, TVA Chairman Glenn McCullough noted that transmission-line congestion threatens U.S. energy security and raises consumer electric bills unnecessarily. "We have a problem that we can—that we must—solve," McCullough said. Gerald Boyd, manager of DOE's Oak Ridge Operations, added, "Never before has there been such an important need for transmission research."

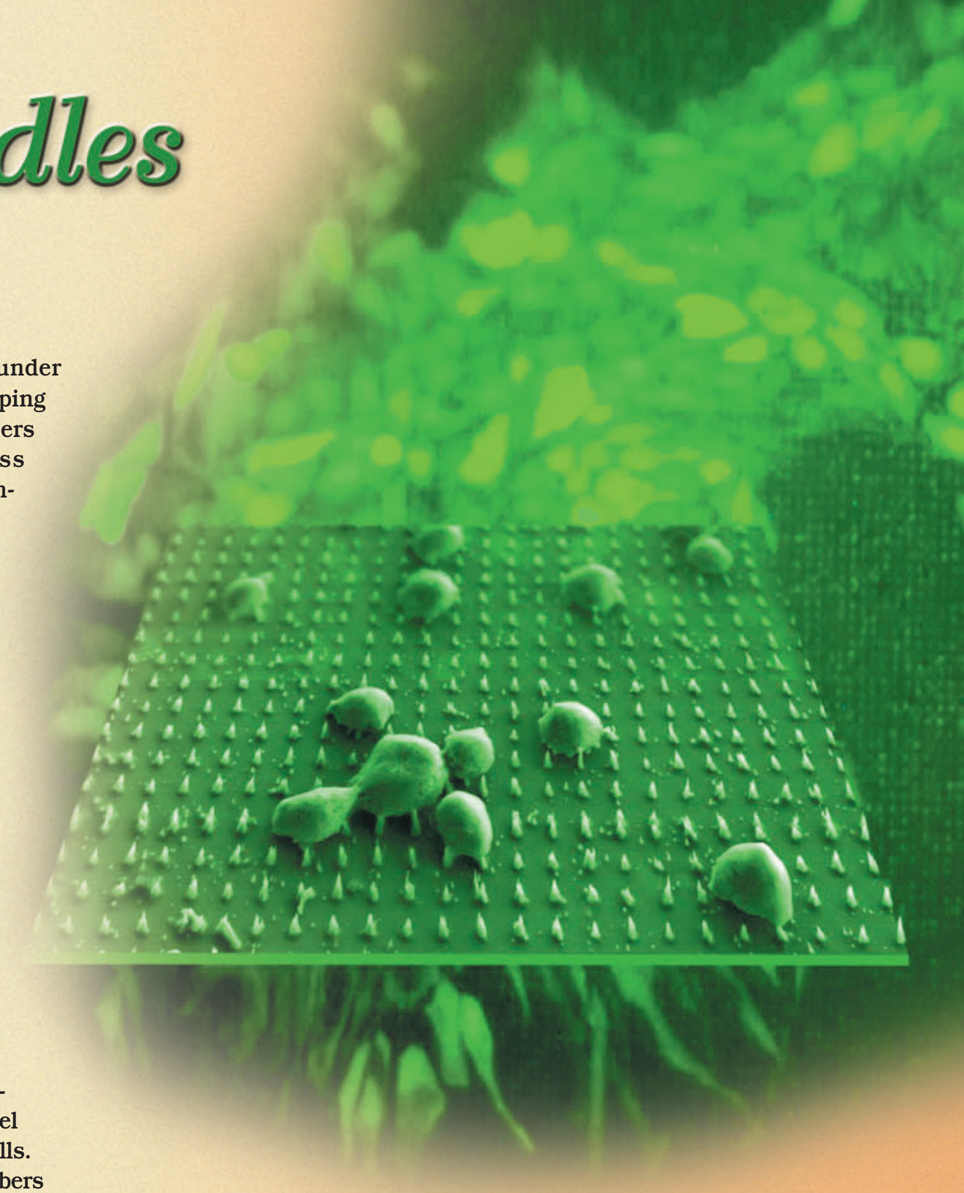
Today's overhead ACSR transmission lines consist of aluminum conductor strands wrapped around a steel core, which tends to corrode in air. Because the weight and properties of the steel make these cables vulnerable to stretching when overheated, 3M and ORNL investigated alternative materials. As part of a cooperative research and development agreement with ORNL, 3M developed a composite consisting of a core of 3M Nextel 650 ceramic fibers embedded in an alloy of aluminum and zirconium (added to make the matrix less likely to deform at higher temperatures). Vinod Sikka and Evan Ohriner, both of ORNL's Metals and Ceramics Division, helped 3M improve the quality and production of the composite material.

John Stovall, Tom Rizy, and Roger Kisner, all of ORNL's Engineering Science and Technology Division, have been testing 3M's advanced cable material to determine how well it holds up over time and through many thermal cycles of current flow. They seek to determine whether the new conductor can handle higher temperatures of up to 240°C for emergencies and 210°C for normal operation without sagging more than ACSR cables at 100°C. A few months of testing is designed to simulate the stresses of years of normal operation. The ORNL and 3M teams are working to develop algorithms that will predict how much sag will result from specific temperature changes in the new cable.

Advanced composite conductor lines can be kept in inventory and put up faster than conventional lines to replace an ACSR line that has been knocked down. Power can be restored quickly in an emergency by stringing the new, lighter lines between temporary towers that are farther apart than regular towers.

Advanced cables can provide a lifeline for our nation's aging power grid, boosting our energy security.

Nano-needles to Cells



Living cells impaled on carbon nanofibers. In background a colony of cells penetrated earlier by DNA-modified nanofibers express green fluorescent protein.

An ORNL group is finding a way to get under your skin and coax your cells into pumping out a gene product that's good for you. The researchers hope to make a tiny patch dotted with painless nanofibers that would needle your cells into becoming a specialized protein factory.

Imagine you are diagnosed with an acute bacterial infection that, if left untreated, could cause a severe peptic ulcer and ultimately gastric cancer. You might be prescribed a course of antibiotics and told that if you miss even one dose, the treatment would be useless. What if you could simply wear a patch that coaxed your own cells, already intimately coupled with your circulatory system, to produce a blood-borne peptide that destroys the invading microbe? Ideally, you could wear the patch during treatment and remove it when the infection is eradicated, thus eliminating pills and the potential for missed doses.

This mode of gene therapy might be possible using a recently demonstrated drug and DNA delivery technique. Harnessing vertically aligned arrays of carbon nanofibers as parallel injectors, researchers in ORNL's Molecular Scale Engineering and Nanoscale Technologies (MENT) Group and Life Sciences Division have demonstrated massively parallel delivery of macromolecules to groups of mammalian cells. They have shown that living cells impaled by the nanofibers take up the small molecules of a fluorescent dye, propidium iodide, from the surrounding solution. Shortly after fiber penetration, however, the cells can reseal and exclude the dye. Larger molecules, such as gene-containing DNA, may be delivered by physically impaling cells upon DNA-modified nanofibers.

"The DNA can either be adsorbed onto the nanofiber tips or linked by covalent bonding," says Tim McKnight, a researcher in the MENT Group in the Engineering Science and Technology Division. "In both cases, when fibers are introduced into cells, the delivered DNA can be expressed, even when it remains tethered to the nanofiber scaffold." In an ORNL seed-money-funded demonstration, expression resulted in the production of a green fluorescent protein within targeted cells.

An array of DNA-modified carbon nanofibers could prompt cells to produce a needed protein.

With this technique, the introduced genes can be tethered to the nanofiber scaffold, potentially allowing them to be withdrawn from the manipulated cells when the gene products are no longer required. Upon removal, the cells would revert to their normal behavior, and the temporary genetic change imparted to those cells could not be inherited.

"We are seeking funding to explore the use of this technique for controlled delivery of genes to tissue, including potential delivery through skin," says McKnight. "It could provide a whole new approach to gene therapy."

The aim of gene therapy has been *permanent* gene insertion to provide missing genetic machinery to cure a patient of a specific disease or deficiency. However, permanent insertion can cause undesired side effects, as recently reported for retroviral-based gene therapy patients in France. Problems arise when delivered genes insert into and disrupt other necessary genetic elements within the cell. As such, gene therapy normally is limited to patients with life-threatening conditions.

"The use of scaffolded genes might reduce the potential for unwanted insertion and provide a potential control mechanism to return patients to their original condition if necessary," McKnight says. Although this approach will not achieve permanent changes sought through conventional gene therapy, the controllable nature of fiber-mediated delivery may increase the safety and potential use of gene-based therapies to treat non-life-threatening conditions.

New Answer for Cancer?

The radioisotope californium-252 in a miniature source designed at ORNL may someday help destroy often-fatal brain tumors and other cancers, too.

A radiation source the size of a ballpoint-pen clip has been shrunk to the diameter of a ballpoint-pen tip, a feat of miniaturization that could mark a major step in combating cancerous tumors previously deemed untreatable. This encapsulated wire-like source containing ORNL-produced californium-252 (^{252}Cf) was developed by researchers from the Laboratory and Isotron, Inc., of Alpharetta, Georgia, under a cooperative research and development agreement.

^{252}Cf, a neutron-emitting radioisotope produced at ORNL's High Flux Isotope Reactor by neutron bombardment of curium, is the heart of Isotron's neutron brachytherapy system. This treatment regimen permits physicians to deliver a highly concentrated dose of neutrons directly to the tumor. Neutron brachytherapy has proved particularly useful against cancers that are resistant to treatments with photons and gamma rays, which do not kill cancer cells as effectively as do neutrons.

Cancers most resistant to the conventional treatments include brain tumors, melanoma, sarcoma, certain types of prostate and cervical cancer, locally advanced breast cancer, and cancer of the head, neck, and mouth. Since 1969 ^{252}Cf has been used to treat more than 5500 patients with cervical, mouth, esophageal, head, and neck cancers from the United States, Japan, England, Russia, Czechoslovakia, China, and Lithuania. A recent study in the Czech Republic showed that the survival rate after five years for cervical cancer patients treated with ^{252}Cf was significantly higher than it was for patients treated with gamma radiation only.

"We are particularly hopeful that this miniature californium source can greatly prolong the lives of patients suffering from glioblastoma multiforme, the most common primary brain tumor that is often fatal within six months after diagnosis," says co-developer Rodger Martin of ORNL's Nuclear Science and Technology Division. "This tumor is extremely resistant to conventional forms of treatment. Less than 1% of patients having this tumor survive five years. Our advance in neutron brachytherapy will enable unprecedented treatment of this and almost 20 other types of cancer."

ORNL's main contribution was the miniaturization of the neutron source. After three years of effort, Martin and his colleagues shrank the source diameter by more than half, to a little over a millimeter. The source is actually a palladium wire containing a few percent ^{252}Cf. A barely visible piece of the wire is welded into a cylindrical metal alloy capsule less than a centimeter long. The capsule can be inserted into a catheter, a hollow tube inserted into the tumor or residual tumor cells after surgery. Because of this development, tumors that previously

An ORNL hot cell where actinium-225 is extracted from thorium-229, a decay product of uranium-233.

Fuel for Therapy

Saed Mirzadeh says that part of his job at ORNL involves "milking a cow." The "milk" is radioactive actinium-225 (^{225}Ac) extracted from thorium-229 (^{229}Th), a decay product of uranium-233 (^{233}U). The actinium decays to bismuth-213 (^{213}Bi), which appears to be prolonging human lives as part of a "last resort" experimental blood cancer therapy.

The "cow" is a stock of ^{229}Th taken from ORNL's ^{233}U stockpile in the center of its old campus. The fissionable ^{233}U was produced at a Hanford, Washington, reactor using natural ^{232}Th as neutron targets as early as the 1950s. Back then, when nuclear power was being developed, it was thought that natural uranium containing ^{235}U was scarce. So, researchers developed thorium targets for the production of ^{233}U fuel. Large uranium deposits were later discovered in New Mexico, so the concern about a uranium shortage evaporated. In the 1960s some of Hanford's ^{233}U was shipped to ORNL for nuclear fuel breeding experiments at the Molten Salt Reactor.

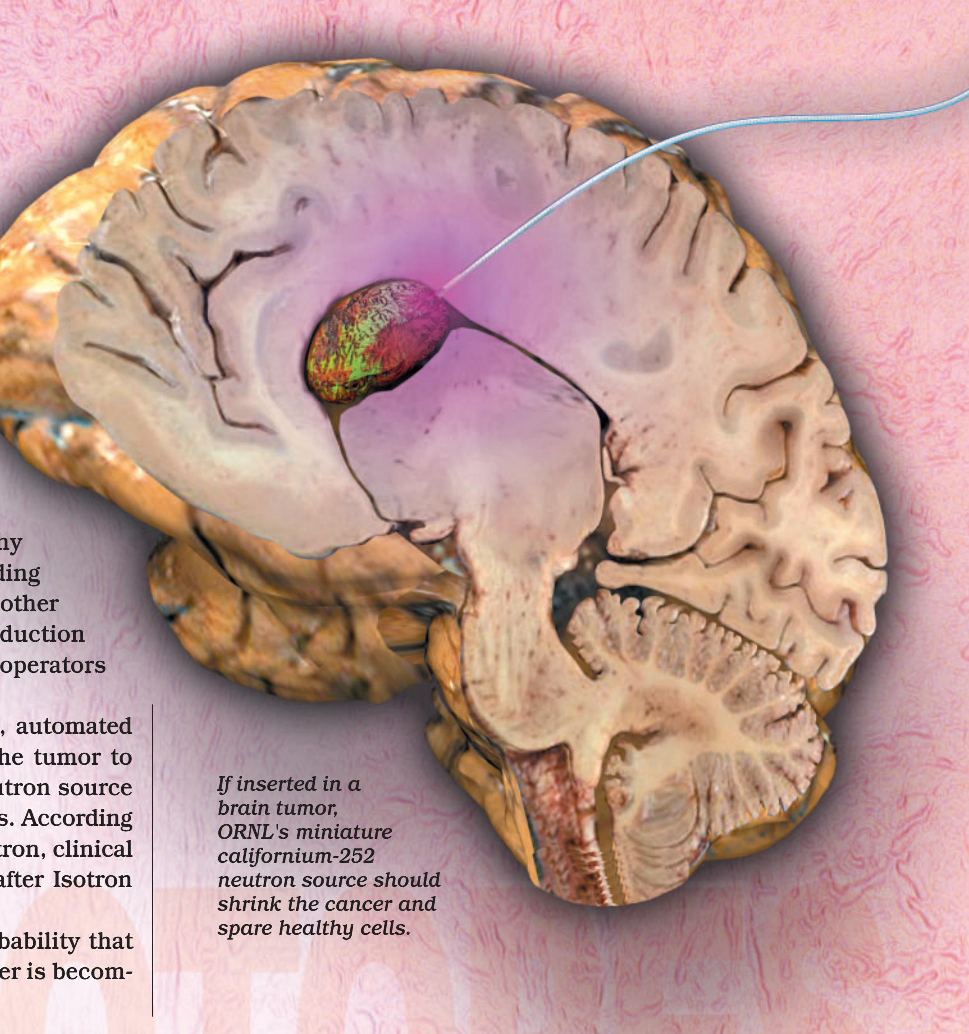
After joining ORNL's Nuclear Medicine Group in 1989, Mirzadeh looked for opportunities to develop sources of alpha particles for cancer therapy. An alpha particle, which consists of two protons and two neutrons, penetrates only a few cell diameters in tissue.

In 1995 Brad Patton received an inquiry from a private Dutch company about purchasing 2 kilograms of ORNL waste left from could be treated only with conventional photon and gamma brachytherapy or with external beam treatments can now be bombarded with neutrons.

Martin's ORNL co-workers devised a method of attaching the capsule to a positioning cable that would allow medical personnel to deliver the radiation dose to the target, avoiding healthy tissue. The ORNL team modified a commercial welding system for miniature capsules and overcame several other fabrication challenges that ultimately allowed production of the miniature sources in hot cells that shield operators from the radiation.

Isotron researchers also developed a remote, automated storage and delivery system that uses images of the tumor to guide the insertion of the catheter and then the neutron source to ensure patient safety and the best medical results. According to Steve Jacobs, acting chief executive officer of Isotron, clinical trials using the miniature ^{252}Cf source will begin after Isotron receives Food and Drug Administration approval.

Although the new source is smaller, the probability that patients with often-fatal brain cancers will live longer is becoming larger.



If inserted in a brain tumor, ORNL's miniature californium-252 neutron source should shrink the cancer and spare healthy cells.

ORNL is the only major source of the radioisotope bismuth-213, used to extend the lives of leukemia patients.

^{233}U processing about 30 years ago. Patton asked Mirzadeh to determine if the waste material might have economic value. In 1996, Mirzadeh, Patton, Ken Given, and Steve Kennel received internal funding from the Laboratory Directed Research and Development (LDRD) Program to study the ^{233}U waste.

"Our LDRD mission included extracting ^{229}Th from the ^{233}U waste material and residual uranium," he says. "Our second goal was to develop actinium-bismuth (^{225}Ac-^{213}Bi) generators for internal use (^{229}Th decays to ^{225}Ac), and our third objective was to show that alpha particles from ^{213}Bi could be used to treat cancer in mice.

Rose Boll, a postdoctoral scientist, developed the processing chemistry for the project. Mirzadeh modified a radium-lead-bismuth generator developed at DOE's Argonne National Laboratory, producing a hand-held ^{225}Ac-^{213}Bi generator. Working with Mirzadeh, Kennel attached ^{213}Bi to antibodies he made that target blood vessels in lung tumors in mice. The injected bismuth's alpha particles damaged the blood vessels, possibly reducing the tumor's nutrient supply. Kennel found he could prolong the lives of mice with implanted lung tumors using ^{213}Bi-antibody complexes.

David Scheinberg, who heads leukemia research at the Memorial Sloan-Kettering Cancer Center in New York, gave a talk at ORNL. In discussions with Mirzadeh, Scheinberg indicated his interest in a source of ^{213}Bi for attachment to antibodies he was developing for human patients.

By 1997 Sloan-Kettering had started clinical trials for 10 patients dying of acute myeloid leukemia despite radiation and chemotherapy treatments. Their white blood cells were proliferating uncontrollably. Mirzadeh supplied Scheinberg with an actinium-bismuth generator and a few millicuries of ^{225}Ac, shipped by an overnight express service. At Sloan-Kettering, the ^{225}Ac, which has a half-life of 10 days, is loaded into the top of the generator. A dilute acid solution is forced through it every three hours, selectively removing the decay product, ^{213}Bi, which loses half its radioactivity in 46 minutes.

The ^{213}Bi is attached to an antibody that targets the misbehaving white blood cells after the ^{213}Bi-antibody complex is injected in the patients. Recently, Sloan Kettering began the Phase II clinical trial, and so far two patients have gone into complete remission.

In 2002 ORNL's largest shipment of ^{225}Ac was made. From the last campaign in 2002, about 60% of the 100 millicuries shipped was delivered to Sloan-Kettering for patient studies. The rest went to a number of other facilities for animal studies.

At $1500 per millicurie, the therapeutic isotope program at ORNL is now self-supporting. "We expect to sell $1 million worth of actinium in 2003," Mirzadeh says. For dangerously ill patients, ORNL's "milk" is worth a million.

...and the WINNERS are...

Accomplishments of Distinction at Oak Ridge National Laboratory

***Ian M. Anderson** has received two major awards recently. He was a recipient of a Presidential Early Career Award for Scientists and Engineers for his development of electron beam microcharacterization techniques and their use in understanding and improving materials. He also received the 1998 Burton Medal from the Microscopy Society of America, which goes annually to a young scientist who has made "distinguished contributions to the field of microscopy and microanalysis." Anderson is a world leader in the development of electron beam microanalysis, including spectrum imaging methods and techniques for the statistical analysis of resulting large data sets. His advancement of the "atomic location by channeling enhanced microanalysis" (ALCHEMI) technique has helped scientists explain how elemental additions to intermetallic alloys partition among crystal lattice sites, thereby improving alloy properties such as strength and ductility.*

ORNL's most recent recipients of Presidential Early Career Awards for Scientists and Engineers are **Ian M. Anderson**, for his leading-edge research in the development of electron beam microcharacterization techniques and their application to materials research and development; **Thomas V. Cianciolo**, for innovative definition of a unique measurement program for an experiment on the Relativistic Heavy Ion Collider (at Brookhaven National Laboratory) and leadership in organizing and designing a principal detector that has been implemented at the facility; and **Jizhong Zhou**, for pioneering research and leadership in functional genomics and microbial ecology through application of genomic technologies to address complex environmental problems.

Carlos Reinhold, **Thomas Thundat**, and **Mohana Yethiraj** have been elected fellows of the American Physical Society.

ORNL received two of five excellence awards and an honorable mention award from the nine-state Southeast Region Federal Laboratory Consortium, which represents 40 federal laboratories. Winners of Excellence in Technology Transfer awards were "Automated Image Retrieval System for Semiconductor Yield Improvement," by **Regina Ferrell**, **Shaun Gleason**, **Bruce Jatko**, **Tom Karnowski**, **Ken Tobin**, and **Bobby Whitus**, and "Carbon Composite Bipolar Plate," by **Ted Besmann**, **Tim Burchell**, **John Henry Jr.**, and **James Klett**. Honorable mention went to "Expression Data Clustering Analysis and Visualization Resource (EXCAVATOR)," by **Dong Xu**, **Ying Xu**, and **Victor Olman**.

Because of the effectiveness of their protein structure prediction software, **Ying Xu**, **Dongsup Kim**, **Dong Xu**, **Juntao Guo**, **Manesh Shah**, **Sergei Passovets**, and **Kyle Ellrott** placed 5th in a field of 150 in the fifth Critical Assessment of Techniques for Protein Structure Prediction Experiment, called CASP5. ORNL was the top-placing Department of Energy national laboratory in this international competition.

Robert J. Harrison, the principal architect of the Northwest Computational Chemistry Software (NWChem), received the IEEE Computer Society's 2002 Sidney Fernbach Award.

Man H. Yoo and **Chong Fu** have received the Minerals, Metals & Materials Society's Champion H. Mathewson Award.

The **Carbon Dioxide Information Analysis Center** at ORNL recently received an appreciation award from Ray Orbach, director of DOE's Office of Science, congratulating DOE's "premier center for global change data and information" on its 20th year. The inscription says that CDIAC "set the standard for quality-assuring and documenting key global-change data bases and provided this information to a diverse user community of researchers, educators, students, government and corporate officials, the media, and the interested lay public."

Sergei Kalinin and **Maria Varela del Arco** have been named Eugene P. Wigner Fellows. **Kalinin** also received the Ross Coffin Purdy Award from the American Ceramic Society for making a valuable contribution to ceramic technical literature.

ORNL Corporate Fellow **David Greene** has received a lifetime appointment as a National Associate of the National Academies (the National Academy of Science, National Academy of Engineering, Institute of Medicine, and National Research Council). This appointment recognizes his "extraordinary work and service to the National Academies in advising the government and the public on matters of science, technology, and health."

Bill Madia
Laboratory Director
2000–2003

Photo courtesy Knoxville News Sentinel

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