OAK RIDGE NATIONAL LABORATORY

REVIEW

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

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Global Security Technologies

Securing nuclear materials in Kazakhstan

Making water in the desert

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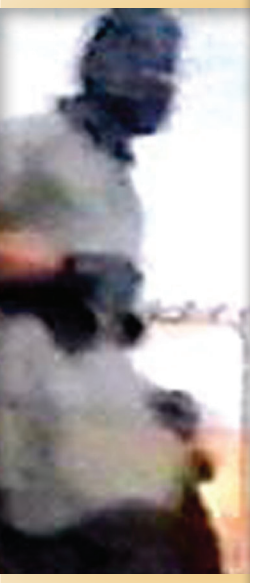
contents

Renewing the commitment



Oak Ridge National Laboratory is America's largest energy research facility, supported by capabilities in advanced materials and high-performance computing recognized as among the foremost in the world. Until recently, ORNL's international reputation for cutting-edge research in energy, materials and supercomputing was not widely associated with comparable capabilities in the area of national security technologies.

Time and circumstances have changed dramatically. Today, ORNL has a research portfolio that contains more than $400 million in projects related directly to national security customers. These customers predictably include agencies such as the departments of Energy, Defense and Homeland Security. Perhaps less predictable, ORNL is increasingly the laboratory of choice for industrial clients seeking to find new and unique uses for a broad array of technologies.

This issue of the *ORNL Review* examines the Global Security Directorate, one of the laboratory's fastest growing sectors and a program that, by its very nature, is less visible than other research areas. While much of the directorate's work is appropriately classified, a look into the growing number of projects reveals activities that would surprise many not familiar with the technological challenges of thwarting a complex and diverse set of security threats.

Indeed, a recurring theme is the fact that solutions to a host of security-related needs do not require the development of brand new technology. Instead, they often involve identifying existing technologies—developed at ORNL as a part of other research projects—and adapting these technologies to solve an entirely different, security-related problem.

ORNL's strategy of identifying security needs and matching them with existing technologies can be a critical asset in the effort to stay ahead of a sophisticated adversary whose success is measured in violence and destruction. In many instances, the most important factor is the time saved by using existing technologies, as opposed to a start-up approach, to develop solutions or countermeasures to a rapidly evolving variety of terrorist threats.

Some of ORNL's contributions to national security are relatively well known. The laboratory has played a leading role in the Department of Energy's successful effort to reduce the proliferation of nuclear materials, especially in the former republics of the Soviet Union. ORNL has also undertaken less well-known projects for both the Navy and the Army. One is designing signal processing improvements for submarines; another seeks to support troops in the desert by making potable water from diesel exhaust. The ultimate goal of both projects is to save American lives.

In some respects, the expanding role of Oak Ridge National Laboratory in the field of national security should not be surprising. The laboratory was founded in the dark days of World War II with the sole purpose of responding to the greatest security threat in America's history. The response was absolutely vital to the defeat of our enemies and the preservation of our democracy. That purpose and that history are the context for a renewed commitment to making the laboratory's talents and assets available to meet a different, but equally serious, contemporary threat to the public we serve and to the freedoms we cherish.

Billy Stair
Director
Communications and External Relations

Governor dedicates Neutron Sciences Institute

In one of his last official acts, Tennessee Governor Phil Bredesen joined officials from the University of Tennessee and the Department of Energy in dedicating a new state-funded research facility on the Oak Ridge National Laboratory campus. The event celebrated the opening of the Joint Institute for Neutron Sciences, a 31,000 sq. ft. facility that contains 82 offices and 7 laboratories. Located adjacent to the Spallation Neutron Source, the Joint Institute serves as an intellectual hub for the neutron science community and a gateway that provides researchers access to the world's most powerful neutron scattering facilities. Through the Joint Institute, UT faculty members have joint appointments with the university and ORNL as part of one of the world's leading centers for materials research.

Governor Bredesen was joined in the dedication by UT Interim President Jan Simek, UT Knoxville Chancellor Jimmy Cheek, and ORNL Director Thom Mason. Their remarks expressed appreciation to the Governor for his support of the UT-ORNL partnership over an 8-year period that Mason predicted "in the years to come will be viewed as one of the most important periods in the history of Oak Ridge National Laboratory."

The Governor echoed the sentiment, stating that "our goal has been to create jobs by combining the tremendous research capabilities of a great university and a great laboratory. Today's events mark some of the success we've achieved, and my hope is that the tremendous progress we have made is only an indication of greater things yet to come."

The Joint Institute for Neutron Sciences is a state facility located on property deeded to the state of Tennessee and managed by UT-Battelle for the Department of Energy. The facility is the third joint institute facility funded by approximately $30 million in state funds since UT-Battelle became the laboratory's managing contractor in April 2000. The project represents the completion of a 1999 commitment by a previous governor, along with the House and Senate speakers, to fund three state facilities at ORNL.

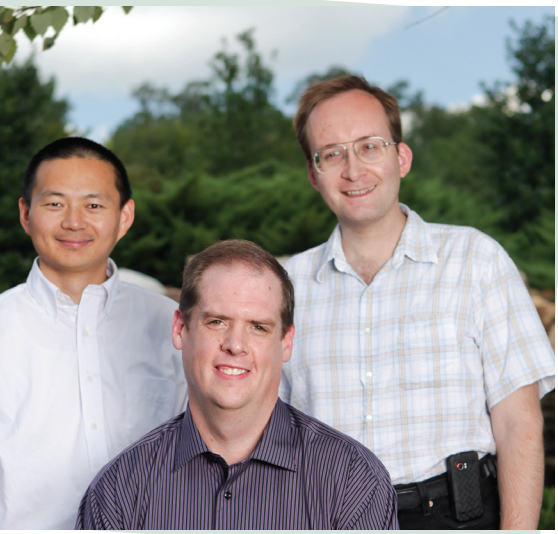
UT Interim President Simek said the three institutes in biology, computation and neutron sciences have served the twin goals of making ORNL facilities accessible to UT faculty and staff while also helping the university and the lab compete successfully for large research programs. Simek pointed to the biofuels research at the BioEnergy Science Center and Kraken, the world's largest university computer awarded to UT by the National Science Foundation, as examples of how the joint institutes have paid dividends for UT and ORNL.

The Joint Institute for Neutron Sciences will be used by UT faculty and students in a new graduate program in energy sciences. Proposed by Governor Bredesen and approved by the General Assembly in last January's special session, the graduate program has among its goals a significant increase in the number of UT graduates in science-related fields.

Chancellor Cheek said that because of Governor Bredesen's leadership, "Tennessee is among the few places in the United States where we can mount a joint venture between a major public research university and a top research laboratory." Cheek added that the Governor's contributions will make a lasting contribution to the university's goal of becoming a Top 25 research institution.

During Governor Bredesen's tenure, the number of joint faculty appointments between UT and ORNL has more than doubled to a total of 95.

ORNL Director Thom Mason (left) and University of Tennessee Interim President Jan Simek (right) with Gov. Phil Bredesen at the dedication of the UT-ORNL Joint Institute for Neutron Sciences.



(From left) De-en Jiang, Jeremy Busby and Sergei Kalinin are among 13 Department of Energy researchers to receive the Presidential Early Career Award for Scientists and Engineers.

Four ORNL researchers receive presidential early career award

Oak Ridge National Laboratory researchers Jeremy Busby, De-en Jiang, Sergei Kalinin and Rahul Ramachandran are among 85 scientists to receive the Presidential Early Career Award for Scientists and Engineers, or PECASE. One of the nation's top honors for young scientists, The PECASE was designed to recognize researchers who demonstrate exceptional potential for leadership at the frontiers of scientific knowledge.

"Science and technology have long been at the core of America's economic strength and global leadership," President Obama said. "I am confident that these individuals who have shown such tremendous promise so early in their careers will go on to make breakthroughs and discoveries that will continue to move our nation forward in the years ahead."

Busby, Jiang and Kalinin were recognized as Department of Energy awardees, and Ramachandran, who recently arrived at ORNL, was honored as a NASA PECASE recipient. The awardees, who are for the year 2009, will be recognized in a White House ceremony.

Energy Secretary Steven Chu said, "These gifted young scientists and engineers represent the best in our country. The awards recognize ingenuity, dedication, diligence and talent. I congratulate the 2009 PECASE awardees and wish them continued success toward new discoveries and advances in science, energy research and national security."

ORNL Director Thom Mason said this year's winners demonstrate the lab's continued commitment to attracting and retaining young scientific talent. "These awards recognize the outstanding creativity that early career researchers bring to the community of science at ORNL," Mason said.

Busby, a member of ORNL's Materials Science and Technology Division, focuses his research on structural materials for nuclear reactors, including the testing and development of advanced reactor materials. His research contributions have been both substantial and diverse, ranging from support for light-water reactors to space reactor systems as well as research for the ITER fusion project.

Jiang was recognized for internationally acknowledged and pioneering computational research, which probes novel properties of nanostructures and chemically modified interfaces. Since he joined ORNL's Chemical Sciences Division in 2006, his versatile applications of computational methods have been applied to solving chemical problems in materials such as grapheme and thiolated gold nanoclusters.

Kalinin's research at ORNL's Center for Nanophase Materials Sciences focuses on advanced scanning probe microscopy methods and applications. His innovative work has introduced several novel analytical and experimental advances in scanning probe microscopy that expand the range of physical phenomena that can be explored with nanoscale precision, including polarization dynamics, ionic motion, electronic transport and energy dissipation.

Ramachandran, a member of ORNL's Computational Sciences and Engineering Division, comes to ORNL from the University of Alabama in Huntsville. His primary research interest focuses on earth science informatics. His award recognizes his work in applying informatics to address NASA's need to make high-value geospatial data sets discoverable, accessible and usable by the science community.

Australia's Sean Smith named Nanocenter director

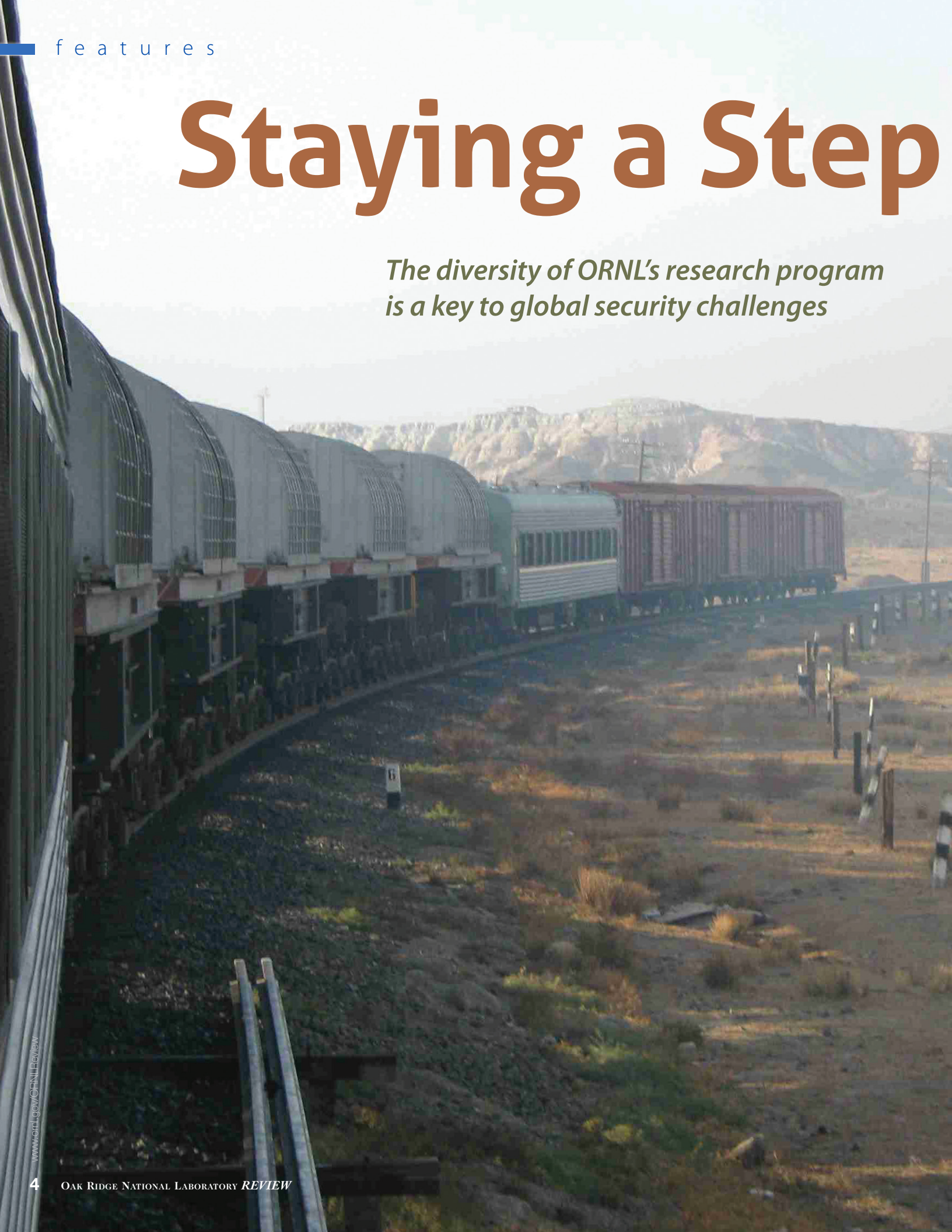
Sean Smith from the University of Queensland in Australia has accepted the position of director for the Center for Nanophase Materials Sciences, Physical Sciences Associate Laboratory Director Michelle Buchanan announced just before the holidays.

Smith currently serves as group leader for computational biology and nanotechnology at the Australian Institute for Bioengineering and Nanotechnology, professor of computational molecular science at the School of Chemistry and Molecular Biosciences, and director of the Centre for Computational Molecular Science.

ORNL's nanocenter is one of five Department of Energy Nanoscale Science Research Centers that together form a national user network. Each facility is associated with other major national research institutions, enabling nanoscale science and technology to be applied to a variety of research areas. ORNL's nanocenter provides unique opportunities for scientists to understand nanoscale materials by creating a research environment that accelerates the process of discovery by working across disciplines.

Staying a Step

The diversity of ORNL's research program is a key to global security challenges



Ahead

Shipment of nuclear materials to safer location in rural Kazakhstan

The question increasingly shapes the agenda of one of America's largest research institutions. How does the United States meet the technological demands of anticipating and defending against constantly evolving threats to the nation's security? "We need to have more smart people working the problem than the bad guys. It's that simple," says Brent Park, who heads ORNL's Global Security Directorate (GSD). Park's organization is responsible for matching the needs of customers in the national and homeland security community with ongoing projects in the laboratory's broad research portfolio, a job made more challenging by the dynamic nature of both national security requirements and the laboratory's research portfolio. As security threats become more sophisticated, anticipation and constant learning are required to stay a step ahead of America's adversaries. Park believes only research organizations with the depth and diversity of national laboratories have the resources and agility to quickly respond to evolving security needs.

Park's organization serves as the catalyst for research projects funded by customers working in the areas of defense, homeland security, nuclear nonproliferation and intelligence. Perhaps surprisingly, these projects are not limited to a handful of security-related disciplines but rather represent a variety of research capabilities from environmental sciences to nanotechnology. At one time or another, GSD has partnered with every research division at ORNL. Park's staff works with any group whose research—regardless of its original purpose—demonstrates the potential to meet a national security need. Sometimes the process involves recognizing ready-made solutions that GSD customers can adapt with little additional development. Increasingly, however, GSD's emphasis is on identifying promising results much earlier in the research process in an effort to fast-track the development of beneficial security technologies. As a result of this proactive approach to matching nascent research with security needs, GSD is significantly expanding the directorate's role as a supplier of research and development opportunities for the remainder of ORNL's research program.

As part of these efforts, the laboratory also provides seed money to jump-start projects judged to be of particular interest to the national security community. Such funding was recently used to develop a technology that extracts water from diesel exhaust. The project's goal is to provide military personnel in remote locations with a source of water. Park notes that a significant number of wartime casualties are the result of attacks on vehicles or aircraft delivering supplies like food and water. This water-extraction technology thus has the potential to save lives by lowering the supply requirements of soldiers in the field. "When we see the opportunity to save a life, we go out of our way to make it happen. The Department of Defense has expressed great interest in this technology," he adds.

To continue this kind of success, Park's organization is expanding its collaboration with ORNL's research organizations by rolling out large-scale initiatives in several areas.

Cybersecurity

The largest of these initiatives is a collaborative effort with the laboratory's Computational Sciences and Engineering Division in the area of cybersecurity. Park says the focus of this partnership is to develop diagnostic tools that enable researchers to use advanced modeling and simulation capabilities to pinpoint vulnerabilities in computer networks—allowing them to be strengthened before they are exploited. The demand for sophisticated cybersecurity tools has sharply increased among military, intelligence and homeland security organizations, as well as among state and local governments. "Of course this work also could be applied in the industrial sector to strengthen and protect private information systems," Park observes. In fact, part of the initiative involves collaborating with private companies to set up information systems that serve as targets for computer hackers. These systems provide researchers with real-world data on how computer networks and network administrators react to cyber attacks. The data is used to improve GSD's ability to apply ORNL's high-performance computing capabilities to simulating cyber attacks with a high degree of authenticity.

To complement these efforts, researchers are also developing a modular, scalable test-bed concept that combines simulated attacks on real-world network components with a modeling and simulation system. The system uses data from the test bed to simulate the effects of cyber attacks on a range of larger and more complex systems. As a result, the simulations' reactions to cyber threats are based on data gathered from actual systems faced with realistic cybersecurity threats. This combination of real-world hardware and network simulation enables researchers to evaluate cybersecurity threats on a variety of authentic network configurations quickly and with less cost.

"We sometimes need to evaluate threats quickly to determine whether, for example, a threat against a computer network or a 'smart' electrical grid has a realistic chance of succeeding," Park says. "This system enables us to do that." He observes that the impact of a successful attack could have far-reaching implications for the nation's military command and control system, the stock market and the business sector, that depends heavily on integrated computer networks.

Nuclear forensics

Another of GSD's high-level initiatives is in the area of nuclear forensics. The science of tracing the source of nuclear materials, nuclear forensics is a critical tool in the effort by governments to control the proliferation and use of bomb-grade materials. This expertise would also be critical to investigating the aftermath of the detonation of a dirty bomb—a non-nuclear explosive device designed to contaminate an area with nuclear material. Drawing on the laboratory's decades of nuclear research, as well as the expertise from ORNL's Nuclear Science and Engineering, Physical Sciences, and Energy and Environmental Sciences directorates, GSD is applying ORNL's R&D capabilities to meeting a variety of current nuclear forensics challenges.

Park explains that the primary concern for the U.S. is the ability to control and track the movements of HEU, or highly enriched uranium. Forensic researchers are often asked to identify the origin of HEU and how was it processed. The answers require researchers to apply techniques that include nondestructive test methods, such as high-resolution aerial photography and analysis of radiation detector data, and destructive testing that involves chemically analyzing small samples of material. The process can involve chemists, physicists and nuclear engineers. Fortunately, nearly seven decades of experience with nuclear fuel cycle research provides ORNL scientists with an exceptional array of assets to understand the nuances of nuclear material processing. "This is an immensely valuable capability," Park says. "ORNL aspires to be at the forefront of the world's forensic research, particularly with regard to uranium."

> The impact of a successful attack could have far-reaching implications, for the nation's military command and control system, the stock market and the business sector

Intelligence

Park believes a lot of misconceptions remain about intelligence R&D. He explains that while the results may be used differently, research and development conducted for intelligence applications is no different than that conducted for other programs at ORNL. "The process always starts with a challenge we need to meet," Park says. "We get creative minds together to create a research plan. We then perform experiments, apply modeling and simulation and finally develop the specific tools required to address the challenge."

"Not surprisingly, this research is often found in the 'sweet spot' of ORNL's capabilities," Park says. "Global Security and our sponsors apply ORNL's climate change science, applied materials, systems engineering expertise and our broad portfolio of sensor research to solve intelligence-related requirements. Only the end application is different. The reason the research is sensitive is because the nation's security is at stake. It's a sad reality, but there are bad people out there, and we need to be able to counter their threats."

Nuclear nonproliferation

Restricting the spread of nuclear weapons and weapons-grade materials is among the most critical elements of the nation's defense. By being proactive and engaging with international partners, GSD plays a key role in removing special nuclear material that has the potential to find its way onto the black market and into the hands of terrorists. GSD helps to safely dispose of this material, including arranging for down-blending into nuclear reactor fuel. ORNL's research in this growing sector relies heavily on extensive experience with uranium, expertise in the area of detectors, and the overall nuclear technology expertise the laboratory has sustained since the Manhattan Project.

Park predicts that the next frontiers for nonproliferation research will include the use of unmanned aerial and under water vehicles to monitor and detect the movement of

special nuclear materials. "The scenarios in the air and underwater are quite different," Park says. "We are looking at better ways to help protect our nation's borders and identify nuclear materials. Likewise, we are working with a range of national and local agencies to try to make a contribution in these areas. Ultimately, we hope to combine our modeling and simulation abilities with the laboratory's geographic information system capabilities and consequence management tools as yet another way of enhancing America's border security."

Department of Homeland Security

Growing recognition of ORNL's unique nonproliferation credentials is reflected in GSD's business volume in a variety of areas. In the last few years, GSD's work for the Department of Homeland Security has grown substantially, increasing from $3 million in 2004 to $50 million in 2010. Among other things, the funding provides support for radiation detector testing and the development of a range of radiation detection technologies. Park notes that GSD is also supporting other research efforts aimed at determination of motivation and intent, threat assessment and other activities that draw on ORNL core competencies.

Department of Defense

The widest application of ORNL capabilities is arguably in the defense sector. During the recent visit of a U.S. Navy admiral to examine technologies that could be of use to the Department of Defense, he was particularly interested in the climate research being conducted using the laboratory's high-performance computing resources. The research is supported by both the Energy and Environmental Sciences and Computing and Computational Sciences directorates. The organizations, with ostensibly quite different areas of expertise, are working closely together on the climate initiative. "The partnership is a good illustration of how GSD's Department of Defense (DoD) program office is leveraging the entire laboratory's assets," says Park.

In addition to climate research, GSD has active DoD programs using biological systems science applications, chemical and molecular science, and numerous applied materials science and engineering applications. The projects range from biological-agent sensing to cooling the gun barrels of automatic weapons. Park says it is hard to imagine that a sponsor could receive the breadth and depth of scientific support for their mission from any other single institution.

The mission

Responding to the scope and complexity of current national security threats requires the unique facilities and assets of America's national laboratories. The threats are often ones that need to be detected, analyzed and evaluated in real time. As problems of national and global security become increasingly difficult, Park foresees partnerships with other laboratories, largely because of time constraints and the fact that no single institution has the capacity to solve every challenge.

"The sooner we can deliver solutions to the field," Park says, "the better off everyone in the country will be. Delivering solutions on a timetable of years is just no longer good enough. Our mission is to be relevant to national security, to national defense and to the needs of peace-loving people all over the world. Science has a distinct role to play. We need to be at the forefront of finding research solutions, and we need to be proactive. After all, in this arena there's little benefit to solving a problem after the fact."

The Ultimate Threat

ORNL technologies seek to keep nuclear materials from falling into the wrong hands

Few activities at Oak Ridge National Laboratory are more important, and at the same time less visible, than the effort to protect the world's inventory of nuclear materials. ORNL's Global Security & Nonproliferation (GS&N) program is assigned responsibilities ranging from nonproliferation and uranium fuel cycle research to detection technologies and nuclear forensics. "Our program works with the Department of Energy, the defense community, customs, law enforcement organizations, and other government agencies on projects designed to counter the nuclear threat and the threat of proliferation," says GS&N Director Larry Satkowiak. "We cover the waterfront in the world of nonproliferation, from basic research and development to 'boots-on-the-ground' implementation." To make the most of the laboratory's capabilities, GS&N dedicates a team to understanding the unique problems encountered by federal agencies responsible for nuclear security and identifying potential solutions from research conducted by dozens of scientists across the laboratory.

Reducing the threat

Satkowiak points to work in Ukraine, where ORNL staff has helped move highly enriched nuclear fuel from Soviet-era research reactors and repatriated it to Russia, where the bomb-grade material is blended down and transformed into low-enriched fuel for reuse in reactors, including several in the United States. In addition to assisting with the removal, GS&N sends scientists to Russia on a monthly basis to monitor the blend-down process. Many of these research reactors date to the 1950s, when the Soviets supported nuclear research in much the same way as the U.S. Atoms for Peace program. Growing concerns about the ability of terrorist groups and hostile governments to gain access to nuclear materials have motivated both Russia and the U.S. to expand efforts to recover the large quantities of spent fuel stored at these facilities located in several countries. Satkowiak's program has helped to repatriate fuel from both U.S. and former Soviet programs, significantly reducing the threat of nuclear proliferation through cooperation of the world's two leading nuclear powers.

Because highly enriched fuel can be adapted for use in nuclear weapons, the Russians are in the process of converting many of their older research reactors to operate using low-enriched fuel. Much of the used fuel being repatriated to Russia from former Soviet republics has been stored for more than 30 years at reactor

ORNL's nonproliferation program played a key role in 2004 in removing 1.8 metric tons of high-risk material from Libya.

sites, where since the dissolution of the Soviet Union in 1991, security has often been less than adequate. Moving this weapons-grade material to Russia greatly reduces the risk of the fuel being stolen or purchased by parties seeking to construct nuclear or radiological weapons.

Operations like the one in Ukraine are highly sensitive, both in terms of the assets being handled and relationships between the governments involved. Satkowiak stresses that such delicate projects are cooperative in nature and that ORNL is just one of many U.S. and international partners. "We don't package the fuel," he explains, "but we oversee the packaging. We don't transport the fuel, but we make sure the transportation is adequate. We also assist the Russians in developing low-enriched replacement fuels for these reactors."

Nuclear fuel recovery operations are a good example of how nations work together out of the spotlight to address one of the world's most serious security problems by converting high-risk material to something of lasting benefit. "This is the same program that removed 1.8 metric tons of uranium hexafluoride and over 500 metric tons of centrifuge components and related materials from Libya in 2004," Satkowiak adds. "We are trying to replicate the Libyan success wherever we can by reducing the risk of nuclear material falling into the wrong hands."

Nuclear fingerprints

Another critical research area in which ORNL offers a broad suite of capabilities is the nuclear fuel cycle. The laboratory's ability include identifying the physical (including chemical and radiological) "fingerprints" associated with every stage of the nuclear fuel cycle, from production to reprocessing to final disposition. This sort of critical knowledge can enable nuclear inspectors to detect evidence of unauthorized nuclear fuel reprocessing on equipment or in the environment. Of course, increasing the probability of detecting cheating makes it easier to hold nations to their agreements with regard to the reprocessing of nuclear fuel.

"We ask ourselves what we can learn using the technologies we already have," says Jeff Johnson, project manager for GS&N's Nuclear Threat Research and Development Initiative, "as well as what technologies we can develop to enable us to see those signatures better—from a distance, remotely or during an inspection." Much of the research conducted at ORNL in support of the nonproliferation program is designed to detect progressively lower quantities of nuclear material. This capability enables researchers to see through the background noise, such as chemicals in the environment, to detect proliferation activity.

Johnson describes a logical progression in the development of detection technologies. First, one of ORNL's R&D programs performs fundamental research to determine which chemical signatures can be detected that would indicate that the presence of nuclear reprocessing. The process is tested in the laboratory, then in a prototype, and finally in a field-deployable system. Johnson says that throughout the testing researchers pose a number of questions, including the type of platform on which the technology will be deployed. "There's an engineering challenge combined with many of our technologies. This often involves determining how we can make a system small enough, light enough, or efficient enough for a particular use." Johnson's Nuclear Threat R&D Initiative addresses the detection technology needs of several government organizations including the Department of Energy's National Nuclear Security Administration (NNSA), the Department of Defense's Defense Threat Reduction Agency and others.

GS&N has also been called upon to provide support for the NNSA's Office of the Second Line of Defense and one of its two components—the Megaports Initiative. The objective of this initiative is to develop and evaluate radiation monitors for use at international shipping ports. With approximately one-half of the goods shipped to the United States originating in China, Megaports approached Chinese officials about using radiation monitors located at these shipping facilities. The Chinese agreed but chose to produce and use their own monitors made to U.S. specifications. Prototype units were provided to ORNL for extensive testing. Now deployed in a number of Chinese ports, the radiation portal monitors are evidence that China, like most nations, is prepared to join the international effort to restrict the movement of nuclear material.

From a U.S. perspective, the primary value of the Megaports Initiative is the ability to intercept shipments of nuclear materials before they reach U.S. friends and allies and ultimately the U.S. homeland. With some cargo ships holding as many as 20,000 containers, an individual container becomes a veritable needle in a haystack. Detecting a single container of nuclear material on a fully loaded ship is extremely difficult, particularly in a port as busy as Long Beach, the second busiest port in the United States. The challenge of locating hidden nuclear materials on a fully loaded ship combined with the extraordinary consequences of failing to find a nuclear bomb have motivated efforts at ORNL to develop technologies and procedures to monitor containers when they are loaded and before they dock at U.S. ports.

The threat continues

Despite the unquestionable success of GS&N's efforts in the areas of nuclear nonproliferation and detection technologies, Satkowiak cautions against the temptation to believe that we have resolved the nuclear security threat. "If anything, the international attention focused on the nuclear threat is increasing, so the demand for our capabilities continues to grow." Satkowiak warns that even if the nations with nuclear capabilities achieve the goal of "global lockdown" of nuclear materials—putting all potential nuclear materials beyond the reach of terrorists or unstable regimes—the need would still exist for nonproliferation efforts to control the transfer of the technology required to produce nuclear material and nuclear weapons.

"Rogue nation states and terrorist groups will continue to pursue nuclear weapons technology," Satkowiak adds. "The nuclear terrorism threat will always be out there—however, so will we." ®

The Sum of All Fears

ORNL plays a role in securing nuclear materials in Kazakhstan

Kazakh, Russian and American partners are working to move a large stockpile of spent nuclear fuel to a more secure facility.

Sixty casks rise like towering white silos over a remote storage pad in the Kazakhstan steppe, 40 miles from the closest town and, more significantly, thousands of miles from terrorist hands. The casks, which hold more than 100 tons of nuclear material, are the result of an international nonproliferation project that has lasted more than a decade to secure nuclear fuel left in a former Soviet Republic.

Working alongside hundreds of Kazakh, Russian and American partners, ORNL scientists and engineers have been key players in a mission to safely move one of the world's largest stockpiles of spent nuclear fuel from a facility in western Kazakhstan to a more secure—and far more remote—area 2000 miles away. A November 18, 2010, completion ceremony marked the last shipment of nuclear material as officials, diplomats and representatives from the United States, Kazakhstan, the United Kingdom and the International Atomic Energy Agency (IAEA) gathered to celebrate the success of the unprecedented project.

The target was a Soviet-era nuclear reactor known as BN-350, located in Aktau, Kazakhstan. The reactor has been a top priority in international nonproliferation efforts because of the quantity and quality of its spent fuel—enough for approximately 775 nuclear weapons. Originally built in the early 1970s to produce electricity, desalinize water and synthesize weapons-grade plutonium, the reactor was shut down in 1999, 8 years after the collapse of the Soviet Union and the establishment of Kazakhstan as an independent state. As Kazakhstan adopted a non-nuclear foreign policy, the spent fuel remained at the site, stored in reactor pools. Although the BN-350 material was sealed, secured and carefully monitored in accordance with IAEA requirements, the reactor's location generated concern among officials worried about terrorist efforts to obtain similar materials needed to build a nuclear weapon.

Located in westernmost Kazakhstan on the shores of the Caspian Sea, the BN-350 reactor lies only a few hundred miles across the water from Iran and the Russian Republic of Chechnya, regions that are home to terrorist groups known to be looking to obtain nuclear material. Concerns were heightened by the fact that the BN-350 fuel was

unique. The spent fuel was weapons grade, containing approximately 10 tons of highly enriched uranium and 3 tons of plutonium.

"This fuel is well known," says Randy Snipes, an engineer in ORNL's Global Nuclear Security and Technology Division. Snipes, who has been involved since 2001 in the international project to secure the BN-350 material, says the international effort was designed to deter nuclear materials from falling into terrorist hands.

A package deal

Initial efforts to secure the BN-350 fuel started in the 1990s, as fuel assemblies stored in the reactor pools were removed, conditioned and stored in canisters. The project gained momentum in 2002 when a feasibility study recommended moving the material from Aktau. "The project's primary focus was to package the fuel more securely and transport it to a safer area within Kazakhstan agreed upon by both the United States and the Kazakhstan governments," Snipes says.

Packaging the fuel was critical to the project's success. The fuel casks had to serve the dual roles of keeping intruders outside and the fuel inside. As project lead for the cask design, ORNL, along with contractor NAC International, assisted Russian designers in developing and certifying a specialized container for the BN-350 material. Snipes says the concept stemmed from a family of similar metal and concrete casks used by the Russians to store fuel from nuclear submarines and civilian reactors.

"Much of ORNL's activity in this project was on the front end, which involved working with the Russians on designing and certifying the package," Snipes says. "The casks may look like big hunks of metal, but in fact they are very sophisticated items." Two Russian manufacturers produced a total of 60 casks for the project. ORNL staff helped provide oversight to ensure the fabrication met Russian and Kazakh guidelines for certification.

Inside the casks' thick metal and concrete walls is a metal framework, called a spacing grid, which houses the fuel canisters. Once the canisters are loaded into the spacing grid, each cask weighs approximately 100 tons—an unwieldy container to transport and maneuver. The specially designed casks required specialized equip-

ment to move and manipulate them. ORNL researchers monitored the development of cask-handling machinery, including an up-ending yoke that clasps onto the cask and upends or lays it down following fabrication. Other Department of Energy labs, including Sandia, Los Alamos, Idaho and Pacific Northwest, contributed supervision of associated project elements, such as the design of the cask-handling crane and storage pad, physical protection of the casks and other nuclear safeguards measures.

"The most vulnerable part"

In addition to oversight of the cask design, ORNL served as the project lead for the transport phase. "The need to protect the fuel made transportation the most vulnerable part of the entire activity," says Snipes, one of four primary U.S. team members responsible for overseeing the shipments. "The U.S. intent was that the right security levels were provided by Kazakhstan during the transport phase."

The 3-week journey of 2000 miles originated in Aktau, where five casks per shipment were loaded onto railcars for the trip's first leg. Specially designed for the project, the railcars carried the 100-ton cask plus an armor-like overpack weighing an additional 25 tons.

"Even though Russia uses a very similar cask and overpack for some of their civilian power plant fuel, they had no experience using rail transport, so these were the first railcars designed and manufactured for these specific casks," Snipes says. Researchers from ORNL's National Transportation Research Center supported the rail effort.

A convoy of five vehicles, flanked by guard and buffer vehicles to protect the fuel from potential attack, wheeled out a total of 12 shipments beginning in January 2010. The rail convoy brought the fuel to a transfer point 70 kilometers from its final destination. Because the railways did not extend the entire distance, tractor trailers carried the 125-ton packages the last leg of the trip to a remote complex. The storage pad, located in northeastern Kazakhstan, is part of the Semipalatinsk Test Site where the Soviets conducted hundreds of nuclear detonations before the site closed in 1991.

The task is not over

For now, the 60 casks will remain at the storage pad, primarily a concrete and rebar slab 1 meter thick. Officials from the IAEA and project participants will continue to monitor the casks to ensure their integrity and security. "We envision visiting every 3 to 6 months to work with the Kazakhs to ensure that the assets are properly maintained," Snipes says, indicating that the cask visits would be more like a checkup than a tune-up. "We prefer something that will last up to 50 years in storage, with minimal maintenance. We don't want a research project, where we simply open the casks after 5 years and see what they look like."

Although Snipes does not view the BN-350 casks as an experiment in progress, he does believe the cask design and fabrication serve as a template for future nuclear storage projects. "We can apply the lessons learned from this project to other similar applications, which at present would primarily be related to civilian fuel," Snipes says, noting that there have been proposals to use the same cask design for nonproliferation projects in other former Soviet states.

"The international community wants to protect all the fuel. We must keep in mind that conventional power plant fuel still has components that we don't want in the hands of terrorists." ®

Specially designed railcars are used to transports casks of spent nuclear fuel on their 2,000-mile journey.

Making drinking water from diesel exhaust could reduce the number of casualties associated with military supply operations.

Lifesaving Technologies

ORNL is finding innovative solutions for the Department of Defense

George Fisher is focused. His single goal is ensuring that ORNL's substantial research portfolio is used to strengthen national and international security. Fisher, who manages the Global Security Directorate (GSD) Department of Defense (DoD) Programs, views one of GSD's primary jobs as engaging ORNL in research and development designed to address specific challenges for the DoD. "There's an urgency to this work because of real-world implications," he explains. "This country is in a fight. When we apply our technology to solve problems, we are impacting peoples' lives."

GSD also advises DoD of new laboratory developments that might be of future interest. With some 400 years of collective military experience, Fisher's staff has a unique ability to understand both needs and opportunities in the national security arena. "That experience means we can take DoD requirements and translate them into what scientists must know to determine whether they will be able to address the problem. Likewise, we spend a great deal of time with the scientists, so we in turn can explain to DoD what the science might deliver in terms of operational impact."

From diesel to water

A straightforward illustration of the DoD partnership can be found in research under way at ORNL to extract drinkable water from the exhaust of diesel-powered vehicles and generators. The technology's implications have particular value for U.S. troops deployed in remote regions. For example, in Afghanistan, the delivery of water accounts for approximately one-half of the military's logistical burden. Finding a technological solution that wrings drinking water from diesel exhaust could produce a dramatic reduction in the casualties and costs associated with this key aspect of military operations.

"It may sound funny to describe this kind of progress as just improving logistics," Fisher says. "We are talking about thousand-mile supply convoys. Sometimes they get ambushed. People get injured or killed, and there are impacts on families. The 'cost' of logistics, in every sense of the word, is what we are trying to reduce."

To date, the project shows promise. Using inorganic membrane technology to filter out impurities in the exhaust, researchers can extract more than a half gallon of water from the exhaust produced by a gallon of diesel fuel, with no effect on the performance of the vehicle or generator.

Life-extending research

Research designed to extend the life of the U.S. Marine Corps' Light Armored Vehicle (LAV) is another example of ORNL's expanding partnership with DoD. One of the Marines' primary fighting vehicles, the LAV was first fielded in 1983. The Marines would like to keep the LAV in the field for 20 to 30 more years.

ORNL is using two approaches to extend the LAV's longevity. Researchers are integrating sophisticated sensors into critical

vehicle components, with the goal of detecting when these components need to be serviced or replaced. The ability to monitor the status of these components would enable the Marines to employ a sophisticated system of condition-based maintenance, rather than the current process of servicing components at arbitrary intervals. "We are experimenting with vibration and torque sensors to get a better idea of the mechanical stresses the equipment is under," says project scientist Steve McNeany of ORNL's Measurement Science and Systems Engineering Division. McNeany's group is considering installing slope indicators, cameras and GPS to correlate the terrain the vehicle is moving across with the rest of the data. Understanding how to predict maintenance needs would reduce the number of breakdowns as well as the costs and logistics involved in maintaining the vehicles. "If we can provide a condition-based maintenance system for this vehicle," Fisher says, "the result could influence the entire Marine Corps vehicle fleet."

Over the years, the Marine Corps has experimented with several basic sensor suites on the LAV, accumulating substantial data related to the performance of critical components and vehicle maintenance. ORNL researchers are taking advantage of this extensive cache of performance and maintenance data to uncover correlations between sensor readings and maintenance issues that will help the Marines avoid expensive breakdowns by recognizing when an LAV component needs to be serviced.

The Marines hope that a condition-based maintenance approach could also have a significant impact on the "logistics tail" that accompanies every LAV. McNeany says that a vehicle shipped to Afghanistan is literally followed by a ton of spare parts, what the Marines call the "iron mountain." Reducing the need for maintenance and the number of spare parts in the logistics tail would likely reduce the risks to troops involved in hauling the iron mountain back and forth across hostile territory.

Making sense of it

Yet another ORNL capability—intelligent agent technology—is being adapted to help DoD analyze large volumes of text data quickly and accurately. Intelligent agents are computer programs that rapidly extract relevant information from databases containing thousands or even millions of individual documents. The need for such technology is not as rare as one might assume. Within large military commands, the need to quickly sift through millions of documents is common. Fisher says that a U.S. Army brigade in Baghdad was processing three million reports an hour from its area of operations, with no ability to route the information to a central location and make sense of it manually. Effective analysis was possible only with the use of computational tools. A staff experienced with intelligent agents and data analysis, housed in the world's foremost center for high-performance computing, made ORNL the ideal place to find a solution to this problem. Laboratory researchers have demonstrated that their intelligent agents are capable of quickly traversing a computer network in search of very specific types of information, finding exactly what they are looking for and bringing the information back for people to analyze.

New condition-based maintenance procedures could extend the life of the Marine Corps' Light Armored Vehicle and reduce the need for spare parts.

Scientists are applying high-performance computing to the challenge of quickly extracting relevant information from trillions of documents.

"We typically work with a military or intelligence organization that must analyze many thousands or even millions of pieces of information from a variety of sources," says Tom Potok of ORNL's Computational Sciences and Engineering Division. "Within such a massive collection of information, there may be a report that a terrorist is involved in a plot to blow up a plane, a document that provides the person's profile, another indicating the kind of explosives he might be using, and yet another that indicates where he obtained his funding." The challenge is how to search through this vast collection of data, identify the documents that highlight the plot, and share the information in time to respond. The challenge is enormous in its complexity, both for the government and for computer science, and is one that researchers have been working on for years. Potok says his group has developed some very clever statistical and machine learning algorithms that make it possible to glean important pieces of information previously lost in the mass of data.

Using intelligent agents to locate relevant data enables defense or intelligence personnel to spend less time reading and searching and more time analyzing the relevant information. The process is typically iterative, meaning that the intelligent agent provides data and a human analyzes the results, associates them with other significant information and if necessary initiates a new search. The process is repeated until the results are sufficiently relevant. The computer does not create the solution but instead sifts the available data to the point that a human can identify relationships among the various information threads. Incredibly, Potok believes ORNL will eventually be called upon to perform a similar analysis of information contained in more than a trillion documents.

An achievable vision

Building on these promising successes, George Fisher believes that future projects will draw on experts from an even broader suite of the laboratory's emerging technologies. "In the coming years, we can anticipate a continued emphasis on leveraging the capabilities of national laboratories to address DoD's research and development needs. ORNL is in an excellent position to meet those needs."

"What sets ORNL apart from many scientific organizations," Fisher observes, "is that when we provide a sponsor with a vision of what can be achieved, it is a technologically sound vision based on best-in-class technologies and a vast amount of operational experience. This means, simply, that the solution really can be built and that we can build it better than anyone else."®

Smaller is Better

New technologies provide a lightweight solution for the Navy's communications

One key component of the Global Security Directorate's research agenda is its work for the U.S. Navy. Heading up this effort is Richard Snead, whose experience as a naval officer, commander of a submarine attack squadron, and Pentagon financial specialist affords rare insight into the Navy's decision process for funding R&D projects. Snead says funding decisions are always contentious and are not always driven by acquiring the latest technology. Some communities within the Navy are concerned that new technologies might not be as reliable as those that have served well for years, while others have a more open attitude toward the potential of R&D. While navigating these organizational dynamics, Snead's job is to match ORNL's comprehensive technology portfolio against gaps in the Department of the Navy's R&D program. "My charter is to represent the laboratory's capabilities in the right places," Snead says. "I find the guys who are interested in whether we can deliver what they need, and then I make sure we deliver."

Laser communication

Among the Navy's varied needs are several that center around signal processing—the ability to transmit, receive and process information. These activities are particularly critical to the ability of unmanned aerial and submersible vehicles to gather and transmit information. One of the obstacles to providing enhanced signals processing capability is the significant power required for communications systems to operate, particularly in unmanned vehicles where weight is at a premium. A related issue is finding the room in the already-crowded radio frequency (RF) portion of the spectrum for the military to transmit information. "Other than fencing off portions of the RF broadcast spectrum for military use," Snead says, "the only place to find free bandwidth is in the visible light portion of the spectrum."

Addressing these challenges is the focus of a team of scientists in the laboratory's Computational Science and Mathematics (CSM) Division led by Yehuda Braiman. Braiman and CSM researcher Bo Liu have found a way to apply some of the very small and inexpensive components normally used to drive industrial lasers to the task of producing high-quality beams for use in communication systems. A critical advantage of these systems is that they are both cost- and energy-efficient, greatly reducing the power required to transmit optical signals. If applied to an orbiting communication satellite, the reduction in size and energy requirements represents the difference between a system that is overhead for 20 minutes of each orbit and one that could maintain a geosynchronous orbit and provide persistent communications coverage over a large area. Snead notes that such a system could enable the Navy to communicate with the entire fleet using a relatively small number of satellites.

Laser-based communication systems also have a critical advantage over RF-based systems when communicating with submarines and other submersible vehicles. Certain laser frequencies can penetrate hundreds of feet of water, enabling relatively high-bandwidth communication links. Current systems require submarines to rise near the surface and raise a radio mast or deploy a communications buoy before sending or receiving information. Snead contends that for submariners a paramount goal is the ability to communicate while moving at speed in deep water. At present a submarine cannot move fast and maintain communications and cannot maintain communications while tracking a ship or submarine. The importance of this breakthrough technology to the submarine force would be a classic

Laser-based communication systems hold the promise of constant communication with the entire U.S. submarine fleet using a relatively small number of satellites.

game changer. The Navy has been working on similar communication technologies for 30 years, but previous systems were always too big and inefficient. In contrast, the laser source being developed by ORNL is light and energy efficient enough to be mounted on satellites or aircraft, an enabling technology that can be adapted to any number of uses.

Combining strengths

One adaptation pairs the highly efficient laser technology with ORNL's advanced computational capabilities to create a highly sensitive submarine sensor. The sensor applies the laboratory's computing capacity to the challenge of identifying underwater targets such as submarines and geographical features. Until recently, the algorithms that undergird this approach to signals processing were too complex to be used in a system requiring split-second feedback. Researchers, however, have adapted the algorithms to a new generation of multi-core computer processors, enabling the computational load to be shared among a number of processor cores, greatly reducing the time required to generate results.

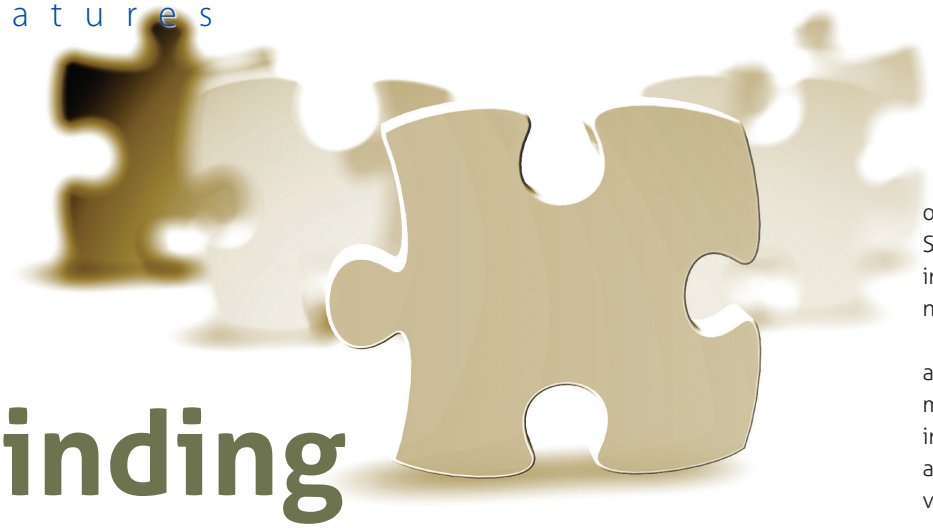
Multi-core processors, such as GPUs (graphical processing units), have also demonstrated the ability to handle computational loads with greater energy efficiency than that of previous generations of computer chips. Snead believes this unique quality makes GPUs an attractive option for boosting the signals processing performance of unmanned aerial and submarine systems, where currently much of the power must be reserved for propulsion. Snead says ORNL is talking with several contractors about applying GPUs to the problem of energy-intensive signals processing equipment.

Elements of progress

Snead's sponsors are interested in making technologies that are smaller, lighter and more efficient. Part of this emphasis is directed toward increasing the capabilities of unmanned vehicles, while part reflects a constant drive for cost-effectiveness. "The smaller a technology is, generally speaking, the cheaper it is," Snead observes. "Since the Royal Navy built HMS Victory for Horatio Nelson, we have bought innovation by the pound. If it's bigger, it's going to be more expensive." A corollary advantage of downsizing technology is versatility. Snead notes that the Global Security Directorate's Navy sponsors want the ability to launch an unmanned vehicle from a torpedo tube, drop it from an aircraft, or have a team of Navy Seals pick the vehicle up and throw it over the side of a ship. To maximize the potential of unmanned systems, Snead believes future technologies must be small, affordable and adaptable to a variety of launch platforms.

Working from this premise, ORNL is applying a range of capabilities to help the Navy realize a vision of smaller, lighter, more capable and more affordable technologies. Snead's lengthy list of promising research areas includes advanced signals processing; affordable, lightweight materials; power electronics; computation; new welding techniques for thinner pressurized hulls; and advanced robotics for hull inspection and improvised explosive device removal.

Snead is convinced that ORNL matches these capabilities with a commitment to customer satisfaction. "When we get involved with a project, we attempt to prove we can deliver. Recently, one of our sponsors told me that a key difference between ORNL and other contractors is that we tell him how we think things can be done, not why they cannot be done. I am excited that we are making a difference." ®



Finding the Right Match

A new strategy aligns security needs with existing technologies

When the Global Security Directorate's (GSD's) predecessor organization was created, ORNL envisioned a tremendous untapped potential for matching the laboratory's diverse research portfolio with an equally diverse variety of needs from organizations in the national and homeland security arenas. Aware that numerous private-sector companies were adept at matching agency requirements and research capabilities, the laboratory saw a similar opportunity. The decision to pursue this opportunity eventually brought Randy Davis to the lab, tasked with the goal of using his background in private-sector program development to create a comparable system for connecting needs and capabilities in GSD. Nearly a decade later, ORNL's work for sponsors in the national and homeland security community has grown to more than $400 million, establishing GSD as a major component of ORNL's portfolio.

Unlike other research directorates, ORNL's Global Security organization does not directly employ scientists or engineers. Rather, the directorate focuses on facilitating laboratory research projects by functioning as the interface between sponsors and researchers.

"We do what I call mining and matching," Davis says. "First, we mine specific and often highly technical needs from our sponsors in the national or homeland security community. We then bring their 'lab-hard' requirements—research problems that only a national research facility could address—back to the lab and determine whether pursuing a given project at ORNL is mutually beneficial. The decision involves determining whether the project would fit the laboratory's agenda and would be something the laboratory can and wants to do." When a match emerges, GSD works in cooperation with the laboratory's diverse research community to structure an agreement with the sponsor to conduct the necessary research and development.

ORNL's approach today is responsible for attracting the equivalent of some 500 full-time employees' worth of research activity. Davis reflects on whether the GSD program has influenced the lab's broader agenda. "I don't know if our success is the chicken or the egg," Davis says. "Global security is one of ORNL's major missions, and the laboratory naturally increased its security profile as a result of the expanded efforts to counter global terrorism. However, the success we have enjoyed over the last decade in responding to sponsors' requirements resulted in ORNL becoming a provider of choice for the Department of Homeland Security, the Department of Defense, the intelligence community and international nuclear nonproliferation efforts."

One key to GSD's success has been an ability to work across the laboratory's multiple research groups, identifying areas in which capabilities converge and taking advantage of exceptional scientists in a variety of disciplines. "An example of ORNL's advantage," Davis says, "is the ability to take a world-class computing capability, link it with materials technology and utilize systems engineering in a different part of the lab to develop a solution that solves a complicated problem. Solutions frequently cross two or more research divisions."

A good illustration of this cross-cutting ability is a GSD project designed to develop capabilities that would extend the operational life of the U.S. Marine Corps' Light Armored Vehicle (LAV), an eight-wheeled combat vehicle. A joint effort of research groups within several research divisions at ORNL, the LAV project required researchers to analyze large volumes of data collected from both vehicle service records and sensors located on or around critical vehicle components. Equipped with this data, researchers have been seeking to understand when and precisely why various components fail. Once the failure mechanisms are understood, the research team will attempt to develop the materials, tools, and techniques needed to extend the operational life of the vehicles, as well as reduce repair costs. By servicing

expensive components on an as-needed bases, rather that on an arbitrary schedule, the Marine Corps hopes to save money and increase vehicle availability. If successful, Davis believes the project could play a significant role in extending the life of the vehicles to 2025.

ORNL's strategy of matching lab capabilities with the security-related needs of GSD's sponsors provides focus for investing of a portion of the lab's discretionary R&D funds. The investments enable Global Security to anticipate, as well as respond to, a variety of security challenges. The effort to anticipate these challenges includes GSD's four programmatic sectors—Homeland Security, Defense, the intelligence community and nuclear nonproliferation—which are staffed by experienced personnel who have worked in these sectors and are familiar with their unique culture, lexicon and technology challenges. The familiarity provides ORNL with the ability to match the laboratory's research agenda with a range of security needs from a variety of agencies.

As the GSD's programs expand, efforts to align this growth with ORNL's broader research agenda will remain a priority. Davis says GSD staff work closely with the laboratory's research divisions to develop a comprehensive understanding of emerging technologies or strategic goals that might be of interest to potential sponsors. As a result, when research divisions develop new capabilities, GSD can quickly match them to sponsors' needs, avoiding much of the time lag involved in the development and application of new technologies.

At numerous other laboratories, comparable organizations tend to "own" their researchers rather than attempting to coordinate complicated projects across multiple research groups. In contrast, in the GSD model most staff members serve as conduits between project sponsors and multiple ORNL research organizations. Davis acknowledges that this unique organizational structure requires a greater degree of cooperation. "We cannot dictate to other researchers. We have to work as part of a team."

As a result of this arrangement, ORNL's Global Security organization has found a way to accommodate the expectations of both sponsors and the laboratory, developing what has become one of the nation's premier programs of security technologies. ®

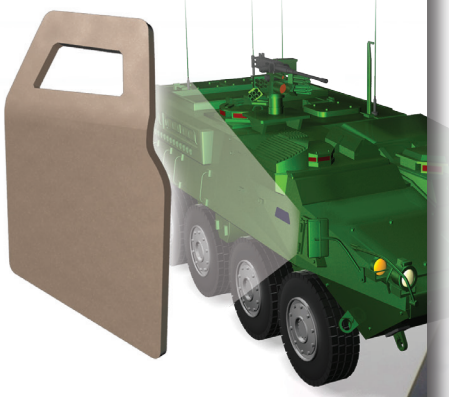
SAVING LIVES

Richard Robertson and his family

Richard Robertson has a better understanding than many of the importance of moving technology rapidly from the laboratory to the battlefield. In 2005, Army Master Sgt. Robertson was severely injured while serving in Iraq. He was later awarded the Purple Heart. The attack that injured Robertson and killed four of his comrades was carried out using an improvised explosive device, or IED.

Now an engineering analyst with ORNL's Global Security Directorate, Robertson serves as a liaison between Department of Defense sponsors and laboratory scientists who are developing innovations designed to safeguard troops and save lives. His knowledge of the Army's techniques, tactics and procedures enables Robertson to translate the Army's unique needs for ORNL's researcher staff. "We have situations where a researcher will have a great idea, but it weighs 600 pounds," Robertson explains. "Obviously a guy out in the field can't carry 600 pounds, so we work across research groups at the laboratory to engineer a more practical application of the technology."

Because he knows how soldiers combat IED threats on a daily basis, Robertson spends considerable time working with defense sponsors and researchers to develop technologies that meet the threat posed by roadside bombs. One of the issues the military has had to address related to protecting troops from IEDs is how to add armor to vehicles that were not designed to carry the extra weight. When standard steel armor is added to a vehicle, the extra weight can overwhelm the engine and transmission, affecting the vehicle's performance and durability. Fortunately, laboratory researchers have engineered a lighter alternative. "ORNL researchers have developed a way to fabricate lower-cost, lightweight titanium composite panels for use in Humvee doors and vehicle armor," Robertson says. "We are also involved in testing this equipment to ensure that it's hard enough to protect the people in the vehicles." ORNL materials scientists are also investigating promising options for other ultralight composite materials that are as strong as titanium.



In addition to helping ORNL research staff understand how soldiers in the field operate, Robertson also lets his Pentagon sponsors know precisely which laboratory technologies show promise for meeting their needs. "Often they are simply not aware of what ORNL can do," he says. "The laboratory has so many developments in materials, electronics and in a number of other disciplines that they are hard to keep up with."

Reflecting on his work, Robertson says, "When we see a promising technology, we push it up through the system to our customers. This is important work. These are technologies that can save lives."

Avoiding the Great Compromise

Protecting public safety without compromising freedom or commerce

Among the most challenging responsibilities for ORNL's Global Security Directorate (GSD) is applying the laboratory's scientific expertise to critical public safety problems for the Department of Homeland Security (DHS) while simultaneously attempting to preserve freedom of movement and avoid the disruption of commerce. ORNL's contributions to the homeland security effort take a variety of forms, including helping to secure the nation's borders against nuclear and radiological threats, combating cyber espionage and cyber terrorism, and developing novel energy sources to provide clean, affordable energy for both military and civilian applications.

Securing America's borders

GSD program manager Tony Turner says when DHS asked for help in screening the cargo that comes into the United States on ships, the task involved determining how the screening could be accomplished without unnecessary delays that would disrupt commerce. The answers provided by the laboratory are primarily technological and involve screening U.S.-bound cargo when it is loaded on ships in foreign ports as well as other forms of screening at different points in the shipping process. "As a result," Turner says, "DHS is investing in technology that provides both the security and the speed necessary to prevent disruption of commerce."

John Doesburg, GSD's head of homeland security programs, notes that his group has been working with ORNL's Global Nuclear Security and Technology Division, which uses similar technology to monitor highway traffic for nuclear or radiological material being

transported in vehicles. The system places cameras and radiation detectors on the side of a busy highway and immediately identifies which vehicles contain radiological or nuclear material. Doesberg says DHS has asked if a similar capability can be installed on a ship to screen approaching vessels for nuclear materials.

DHS assigns a priority to America's borders with Canada and Mexico and the possibility that radiological and nuclear material could be brought into the country through a large number of border crossings. GSD program manager Rich Stouder says ORNL is conducting a study of the maritime pathways in the Great Lakes and St. Lawrence Seaway. The study draws on the expertise of the laboratory's nuclear scientists who build detection devices, as well as the operational expertise of GSD staff. Researchers survey the region's geography and talk to law enforcement, customs, border patrol and Coast Guard personnel to get an overview of their equipment and techniques. This data is analyzed to determine where gaps and vulnerabilities in border security might exist and to develop the mission needs statements DHS uses to devise specific solutions to these problems. Stouder's team is examining the use of radar, cameras and various kinds of detectors, with a broader goal of developing techniques that can blend a variety of resources into a system capable of recognizing and quickly responding to a unique security situation.

GSD also works closely with other DHS contractors such as Lockheed Martin Corporation to develop solutions to security-related problems. Two of the largest programs they are working on for Lockheed Martin are related to energy and cybersecurity. One of the projects is headed by Justin Beaver of the laboratory's Computational Sciences and Engineering Division, whose research focuses on controlling digital information resources and evaluating cyber attacks.

Tracking the information

Beaver is developing a process that would enable an organization to keep track of vast amounts of information stored in computer documents while the documents are being copied, excerpted, changed and stored in various forms throughout the organization's network. The solution Beaver and his team have designed is called HIVE (Host Information Value Engine). Beaver explains that "in any organization's computer network, there is data that is in some way sensitive—either classified or proprietary—that the organization wishes to protect." Because users often have permission to transfer documents or to copy and paste from one document to another, sensitive information tends to move frequently. "Eventually," Beaver says, "it becomes very difficult to control dissemination of information and still give people access to the information they need to do their work. Not knowing exactly where information is complicates the ability to protect the information adequately. Even worse, if the system has been compromised, knowing precisely what information may have been stolen becomes almost impossible."

HIVE is an effort to provide an automated way of understanding where various categories of data exist on an organization's computer network. Beaver's system focuses specifically on text data. HIVE is a system of software agents sent out from a central location to every computer on the network. Once an agent arrives at a computer, it reviews all of the text files and assigns each to a subject category based on a set of standards supplied by the organization. "For example," Beaver says, "if I want to make a category for biological sciences, I would find documents that are good examples and allow the software agent to analyze them and develop an algorithm—a mathematical description—that recognizes other documents belonging in a similar category. HIVE can also be used to recognize classified documents on an unclassified network."

Category definitions are stored in a central HIVE server, as is the information collected by the software agents. The HIVE system provides a summary and analysis of this data that tells the organization how important information is distributed on the network, regardless of how the data has been moved, copied or modified. "From a cybersecurity standpoint," Beaver notes, "this knowledge is critical in a number of ways. For one thing, HIVE identifies which information should be protected by providing an objec-

tive assessment of information on a particular computer based on standards defined by the organization." Using HIVE to conduct the review also saves time. Other tools that could be applied to this problem are manual, making them time-consuming and difficult to update. An automatic system, HIVE can conduct an updated scan as often as necessary. Finally, in the event of a cybersecurity breach, HIVE ensures that the organization knows exactly what kind of information was put at risk.

Beaver says that scanning every machine on a network on a daily or weekly basis would provide adequate oversight for most types of information. Based on early success, HIVE's cutting-edge oversight capabilities have generated considerable interest on the part of numerous government organizations increasingly concerned about cybersecurity threats.

Using ORNL-developed graphite foam material in OTEC heat exchangers has decreased their size by 30 to 50 percent.

Running hot and cold

Another project GSD is facilitating for Lockheed Martin is the work under way in James Klett's group on Ocean Thermal Energy Conversion, or OTEC. Klett and his Materials Science and Technology Division team are working on a system to address the U.S. military's special energy needs in parts of the world where forces currently rely on long supply lines or distant power-generation facilities. According to Klett, OTEC is basically a geothermal energy conversion using the temperature difference of the world's oceans. In the tropics, the water surface temperature is about 25 to 30 degrees C; at about 300 feet deep, the water temperature is about 4 degrees C. Klett says that an ongoing OTEC research project located off the coast of Kona, Hawaii, pumps cold water to the surface using a 3000-foot-long pipe. "They use this water, in conjunction with the warmer surface water, to drive turbines in a Rankine cycle power plant." A Rankine turbine runs warm water through a heat exchanger to boil ammonia, which becomes a vapor and drives the turbine to generate power. The cold water is then used to cool the ammonia, returning it to liquid form. The cycle is then repeated. The novel process produces energy that is both locally generated and cheap.

The downside of OTEC systems is that they are as little as two percent efficient. "A traditional power plant is about 35 percent efficient," says Klett. "However, to achieve that efficiency, we have to burn coal or oil or natural gas and create pollution. With the OTEC system, no pollution is created." Given the state of current OTEC technology, a commercial-scale OTEC power plant would require very large heat exchangers—10 exchangers on the cold-water side and 10 exchangers on the hot-water side measuring 10 feet by 10 feet by 30 feet long. The exchangers would be mounted in the ocean on a floating platform, much like an oil drilling platform. A billion-dollar OTEC power plant would require $200 million in heat exchangers.

To address these efficiency concerns, Klett and his team are developing heat exchangers that they hope will prove to be significantly more efficient. Their goal is to reduce the size of the equipment involved and thus substantially reduce costs. Maintenance and repair expenses, as well as the cost of power to pump the water and ammonia through the system, would also be reduced. Klett's solution involves the design of heat exchangers based on an ORNL-developed graphite foam material, decreasing the size of the units by 30 to 50 percent. "We have already built some subscale heat exchangers that Lockheed Martin is testing," Klett says. "This year we will provide a full-scale heat exchanger three feet in diameter and 20 feet long that will be tested in a pilot plant in Hawaii." If the plant proves to be as efficient as expected, the next step will be construction of a 20-megawatt production plant.

Klett emphasizes that an additional advantage of OTEC is the ability to provide a continuous energy source. "The problem with most alternative energy sources such as wind or solar power is that their power production is intermittent. OTEC has the potential to eliminate that shortcoming—one reason OTEC is attractive to the military."

An expanding role

ORNL possesses a number of capabilities that are increasingly being used to address America's security challenges. These include expertise in nuclear and radiological detection, the ability to leverage computational power to address issues in virtually any area of scientific research, extensive experience in developing and deploying sensing systems that can detect a range of potential threats, and an unmatched portfolio of energy technologies. These abilities suggest that ORNL's role in addressing public safety problems will continue to expand in the years ahead.

As this role expands, the laboratory's Global Security Directorate will take the lead in channeling unique research capabilities into research and development partnerships with DHS. For both the laboratory and the nation, the importance of the mission cannot be overstated. ®

Brent Park

ORNL's Associate Laboratory Director of Global Security is responsible for managing the organization's five program offices with a portfolio that supports national priorities in global and homeland security for the Department of Energy and other agencies.

Before coming to Oak Ridge last July, Park served as the Director of DOE's Remote Sensing Laboratory at the Nevada Test Site, where he managed the organization's R&D efforts in the areas of physical and environmental science; design and fabrication of electronic, mechanical, and structural systems; remote and robotic sensing; and remote field experiments and operations. While in Nevada, Park worked to apply advanced technologies for sponsors in the national defense, homeland security and intelligence communities.

We asked Park about his organization's role in applying ORNL's expertise to some of the world's most pressing security challenges.

What are the most important capabilities that ORNL can provide for Global Security's mission?

The key discriminator is not so much any given capability that ORNL's Global Security Directorate (GSD) brings to bear on national security issues as it is the breadth of capabilities here at the lab. Our basic modus operandi is to have our Customer Focus Leads mine what we refer to as "lab hard" requirements from our national and homeland security sponsors. These are requirements that could only be addressed by the resources of a national laboratory. We take these technology needs and match them to the appropriate capability here at the lab. Not many folks here at the lab know that GSD and its predecessor organizations are responsible for work in virtually every research division, from Research Reactors to Biosciences. The scope of our activities has resulted in literally thousands of matches across the lab where our scientists and engineers are solving pressing national scientific and engineering challenges.

From the perspective of your program, how would you contrast the missions of ORNL and the three weapons labs?

From where I sit, my responsibility for the execution of ORNL's mission is not weapons-centric, but rather science-to-application-centric. Our work is science-based and appropriate for consideration for any national or homeland-security-related challenge—which may include weapons. Said another way, as the nation's largest and most diverse general purpose lab, the range of requirements we are able to address for our sponsors at ORNL is extremely broad and encompasses science from climate change to fuel efficiency. You just don't see that breadth at the weapons labs to the degree you do at ORNL.

How, then, does the breadth of ORNL's R&D portfolio affect your efforts to match the lab's expertise with the needs of government and industry?

We have talked about GSD's role in addressing government requirements. However, an ever-increasing portion of our portfolio is devoted to developing and transferring technology to industry to be used in support of national or homeland security objectives, as well as enhancing America's economic competitiveness in world markets. GSD applies both technology and existing science, in the form of disclosed intellectual property and emerging science, to address a variety of needs from a variety of customers. Our role for the private sector includes developing, integrating and deploying unique solutions in both classified and unclassified technologies.

My responsibility for the execution of ORNL's mission is not weapons-centric, but rather science-to-application-centric.

Simulation science is now integral to many scientific disciplines. How does this capability influence how research is done in your organization?

As one would suspect, our sponsors rely heavily on modeling and simulation to assist them in their decision-making processes. I'll give you an example. The unclassified high-performance computing capability at ORNL's Leadership Computing Facility, coupled with the laboratory's computational science expertise, has positioned GSD well to pursue providing support on a major new design, simulation and modeling initiative for the Navy for two new classes of ships, as well as a new initiative exploring the security implications of energy and climate change for the Department of Defense and the intelligence community.

What do you see as the most pressing global security concern?

Clearly the greatest concern is the potential for proliferation of weapons of mass destruction or weapons of mass effect. Let me give you an example here as well. Larry Satkowiak's Global Security & Nonproliferation program within GSD has gained international recognition as a thought leader and solution provider in science and technology application for nuclear nonproliferation, safeguards, threat reduction, transportation security and related areas. With the current administration's emphasis on both nuclear nonproliferation and nuclear treaties, we see an expanding need for ORNL's capabilities in this area.

How do you see your organization evolving over the next few years?

As the nation—indeed the world—continues down the path of increasing connectivity to the internet, the potential for cyber attacks on online resources demands world-class expertise in defending against these assaults. I see GSD shifting its emphasis in that direction. We have all heard of the recent Stuxnet virus that has the capability of taking over critical operations at nuclear reactor sites. Such threats are the tip of the iceberg. GSD is kicking off an initiative to address cyber-related issues that are truly "lab hard." We are talking about social engineering and phishing on government sites, Stuxnet-like attacks, cyber-warfare detection and countermeasures, and ensuring the security of the nation's power grid. GSD has traditionally been in this lane, but as the lab's capabilities increase in the cyber arena, so too does GSD's ability to apply these capabilities to national or global problems. ®

Natural dissolved organic matter plays dual role in cycling of mercury

Nature has a bit of a Jekyll and Hyde relationship with mercury, but researchers at ORNL have made a discovery that could ultimately help explain the split personality.

While scientists have been aware that microbes in aquatic environments produce methylmercury, a more toxic form of mercury that accumulates in fish, they also know that nature and other types of bacteria can transform methylmercury to less toxic forms. What they have never completely understood are the mechanisms that cause these transformations in anoxic environments—lacking in oxygen—in nature.

"Until now, reactions between elemental mercury and dissolved organic matter have rarely been studied in anoxic environments," says Baohua Gu of the laboratory's Environmental Sciences Division.

In a paper published in the *Proceedings of the National Academy of Sciences,* a team led by Gu reports that compounds from the decay of organic matter in aquatic settings affect mercury cycling. Low concentrations of these compounds can chemically reduce mercury, but as those concentrations increase, the reaction is greatly inhibited. Gu's team performed its experiments by simulating conditions found in nature.

"This study demonstrates that in anoxic sediments and water, organic matter is not only capable of reducing mercury, but also binding to mercury," says co-author Liyuan Liang. "This binding could make mercury less available to microorganisms for making methylmercury."

The authors also note that their paper offers a mechanism that helps explain the seemingly contradictory reports on the interaction of organic matter and mercury in nature. Gu and Liang hope this newly gained knowledge will contribute to a clearer picture of how mercury cycles in aquatic and sediment environments and help in informed decisionmaking for mercury-impacted sites around the nation.

"Our long-term goal is to understand the mechanisms controlling the production of methylmercury in the environment," Liang says. "This knowledge ultimately could lead to ways to reduce levels of mercury in fish, a global problem of enormous significance."

Mercury is distributed around the globe mainly through the burning of coal, industrial uses and natural processes such as volcanic eruptions. Various forms of mercury are widely found in sediments and water.

This research benefits from ORNL's expertise in field-to-laboratory geochemistry and microbiology, computational modeling and simulation, world-class neutron sources and high-performance computing.

Other authors of the paper, "Mercury reduction and complexation by natural organic matter in anoxic environments," are Carrie Miller and Wenming Dong of ORNL and Yongrong Bian and Xin Jiang, visiting scientists from the Chinese Academy of Science.

This 5-year mercury science focus area program, begun in 2009, is funded by DOE's Office of Science.

Research published in the Proceedings of the National Academy of Sciences *by ORNL's Liyuan Liang and Baohua Gu helps explain seemingly contradictory findings.*

Neutron scattering study yields new insights into virus life cycle

Without a host, a virus is a dormant package of proteins, genetic material and occasional lipids. Once inside a living cell, however, a virus can latch onto cell parts and spring into action—mutating, replicating and spreading into new cells.

"There's this thought that a virus has one structure, whether it's in a mosquito or in a human cell," says ORNL researcher Flora Meilleur. "But a mosquito cell and a human cell are very different, which means that a virus may have to reorganize itself."

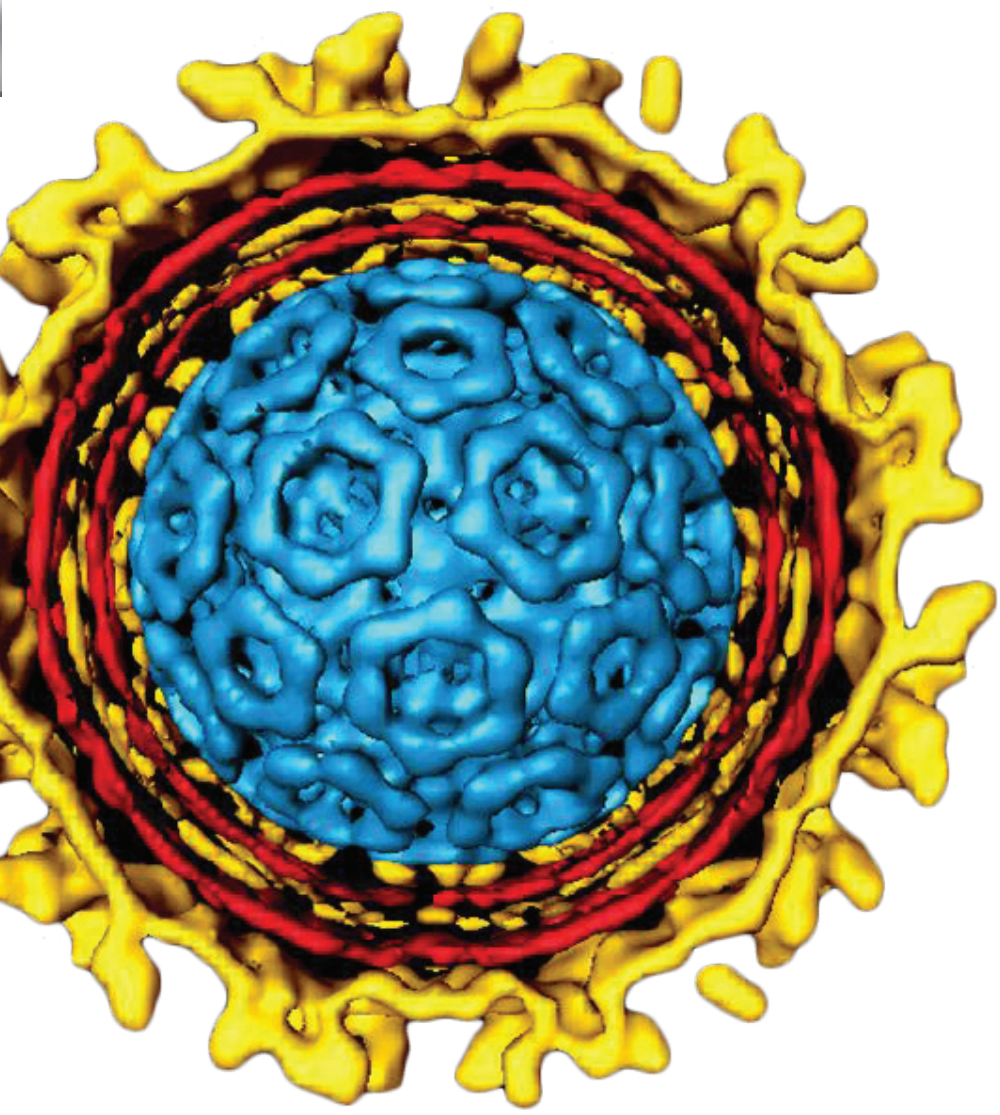
Meilleur is part of a research team from ORNL and North Carolina State University (NCSU) that is examining how viruses change their structure when they move among different host species. Understanding how a virus reorganizes itself when migrating from a mosquito to a human is essential for developing medicines that can block the spread of viruses.

The team's most recent study, published in the *Journal of Virology,* focuses on the Sindbis virus, a member of the arbovirus family that causes infectious diseases like yellow fever, dengue fever and West Nile fever. Scientists have previously observed host-specific differences in the Sindbis virus, but Meilleur says the team's study is the first time that subtle structural variations in Sindbis have been observed and characterized. "This is the first structural comparison of Sindbis viruses grown in different host cells."

The team, which includes Meilleur, Lilin He, Dean Myles and William Heller from ORNL and Amanda Piper, Raquel Hernandez and Dennis Brown from NCSU, used a technique called small-angle neutron scattering to compare virus particles from mammalian and insect cells. Their results revealed that the mammalian-grown viruses exhibited distinct features, including a larger diameter, increased levels of cholesterol and a different distribution of genetic material in the virus core. "The results suggest that structural changes are likely to be important in transmission between hosts," Meilleur says. "The chemical environment of the host cell appears to affect how the virus assembles itself."

The team's structural studies were performed at ORNL's High Flux Isotope Reactor using the facility's Bio-SANS instrument, which uses chilled neutrons to analyze the structure, function and dynamics of complex biological systems. Whereas techniques like X-ray scattering can cause radiation damage in biological samples during analysis, neutron scattering is nondestructive. "Neutron scattering enables us to see differences in the composition of the virus without destroying the sample," Meilleur says. The ability of neutrons to see the composition of biological materials is linked to the particles' sensitivity to hydrogen, which is a key component in compounds like proteins and cell membranes.

Although viral agents from the arbovirus family are a major source of human disease across the globe, very few effective vaccines exist for their control. A detailed understanding of the mechanism by which viruses gain entry into cells will be crucial for the successful pursuit of pharmaceuticals to ultimately treat and prevent infection from members of this virus family.



The mosquito-borne Sindbis virus is a member of the same family that causes West Nile fever and dengue fever. [Image credit: Paredes et al., Virology 324, 373 (2004)]

...and the WINNERS are...

Accomplishments of Distinction at Oak Ridge National Laboratory

Sergei Kalinin was awarded the **Burton Medal** by the **Microscopy Society of America**. The award was initiated "to honor the distinguished contributions to the field of microscopy and microanalysis of a scientist who is less than 40 years of age."

Daniel Bardayan was awarded an **Early Career Research Program** grant by the **Department of Energy's Office of Science**.

Melissa Voss Lapsa, **Teresa Baer** and **ORNL's Sustainable Campus Team** received the **2010 Federal Energy & Water Management Award**, as well as **Estar** awards, from the Department of Energy for their work on the Sustainable Campus Initiative.

Tim Pennycook was presented with the **MSA Presidential Scholar Award** by the **Microscopy Society of America**.

David Joy received the **Peter Duncumb Award for Excellence in Microanalysis** from the **Microbeam Analysis Society**. This award recognizes outstanding achievement in the field of microanalysis through technical accomplishment, leadership, and educational and professional activities.

Sergei Kalinin, **Stephen Jesse** and research partner **Asylum Research** received an **MT 10 Award** from ***Microscopy Today*** magazine for the development of band excitation, a scanning probe microscopy technology. MT-10 Awards recognize the best new products and methods across the entire field of microscopy.

Bill Valdez, **Kathy Collins**, **Keith Joy**, **Jerome Hicks** and **Cassandra Stuart** received the **Dwight D. Eisenhower Award for Excellence** from the **U.S. Small Business Administration**. ORNL is the first Office of Science laboratory to earn this distinction.

ORNL's **Facilities and Operations Directorate** received the **2010 Commitment Award** from the **Tennessee Center for Performance Excellence** for its efforts to improve efficiency, security and safety. ®

Sergei Kalinin

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ORNL's Nuclear Technologies

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