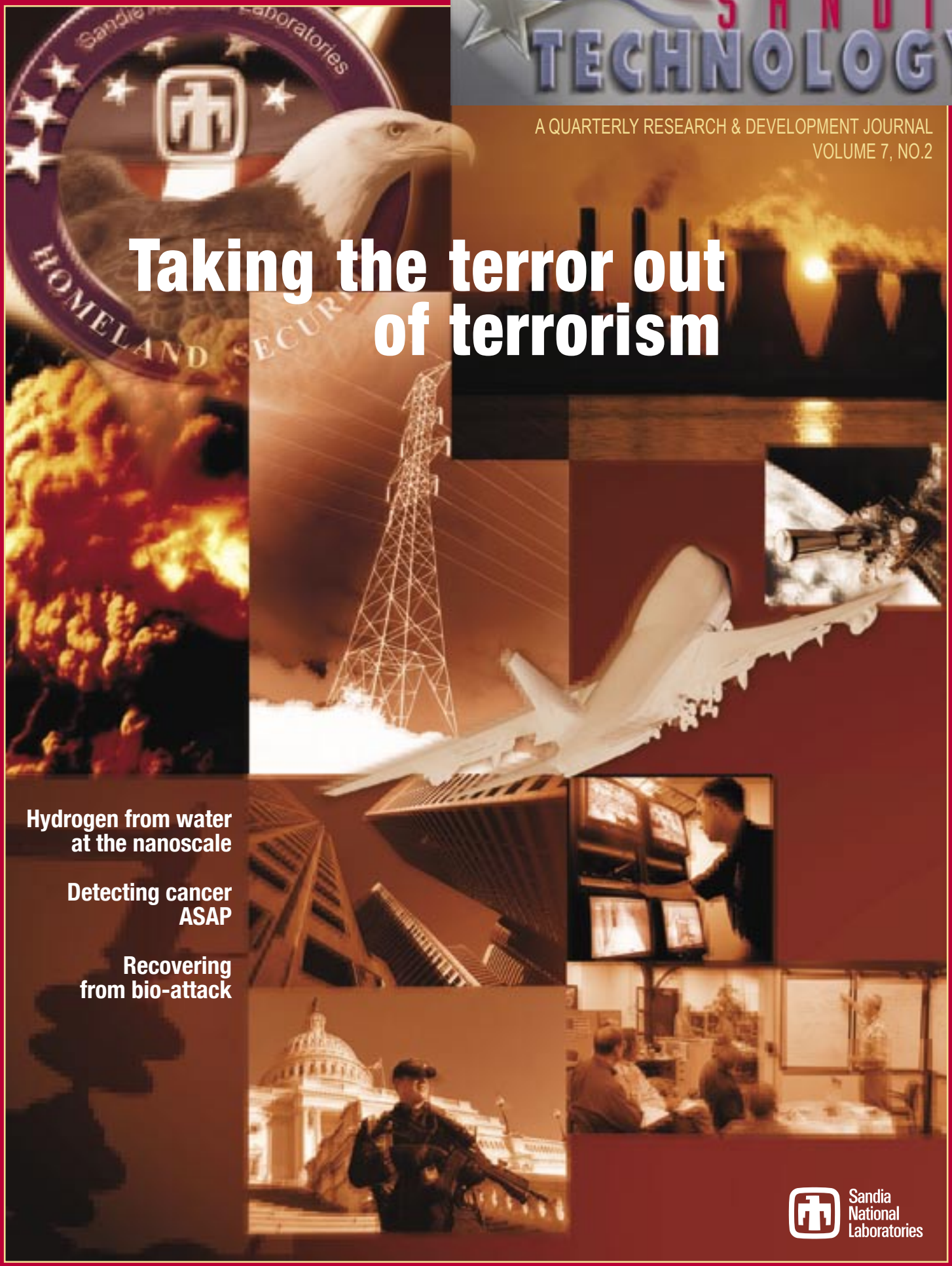
SUMMER • 2005

SANDIA TECHNOLOGY

A QUARTERLY RESEARCH & DEVELOPMENT JOURNAL
VOLUME 7, NO.2

Taking the terror out of terrorism



Hydrogen from water at the nanoscale

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Sandia National Laboratories

What is LDRD

Sandia's world-class science, technology, and engineering work defines the Labs' value to the nation. These capabilities must remain on the cutting edge, because the security of the U.S. depends directly upon them. Sandia's Laboratory Directed Research and Development (LDRD) Program provides the flexibility to invest in long-term, high-risk, and potentially high-payoff research and development that stretch the Labs' science and technology capabilities.

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When the LDRD logo appears in this issue, it indicates that at some state in the history of the technology or program, LDRD funding played a critical role.

On the Cover:

Researchers in Sandia's Advanced Concepts Group are approaching the issues of global terrorism in a number of out-of-the-box ways. (See story beginning on page 2.)
(Photocollage by Douglas Prout)

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FROM THE *Editor*

Dear Readers,

The Summer 2005 issue of *Sandia Technology* looks at Sandia's efforts to help in America's return to space with a safer, better space shuttle and a promising new laser technique for early identification of cancer cells.

The smorgasbord issue delves into the nanoscale – billionths of a meter – to look at work on tiny devices, made with gold and platinum, that may be able to separate water into its components, providing hydrogen as a future fuel.

Our lead article examines a different approach to U.S. homeland security, with analysts standing back to see the forest instead of the trees. The insights from that effort (see page 2) hold promise for helping us make better use of the resources available in the U.S.

Two specific homeland security technologies are the subjects of articles in this issue. One will help personnel at hospitals, airports, and other key public facilities quickly sample and identify contaminants in the event of a bioterrorism attack and follow with an efficient plan for cleanup and recovery of the facility. The other, originally developed to detect explosives, has been used with good effect along the U.S. – Mexico border by South Texas law enforcement officials.

From work at the nano- and molecular-scales to work that helps us explore outer space, Sandia researchers continue to make a difference.

Will Keener
Editor

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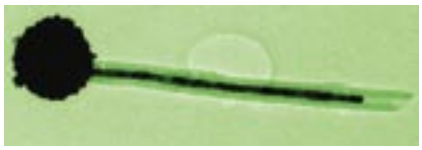

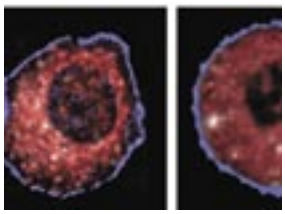

A Sandia team is re-thinking physical security for homeland defense. The analysis may lead to less anxiety, more safety.

Taking the TERROR out of terrorism

Anticipating attacks from terrorists, and hardening potential targets against them, is a wearying and expensive business that could be made simpler through a broader view of the opponents' origins, fears, and ultimate objectives, according to Sandia's Advanced Concepts Group (ACG).

It isn't practical or affordable to harden all of the different terrorism targets against the many means of attack, says ACG member Curtis Johnson.

That kind of U.S. response is actually part of the war plan of our opponents, points out Sandia Vice President and ACG Principal Scientist Gerry Yonas. He reports that an al Quaeda strategy document signed by Sheikh Naji, dated September 2004, reads: "Force the enemy to guard every building, train station, and street in order to plant fear in their hearts and convince Muslims to join and die as martyrs instead of dying as infidels."

Osama bin Laden put it this way, according to Yonas: "We are continuing . . . to make America bleed profusely to the point of bankruptcy . . . ."

The ACG — a technical think tank that influences the direction of long-term research at Sandia — is in the early stages of developing a conceptual program to improve America's defenses against terrorism.

"Something to keep in mind," says Johnson, "is that an attack isn't a goal in itself but a means to a further end. If attacks succeed tactically, but fail to produce the desired terror or bring our society to

its knees, adversaries will be frustrated and likely cease that kind of attack."

"There can never be perfect protection," says Yonas. "We can never stop every conceivable attack. We live with danger every day in many forms."

What follows are some ACG ideas for homeland security.

A nation's people and media can be won over through global initiatives that deal with local problems such as the need for clean water and affordable energy.

Sensing cards

People in airports voluntarily might carry smart cards with computer chips if the cards could be sweetened to perform additional tasks like helping the bearer get through security, or to the right gate at the right time.

Mall shoppers might be handed a sensing card that would help locate a particular store, a special sale, or find the closest parking space through cheap distributed-sensor networks.

"Suppose every PDA had a sensor on it," suggests Sandia researcher Laura McNamara. "We would achieve decentralized surveillance." These sensors could report by radio frequency to a central computer any signal from contraband biological, chemical, or nuclear material."

Danger signals would call forth already-in-place defensive procedures.

"The goal here is to abolish anonymity, the terrorist's friend," says Sandia researcher Peter Chew. "We're not talking about abolishing privacy. We're only considering the effect of setting up an electronic situation where all the people in a mall, subway, or airport 'know' each other — [via technology] — as they would have, personally, in a small town. This would help malls and communities become bad targets."

Starting earlier

"The game really starts when the bad guys are getting together to plan something, not when they show up at your door," says Johnson. "Can you ping them to get them to reveal their hand, or get them to turn against themselves?"

Better yet is to bring the battle to the countries from which terrorists spring,

...while technology will play an important role in the overall struggle, it will be most effective when coupled into the entire range of social, political, psychological, economic, historical, and philosophical issues.

and beat insurgencies before they have a foothold.

"We need to help win over the as-yet-undecided populace to the view it is their government that is legitimate and not the insurgents," says the ACG's David Kitterman. Data from Middle East polls suggest, perhaps surprisingly, that most respondents are favorable to Western values. Turbulent times, however, put that positive view under more stress.

A nation's people and media can be won over, says Yonas, through global initiatives that deal with local problems such as the need for clean water and affordable energy.

Says Johnson, "U.S. security already is integrated with global security. We're always helping victims of disaster like tsunami victims, or victims of oppressive governments. Perhaps our ideas on national security should be redefined to reflect the needs of these people."

This part of the process may have already begun. Peter Davies, director of Sandia's Geosciences and Environment group, says that Sandia has just completed a workshop series in partnership with the Center for Strategic and International Studies on Global Water Futures (*www.csis.org/gsi/water.htm*). This project is focused on innovation in U.S. international water policy and in the way it deploys technology.

More technical actions under consideration are for researchers to enter chat rooms with military commanders to solicit feedback to problems encountered in the field; apply system solutions to monitoring borders without interrupting legitimate traffic flow; and direct more simulated attacks by "red" teams to probe and correct technical weaknesses in U.S. defenses before actual assailants strike.

Range of issues

Yonas believes this global war does not have to last for generations "if we harness the comprehensive capacity of our nation." He means by this, he says, that while technology will play an important role in the overall struggle, it will be most effective when coupled into the entire range of social, political, psychological, economic, historical, and philosophical issues.

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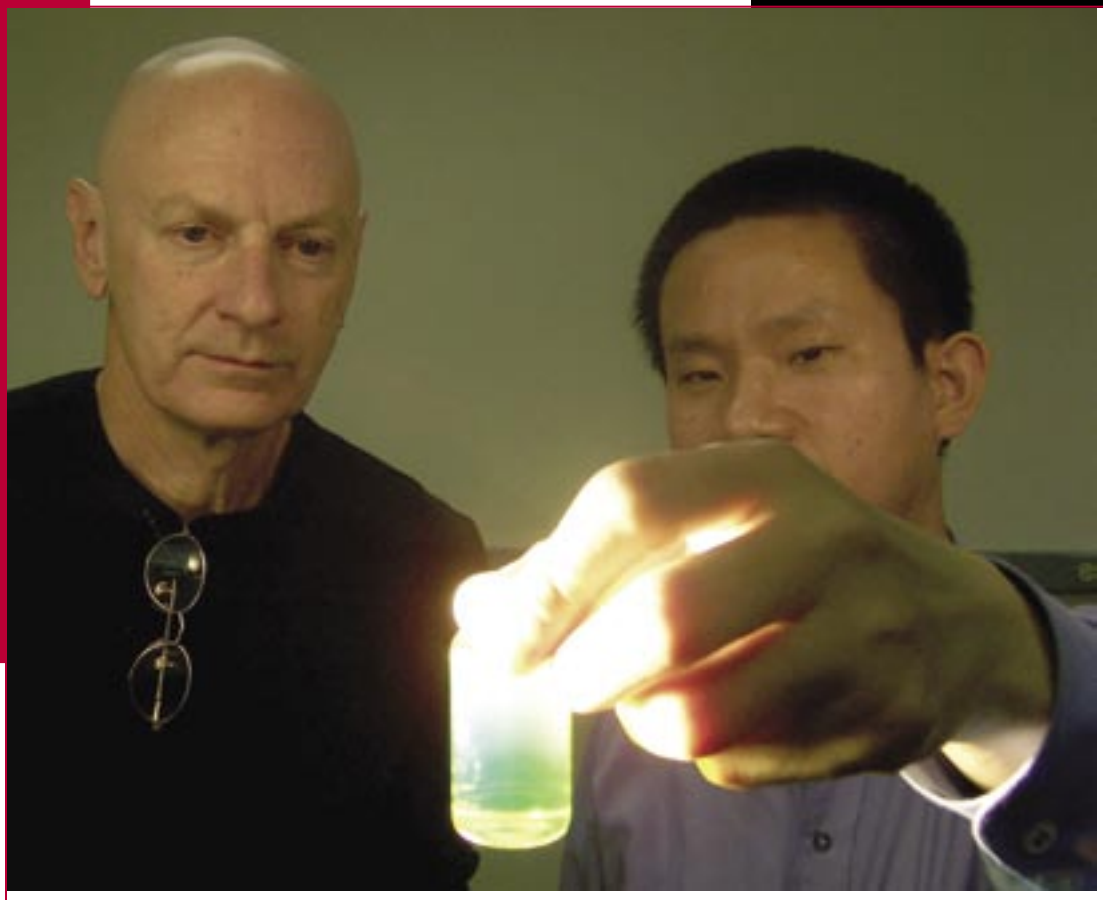
Recent ACG brainstorming sessions.

Hydrogen from water at the nanoscale



Sandia researchers John Shelnutt and Zhongchun Wang gaze upon the glow of porphyrin nanotubes, caused by the nanotubes' intense resonance light-scattering activity.

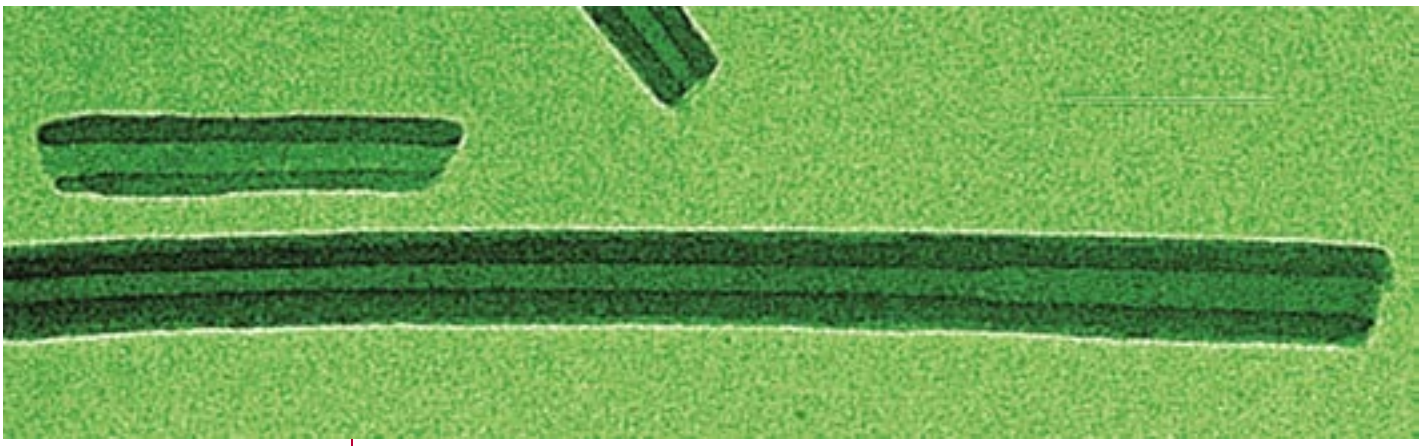
Tiny porphyrin tubes developed by Sandia may lead to new nanodevices. One possible result is clean, inexpensive hydrogen fuel from water.

Imagine sunlight splitting water molecules to produce hydrogen, using devices too small to be seen in a standard microscope. That's a goal of a research team from Sandia that has captured the interest of chemists around the world pursuing methods of producing hydrogen from water.

"The broad objective of the research is to design and fabricate new types of nanoscale devices," says John Shelnutt, Sandia research team leader. "This investigation is exciting because it promises to provide fundamental scientific breakthroughs in chemical synthesis, self-assembly, electron and energy transfer processes, and photocatalysis. Controlling these processes is necessary to build nanodevices for efficient water splitting, potentially enabling a solar hydrogen-based economy."

The prospect of using sunlight to split water at the nanoscale grew out of Shelnutt's research into the development of hollow porphyrin nanotubes. These light-active nanotubes can be engineered to have minute deposits of platinum and other metals and semiconductors on the outside or inside of the tube.

The key to making water-splitting nanodevices is the discovery by Zhongchun Wang of nanotubes composed entirely of porphyrins. Wang is a postdoctoral fellow at the University of Georgia working in Shelnutt's Sandia research group. The porphyrin nanotubes are micrometers in length and have diameters in the range of 50-70 nanometers with approximately 20-nanometer-thick walls. They are prepared by ionic self-assembly of two oppositely charged porphyrins — molecules that are closely related to chlorophyll, the active parts of photosynthetic proteins.



An electron microscope image of a porphyrin nanotube.

The research team has already demonstrated that the nanotubes with platinum particles on the surface can produce hydrogen when illuminated with light.

New class of nanostructures

These hollow structures are one member of a new class of nanostructures made of porphyrins that Shelnutt and his team are developing. The porphyrin building blocks can be altered to control their structural and functional properties. Shelnutt says these porphyrin nanotubes have "interesting electronic and optical properties, such as an intense resonance light-scattering ability and photocatalytic activity."

When exposed to light, some porphyrin nanotubes can grow metal structures onto their surfaces to create a functional nanodevice. For example, when the nanotubes are put into a solution with gold or platinum ions and exposed to sunlight, their photocatalytic activity causes the reduction of the ions to the metal. Using this method the researchers have deposited platinum outside the nanotube and grown a nanowire of gold inside the tube.

The nanotube with the gold inside and platinum outside is the heart of a nanodevice that may split water into oxygen and hydrogen. The research team has already demonstrated that the nanotubes with platinum particles on the surface can produce hydrogen when illuminated. To complete a water-splitting nanodevice, a nanoparticle of an inorganic photocatalyst that produces oxygen must be attached to the gold contact ball that naturally forms at the end of the tube. The gold nanowire and ball serve as a conductor of electrons between the oxygen- and hydrogen producing components of the nanodevice. The gold conductor also keeps the oxygen and hydrogen parts separate to prevent damage during operation.

"Laboratory-scale devices of a similar type have already been built by others," Shelnutt says. "What we are doing is reducing the size of the device to reap the benefits of the nanoscale architecture."

Shelnutt says the nanodevice could efficiently use the entire visible and ultraviolet parts of the solar spectrum absorbed by the tubes to produce hydrogen, one of the Holy Grails of chemistry.

These nanotube devices could be suspended in a solution and used for photocatalytic solar hydrogen production.

Solar light-harvesting cells

"Once we have functional nanodevices that operate with reasonable efficiency in solution, we will turn our attention to developing nano-device-based solar light-harvesting cells and the systems integration issues involved in their production," Shelnutt says. "There are many possible routes to the construction of functional solar cells based on the porphyrin nanodevices. For example, we

may fabricate nanodevices in arrays on transparent surfaces, perhaps on a masked free-standing film. However, we have a lot of issues to resolve before we get to that point."

Water-splitting is just one of the possible applications of the nanodevices based on porphyrin nanostructures. Shelnutt expects the tubes to have uses as conductors, semiconductors, and photoconductors, and to have other properties that permit them to be used in electronic and photonic devices and as chemical sensors.

The work was partially funded by a grant to the University of Georgia from the Department of Energy, Basic Energy Sciences, Division of Chemical Sciences, Geosciences, and Biosciences.

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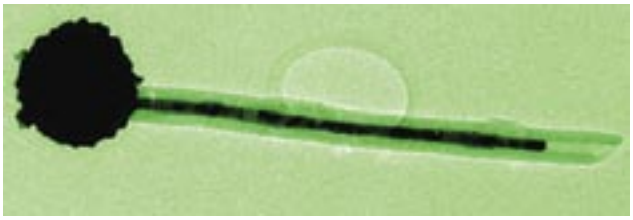
Nanotubes: Porphyrin versus carbon

Porphyrin nanotubes lack the high mechanical strength of the carbon tubes but possess a wider range of optical and electronic properties that can be exploited in making nanodevices.



A gilded nanotube obtained using the Au(I)-thiourea complex

Porphyrins are light-absorbing molecules related to chlorophyll, the active part of photosynthetic proteins and light-harvesting nanostructures (chlorosomal rods). They are the active molecules in many other proteins, such as hemoglobin, which gets its intense red color from a porphyrin.

Porphyrin nanotubes are made entirely of oppositely charged porphyrin molecules that self-assemble in water at room temperature. The more well-known carbon nanotubes are formed at high temperatures and have covalent bonds between carbon atoms.

Porphyrin nanotubes lack the high mechanical strength of the carbon tubes but possess a wider range of optical and electronic properties that can be exploited in making nanodevices. In fact, carbon nanotubes are often modified by attaching porphyrins to increase their utility. This is unnecessary for the porphyrin nanotubes, which can be tailored to specific purposes like water-splitting by varying the type of porphyrin incorporated into the nanotube itself to obtain the desired properties.

Other porphyrin nanostructures such as nanofibers and rectangular cross-section nanotubes have been made and can also be used in the fabrication of nanodevices.

Sandia researcher Paul Gourley examines a biocavity laser photomark. (Photo by Randy Montoya)

Detecting cancer ASAP

Sandia is working with the University of California, San Diego on a lightning-fast laser technique that images mitochondria — the power pack inside of all cells — and can speed up detection of cancer-altered cells at the earliest possible stages.

To investigate tumors, pathologists currently rely on labor-intensive microscopic examination, using century-old cell-staining methods that can take days to complete and may give false readings.

Now, a team led by Sandia researcher Paul Gourley has provided laboratory demonstrations of accurate, real-time, high-throughput identification of liver tumor cells at their earliest stages, and without invasive chemical reagents.

The technique generates a laser beam onto individual human cells, pumped from a flask through tiny microchannels. The beam is altered by what it encounters. These changes, registered by an imaging spectrometer, instantly identify cancer-modified mitochondria in cancer-altered cells. Mitochondria are known as the power pack of cells, energizing them like batteries do flashlight bulbs.

"There are hundreds of mitochondria, sometimes thousands, in a cell," says Gourley. "To see them in the old way requires a time-consuming process, like fluorescent tagging or a chemical reagent. We've found we can see them immediately by light alone."

The techniques could be critical to advancing early detection, diagnosis, and treatment of disease.

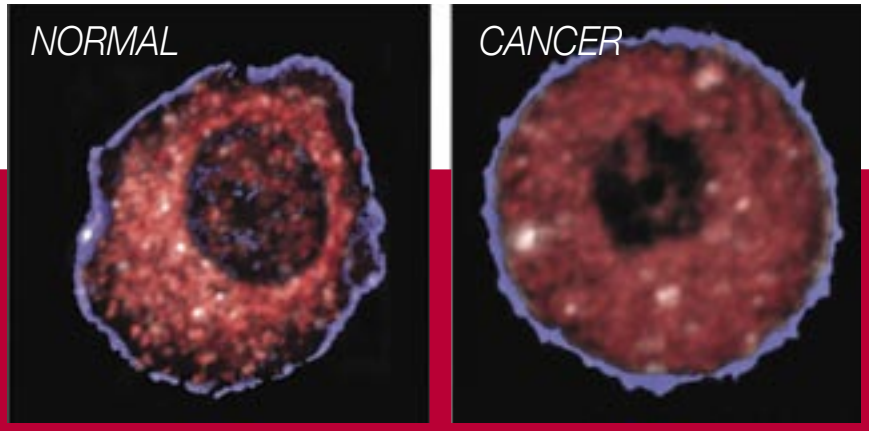
"To rapidly assess the health of a single mammalian cell," says Gourley, "the key discovery was the elucidation of biophotonic differences between normal and cancer cells by using intracellular mitochondria as biomarkers for disease. This technique holds promise for detecting cancer at a very early stage and could nearly eliminate delays in diagnosis and treatment."

The technique is effective because "it measures changes in the cell architecture, especially those arising from alterations in protein density, cytoskeleton shape, and distribution of mitochondria — changes that occur when a cell becomes cancerous," says Gourley.

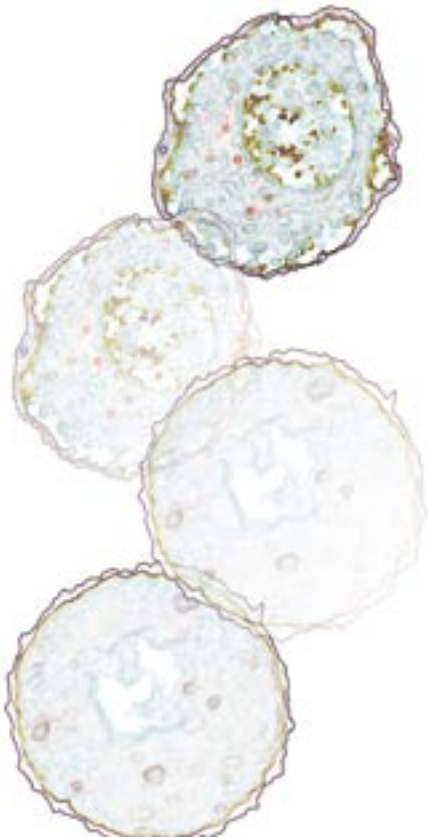
"One would think that if a cell became nonfunctional, it would become disorganized. In cancer, however, that's not the case. A cancer cell is like an insurgent terrorist with a very well-defined agenda. It rearranges the cytoskeleton and the arrangement of mitochondria in the cell. It's no longer a cooperative agent in a collection of cells, but becomes malicious, tries to get outside the area, and hijacks the respiratory machinery of a cell."

The biocavity laser

It is these changes — a kind of beefing-up of the criminal forces — that Gourley's device, called a biocavity laser, detects.



The difference between a normal and cancerous liver cell is shown clearly by the location of mitochondria, as revealed by Sandia's biocavity laser. The healthy cell shows very few mitochondria near the outer cell wall; instead, they cluster densely (red coloration) as they approach the cell's nucleus (black central area). In the cancerous cell, the mitochondria are spread throughout the cell, do not cluster, and under the same lighting produce a more subdued effect.



A nano-thin layering of gallium aluminum arsenide combinations sends up numerous tiny beams from a small cross-sectional generating area. These beams are reinforced or thwarted by the position and density of the mitochondria.

"The pictures we get from normal and cancer cells are very different," says Gourley. "Mitochondria cluster around the nucleus and work together to supply energy to the healthy, functioning cell. In contrast, the mitochondria in the cancer cell sit all over, isolated and balled up in a quiescent, non-functioning state. Apparently, the rapidly growing cancer cells derive energy from an alternative source such as free glucose in the cell."

Novel method

Fortunately, a mitochondrion is nearly the same size as the light wavelength of about 800 nanometers, a frequency otherwise little absorbed by the body. Because of this close match, the laser is very sensitive to subtle changes in the mitochondria size and effects of clustering. To date, the research team has found that 90 to 95 percent of light scatter generated is from optical properties of mitochondria.

According to Bob Naviaux, professor at the School of Medicine, University of California, San Diego, and co-director of its Mitochondrial and Metabolic Disease Center, "What's attractive about this novel optical method for identifying cancer cells is it's a very rapid and general method that potentially can be applied to cancer cells from solid tumors as well as hematological malignancies like leukemia."

Naviaux looks forward to examining a wider population of cancer cells to validate the method, combining the resources of his Center with Sandia's laser expertise.

"There are 300 different cell types in the human body and different mitochondria for each different shape and arrangement," says Naviaux. "We want a library of spectra from different cell types and their cancers."

The biocavity laser may be applied not only to identifying the spectra associated with cancer cells but also those associated with stem cells, and how these optical signals change as they differentiate into nerve, muscle, and other tissues. "At present, there's no rapid method for identifying the transitional states [of a stem cell] with the functional cell type it eventually becomes. That process is a mysterious sequence of metabolic and genetic changes." There are, Naviaux says, metabolic similarities between stem cells and cancer cells, and researchers would like to clearly identify the differences.

"Stem cells are therapeutic," says Naviaux. "How are their spectra distinct from cancer?"

A difficulty still ahead is viewing cancer cells in fluids taken directly from the body, rather than isolated by type in a flask. This problem will be solved by winnowing out unlikely particles through size and frequency.

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Recovering from bio-attacks

The handheld BROOM scanner displays building floor plans and collected samples. Barcodes and other relevant sample data are recorded and later transferred to the BROOM database.

A hardware-software system developed by Sandia is designed to help streamline the cleanup process in the aftermath of a biological attack. Early tests, using bio-warfare simulants, have impressed homeland security officials, who want to use it in a variety of future tests.

Sandia researchers have developed a software-based tool called BROOM — short for Building Restoration Operations Optimization Model — to assist in gathering samples following a release of biological warfare agents in a public facility.

BROOM is intended to help officials of airports, transportation centers, and high-traffic public buildings during planning for a possible reoccupation and return to service and to assist cleanup personnel in restoration operations.

A major piece of the BROOM tool is a handheld electronic device that assists HazMat crews in collecting and managing the many thousands of samples that are collected to characterize contamination in a facility and to verify that the facility is clean following decontamination.

The three-year joint development project, a collaboration with Lawrence Livermore National Laboratory, is sponsored by the Department of Homeland Security and includes partnerships with San Francisco Bay area airports as model facilities for restoration.

Sandia researcher Mark Tucker says the main objective of the BROOM project is to develop methods to minimize the economic impact of a release of biological agent by conducting restoration operations more rapidly than can be done now.

Improved efficiency

"The current process in collecting samples is very cumbersome," says Tucker. "BROOM helps streamline the process." HazMat responders can gather samples only during short periods of time, due to the heavy gear they must wear and for safety reasons. To make it easy for the responders to carry the software tool, the researchers assembled a handheld device that incorporates the BROOM software, a barcode scanner, and a wireless laser range finder to accurately identify where the sample was taken.

The device's scanner reads barcodes placed on vials where the samples are stored. Sample barcodes provide a way to monitor the transfer of samples from the field to the lab. They also help automate

The first sampling is done as soon as a determination is made of what the contamination is, where it occurred, and what techniques should be used to gather samples.

the process of merging field data with laboratory results. Information such as sample type, surface type, surface orientation, surface area, and surface texture is recorded for each sample. The sample collector records himself as the person who acquired the data and may also write additional information about the sample in a notes field.

All data are then transferred to a computer outside the contaminated area by wireless transmission. The results are displayed on a map on both the handheld device and the computer.

The first sampling is done as soon as a determination is made of what the contamination is, where it occurred, and what techniques should be used to gather samples. If spores or other biological contaminants are found, the facility requires decontamination.

During the decontamination process, strips of paper containing non-pathogenic bacterial spores similar to anthrax are mounted throughout a facility. Immediately following decontamination, these spore strips are collected and analyzed for live spores. If live spores are found on the strips, the decontamination process must be repeated.

The final stage focuses on clearance sampling to ensure that the area is safe and clean for reentry. The BROOM tool can be used to assist in each stage of the restoration process.

In an exercise held recently at Sandia, National Institute for Occupational Safety and Health crews get suited in full HazMat gear before entering a simulated area of contamination. (Photo by Randy Montoya)

BROOM exercise

An exercise, in conjunction with the National Institute for Occupational Safety and Health (NIOSH), was held recently at Sandia facilities in Albuquerque, New Mexico, to test BROOM.

NIOSH establishes standards and methods for biological sampling. Previous work done by NIOSH includes anthrax sampling at the Hart Senate Building and at the Brentwood and Trenton postal facilities after the 2001 anthrax incident.

The exercise at Sandia involved a release of a harmless simulant used to mimic a biological agent. NIOSH crews in full HazMat gear using the BROOM tool conducted a realistic sampling exercise. During the first day of the three-day exercise, 24 samples were collected and entered into BROOM. The diagram showed hot spots in the area where the contamination occurred. The remaining two days consisted of additional sample collection, as well as analyzing and testing BROOM.

The exercise was a success, says Tucker. “Although the NIOSH crews provided some feedback about minor changes to the BROOM software, they were, in general, very impressed with the product,” Tucker says. “In fact, they want to further evaluate BROOM by using it in their future sampling operations — both those that involve biological agents and those that involve more routine sampling operations for investigations of occupational hazards.”

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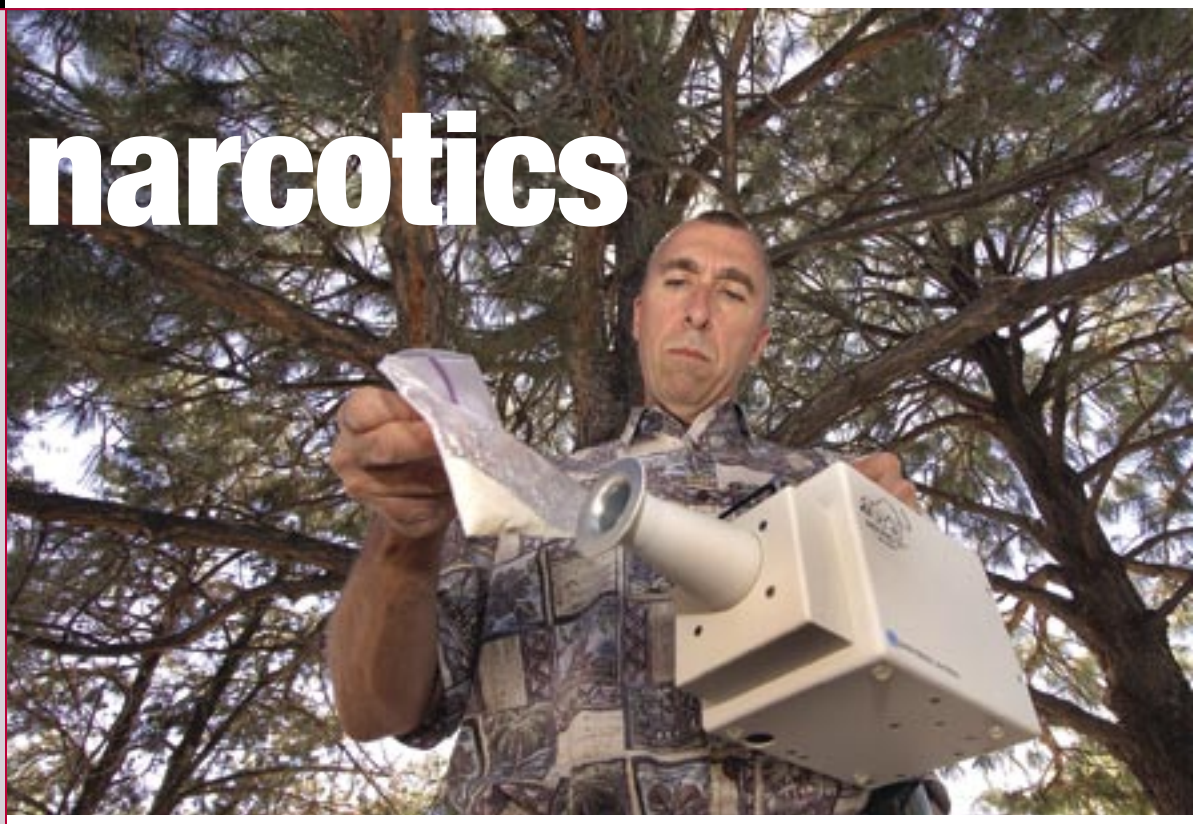
Nose for narcotics



Sandia researcher Dave Hannum demonstrates use of the Hound system on a bag of white powder. (Photo by Randy Montoya)

South Texas police and border agents are using Sandia's sniffer technology to nab drug traffickers. The drug task force credits the Hound system, originally developed to detect explosives, with helping to save lives.

On a South Texas highway, local police and border agents are using a hand-held "sniffer" developed at Sandia to help stem the flow of illegal drugs northward into the U.S. Sandia loaned the South Texas Specialized Crimes and Narcotics Task Force one of its prototype Hound systems in November 2003 as part of a field trial to evaluate the system for drug detection. Since then Task Force officers have used the Hound system at border checkpoints to help screen vehicles for narcotics and drug money.

Task Force officials say its officers have on numerous occasions used the Hound system to help local, state, and federal law enforcement officers detect covert narcotics shipments in vehicles at checkpoints; locate nitro, heroin, cocaine, and marijuana in middle schools and high schools; seize drug money going south into Mexico; and build a case against a suspect in a nightclub shooting.

In a few cases the officers credit the device with saving lives.

"There are not enough good things I can say about this tool," says Task Force Commander Jaime Garza. The field trials are made possible through funding from the U.S. Department of Justice's National Institute of Justice and its National Law Enforcement and Corrections Technology Center (NLECTC).

Drugs in fingerprints

The toolbox-sized Hound system includes a front-end sniffer, developed by Sandia for sample collection, and a commercial chemical detector that works for both explosives and drugs. Although the system was originally developed for explosives, the switch from detection of explosives to drugs is relatively simple within the commercial detector, says Dave Hannum, one of the Sandia developers of the preconcentration technique that makes the Hound system so sensitive.

The sniffer works by drawing a bathtub's worth of air through its nozzle, trapping heavy organic compounds in the air on a filter, then heating the filter and re-distributing the collected compounds into a smaller air sample. The compounds then

are identified in a commercial ion mobility spectrometer-based detector that is part of the system.

It's the equivalent of netting hundreds of fish in a vast ocean, then releasing those fish into a pond and fishing for them, with much increased odds. The Hound system is sensitive enough to detect and identify residues in the fingerprints drug users leave behind on door handles, steering wheels, locker latches, and the like.

Sandia pioneered the preconcentration approach in the mid 1990s and has since developed a family of explosives-detection systems based on the technique, including handheld detectors, a vehicle screening system, and a walk-through portal that can sniff trace amounts of explosives on people's skin and clothing.

A commercial version of the portal has been used to screen airline passengers at a checkpoint at New York's JFK airport as part of a Transportation Security Administration pilot project.

The Hound system is sensitive enough to detect and identify residues in the fingerprints drug users leave behind on door handles, steering wheels, locker latches, and the like.

Helping officers

During the field trials in South Texas, the Task Force has used the handheld Hound system as part of border checkpoint screening procedures, using both drug-trained dogs and the Sandia sniffers to canvass a selection of vehicles that was diverted by officers into a secondary screening area, says Garza.

Task Force officers also respond to requests from the local sheriff's department and U.S. Border Patrol agents to investigate suspicious vehicles and items, he says.

Although the Hound alone won't solve the drug problem, says Hannum, the Task Force has documented situations this past year where it has helped.

In one case the Hound system quickly identified a mysterious substance found in an under-seat compartment as liquid meth — a highly flammable and toxic substance that could have been a health threat to officers. In another case, the discovery of cocaine on a young man's driver's license led to an admission of his addiction and his entry into a drug rehab program.

"It was truly an eye-opening experience to learn about the magnitude of the drug problem that is happening every day along the border," says Hannum. "One Hound system cannot even put a dent in the drug pipeline. However, it is a tool that can clearly help officers detect and correctly identify certain illegal substances that they have to deal with on a daily basis."

He says the information gathered during the trials is being used to improve the Hound system for drug detection applications. Commercialization efforts are under way.

"I am proud and grateful to be in a position to help," adds Hannum.

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Assisting with shuttle rollout

The mobile launch platform and the crawler make their way to the launch pad. (Photo courtesy of NASA)

A Sandia project recently studied applied forces and fatigue on the massive mobile launch platform, part of the system used by NASA to transport the space shuttle from the Vehicle Assembly Building to the launch pad. The results will help reduce fatigue and extend the life of the system.

Sandia recently assisted NASA to conduct a series of tests to understand the fatigue on the space shuttle caused during the first four miles of its trip — the rollout from the Kennedy Space Center assembly building to the launch pad.

The tests are part of NASA's return-to-flight mission, with the first flight scheduled for this summer.

Sandia helped NASA design the test and instrumentation to measure the dynamic vibration environment during the rollout. Sandia also computed the input forces the crawler applies to the mobile launch platform (MLP). These computations are being used by Boeing and NASA to determine the fatigue life for critical shuttle components.

Sandia engineer Tom Carne assisted in a series of tests beginning in November 2003 to develop the data necessary to understand the environment and the response of the space shuttle vehicle.

"NASA requested Sandia to assist them in this project because of our expertise in planning and conducting structural dynamic tests on very large structures," Carne says.

Sandia's solid mechanics/structural dynamics group has done numerous structural analysis projects on large structures including the I-40 Rio Grande bridge in Albuquerque, large wind turbines up to 110 meters tall, and the Department of Energy's Armored Tractor. One of the group's main missions is analysis and testing of the shock and vibration environments for weapons.

Emphasis on fatigue

The three-million-pound shuttle sits on the eight-million-pound MLP, which is carried by a six-million-pound crawler. The crawler transports the vehicle and platform four miles from the Vehicle Assembly Building to the launch pad.

Moving the shuttle that distance, which normally takes five to six hours at 0.9 mph, had been considered a relatively low-stress process during most of the life of the shuttle system. As the equipment ages, however, more emphasis is being given to understanding how the rollout may fatigue the space shuttle.

Data were collected for rollouts of the MLP only and the MLP with the two solid rocket boosters, at five different speeds ranging from 0.5 to 0.9 mph. For the tests more than 100 accelerometers were placed on the MLP, crawler, and solid rocket boosters. A data acquisition system installed inside the MLP for the road test measured and recorded the accelerations. The data were analyzed so that the character of the rollout environment is understood and can be analytically imposed on the shuttle using a finite-element computer model to predict fatigue damage to critical components.

Even though these stresses are much lower than those seen during the launch, the five- to six-hour duration of the transport and the low-frequency vibration could cause fatigue in components within the orbiter.

Carne says the rollout analysis team determined that there are two families of forcing harmonics caused by the crawler drive train that vibrate the platform as a function of crawler speed, in addition to the random inputs induced by the road bed. Fortunately, he says, the harmonic forcing frequencies can be adjusted by merely changing the drive speed of the crawler, resulting in less damaging frequencies.

[The analyses] helped NASA determine that merely reducing crawler speed from 0.9 mph to 0.8 mph would significantly reduce the vibrations in the shuttle by shifting the engagement frequency of the crawler treads.

Estimating applied forces

The team used a Sandia-developed algorithm, called the Sum of Weighted Accelerations Technique, or SWAT, to estimate the applied forces. Carne says the SWAT results were beneficial in choosing a new rollout speed that will extend the fatigue life of the shuttle components that were affected by rollout.

The SWAT-generated input forces have subsequently been used as the force input for NASA's structural analysis of the mobile launch platform. The correlation between the rollout-measured data and the predictions from the NASTRAN analysis has engendered confidence in both the SWAT-computed forces and the NASTRAN models of the MLP and solid rocket boosters, he says.

The analyses showed that the shuttle's vibration response can be much reduced when the driving frequencies are shifted away from the shuttle's own resonant natural frequencies. They helped NASA determine that merely reducing crawler speed from 0.9 mph to 0.8 mph would significantly reduce the vibrations in the shuttle by shifting the engagement frequency of the crawler treads.

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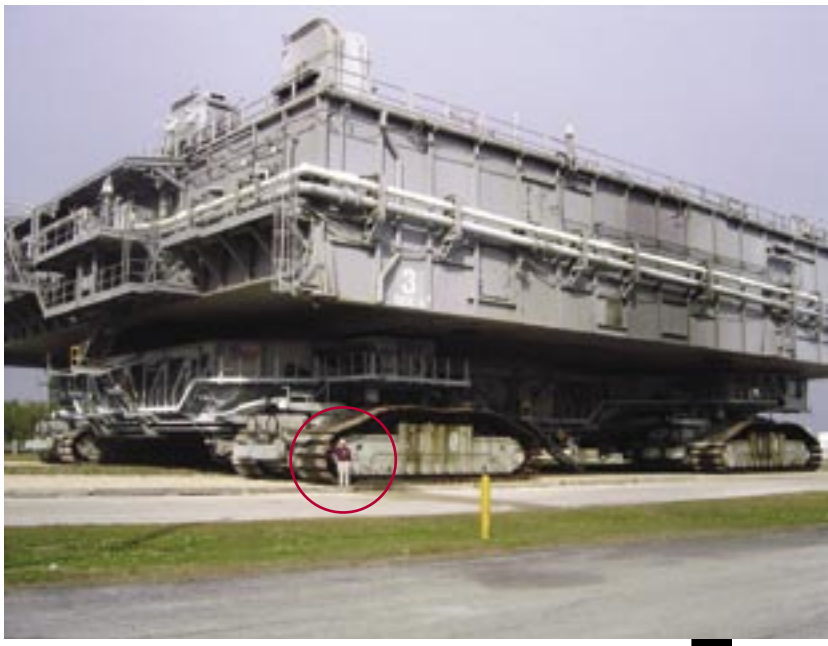


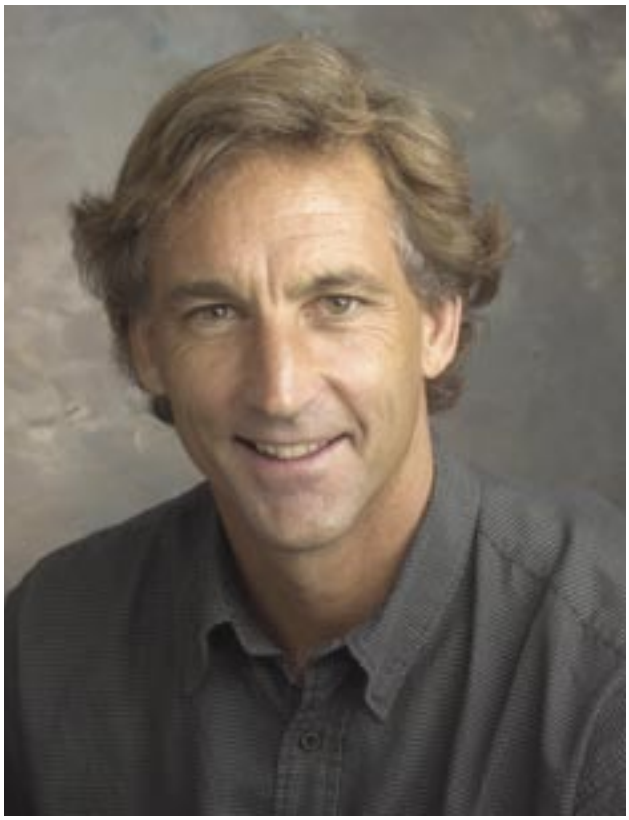
Tom Carne stands in front of NASA's massive mobile launch platform and the crawler that carries the space shuttle from Kennedy Center's Vehicle Assembly Building to the shuttle launch pad.

Entrepreneur in Residence to stimulate spin-off companies

Entrepreneurs in Residence will conduct technology assessments, develop market opportunities, formulate preliminary business cases, and propose business structures for start-up enterprises.

A new Sandia initiative seeks to stimulate spin-off companies to be built around Sandia technologies that are important to the Labs' national security mission. Called the Entrepreneur in Residence (EIR) program, it will allow proven start-up entrepreneurs the opportunity to work directly with technical management and staff at Sandia to identify technologies that will contribute to national security and support economic diversification in New Mexico, the Bay Area of California, and throughout the nation.

EIRs will conduct technology assessments, develop market opportunities, formulate preliminary business cases, and propose business structures for start-up enterprises. The first EIR also will be responsible for recommending policy and business practice modifications for the pilot program to further refine approaches to creating companies based on Sandia intellectual property.



Tom Brennan

Kevin McMahon, Sandia manager for licensing and intellectual property, recently named Tom Brennan as the first entrepreneur for the program. Brennan is chairman of Medical Lighting Solutions (MLS), which uses solid state lighting to treat disease.

"Tom is one of the most accomplished entrepreneurs in New Mexico," McMahon says. "He is uniquely qualified to become Sandia's first Entrepreneur in Residence based on his technical background, business skill, understanding of the Labs, and his extensive experience in high-tech entrepreneurial endeavors."

Prior to Brennan's position at MLS, he was president and CEO of Zia Laser, focused on development of quantum dot laser diodes; founder and managing partner of Zircle LLC; vice president of EMCORE Corporation, focused on space-based solar power; and co-founder and co-president of MicroOptical Devices (MODE), focused on vertical cavity surface-emitting lasers. MODE was a start-up company formed from technologies licensed from Sandia.

"The innovative Entrepreneur in Residence pilot program is a great way to see technologies internal to the laboratories — technologies that otherwise might not see commercial application — identified and used in new applications to strengthen our national defense initiatives through commercial suppliers," Brennan says.

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"The broad objective of the research is to design and fabricate new types of nanoscale devices. This investigation is exciting because it promises to provide fundamental scientific breakthroughs in chemical synthesis, self-assembly, electron and energy transfer processes, and photocatalysis. Controlling these processes is necessary to build nanodevices for efficient water splitting, potentially enabling a solar hydrogen-based economy."

John Shelnutt,
Sandia research team leader

Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000

SAND-2005-3990P

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