DATELINE LOS ALAMOS
U.S. DEPARTMENT OF ENERGY
UNIVERSITY OF CALIFORNIA

LOS ALAMOS CAPTURES FOUR R&D 100 AWARDS

R&D MAGAZINE HONORS THE MOST SIGNIFICANT PRODUCTS, MATERIALS, PROCESSES, SOFTWARE AND SYSTEMS WITH COMMERCIAL PROMISE

Los Alamos has demonstrated its world-class scientific ability by winning four 1998 R&D 100 Awards. These awards give the Lab a total of 56 won during the past 11 years.

The four Laboratory awards, two of which were developed in partnerships with private-sector companies, are from a diverse assortment of technical disciplines — from innovative imaging and computing techniques to novel uses of radio technology and explosives chemistry.

"We are very proud of what Los Alamos has to offer our nation in terms of national security and great science," said Charryl Berger, leader of the Civilian and Industrial Technologies Program Office (CIT-PO).

"These award-winning technical innovations are born out of Los Alamos' core mission of reducing the global nuclear danger," Berger said. "Receiving these R&D 100 awards helps further illustrate how science in the national interest is a natural adjunct to the scientific and technical discipline required to ensure the safety and reliability of the nation's nuclear weapons stockpile."

The R&D 100 awards program, now in its 36th year, honors the most significant products, materials, processes, software or systems with commercial promise. The awards program is international in scope and technologies are nominated in open competition. The Illinois-based *R&D Magazine* uses technical criteria to pick the most important, unique and useful entries to be included in the top 100.

Technologies funded by the Department of Energy this year accounted for 34 of the 100 awards.

"Once again the scientists and engineers at the Department of Energy laboratories are being recognized by garnering a third of this year's prestigious R&D 100 awards," said DOE's Undersecretary Ernie Moniz. "This says more clearly than any words can express how the DOE labs serve as an important engine of American innovation."

This issue of *Dateline: Los Alamos* features the four winning entries as well as nine other innovative Los Alamos technologies submitted to the contest.

DATELINE LOS ALAMOS

A MONTHLY PUBLICATION OF THE PUBLIC AFFAIRS OFFICE OF LOS ALAMOS NATIONAL LABORATORY

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DATELINE: LOS ALAMOS

R&D WINNER

LOW-SMOKE PYROTECHNICS

FIREWORKS COME OF AGE 1,000 YEARS AFTER THEIR INVENTION

A thousand years after the Chinese invented black powder and fireworks, new mixtures developed by Los Alamos scientists make it possible for the first time to produce spectacular fireworks of any size that are safe in either indoor or outdoor settings.

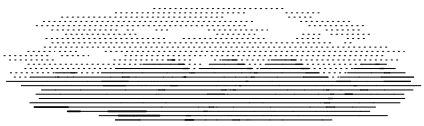
Over the centuries, firework makers have improved the colors, sent aerials higher and replaced excessively dangerous materials, but they have not improved or eliminated the inconsistent, dangerous heart of fireworks: the black powder. New low-smoke, nitrogen-rich mixtures will change this picture.

By combining an energetic, nitrogen-rich fuel with nonmetallic oxidizers and unprecedentedly low levels of metal coloring agents, the new Los Alamos-developed mixtures produce clean flames that generate virtually no smoke or ash. The mixtures enhance the deep, bright colors typical of traditional pyrotechnics and offer a reliable alternative to black-powder-based propellants at a reasonable price.

Fireworks' dazzling colors are obtained by mixing metal salts with a fuel and oxidizer. Strontium, copper and barium salts emit wavelengths of red, blue and green light when they are heated in a flame. Unfortunately, these metal salts, together with metals in the oxidizer, generate significant quantities of smoke and ash, and many of these salts are extremely toxic.

In the past, reducing the amount of metal salts used for coloring the flames has lessened these side effects but has also lowered the intensity of the colors. In a breakthrough discovery, Los Alamos researchers have developed mixtures that contain greatly reduced amounts of metal salts but generate colors deeper and more spectacular than those possible with traditional formulations.

Fourth of July fireworks will be even more dazzling thanks to Los Alamos' new low-smoke pyrotechnic mixtures.



The new mixtures are based on the energetic, nitrogen-rich fuel 3,6-dihydrazino-s-tetrazine (DHT), which can be synthesized by a new recently developed method. DHT is mixed with an inexpensive, nonmetallic oxidizer, either ammonium perchlorate alone, or with mixtures of ammonium perchlorate and ammonium nitrate, and small amounts of metal colorants.

When DHT burns, it releases colorless, harmless nitrogen gas and emits remarkably large quantities of heat and energy that make the flame hot enough for the metal colorants to emit their characteristic colors. The fuel's few remaining carbon and hydrogen atoms react completely with the oxidizer to release heat and colorless, odorless products: water and carbon dioxide gases.

In addition to producing harmless products, the nitrogen-rich fuel burns almost without color, unlike traditional fuels such as charcoal, which burns with a sooty flame that is colored orange by sodium impurities. The Los Alamos fuel's colorless flame results because the DHT is highly pure and contains no sodium.

Coloring this flame requires an amount of metal colorant that is only 2 percent to 8 percent of the mixture's total weight, an amount considerably lower than the 20 to 55 percent of metal colorant found in traditional formulations.

These colored compositions are used to produce either fountains or "stars," small pellets that form individual spots of colors when an aerial shell bursts open. Fireworks, such as aerial shells, that contain stars generally require propellants to launch the device into the air (a "lift charge") and to burst the firework open and scatter the stars when the device is at an appropriate height (a "burst charge").

Typically, the propellant is black powder, an intimate mixture of 75 percent oxidizer (potassium nitrate) and 25 percent fuel (sulfur and charcoal). Because black powder is notorious for producing sulfurous smoke and large quantities of ash, it has been replaced in the Los Alamos version with low-smoke formulations that includes no colorants.

Despite the changes in concentrations and colorants, the new pyrotechnics emit brighter colors than traditional mixtures can produce, for the same reason that colors appear more brilliant when viewed through clear, rather than smoked or tinted, glass.

The flame's suitable temperature and lack of color allows for the standard pyrotechnic colors of red, orange, yellow and green as well as colors that have

traditionally been difficult to produce, such as blue and purple. Two new colors have also been developed: reddish purple and turquoise.

The applications of this technology extend far beyond the realm of entertainment. Because smoke plumes or "signatures" from missiles can pinpoint the location of a launch site and thereby decrease the defensive posture of the attacker, there is a great need for low-smoke, "reduced-signature" propellants in tactical military rockets.

Conventional propellants contain aluminum, which burns to aluminum oxide, the main culprit in white signature plumes. Substituting carbon-based fuels for aluminum reduces the signature but leads to a dramatic 25 percent loss in performance. However, if the aluminum is replaced with the new nitrogen-rich fuel, the signature can be significantly reduced with a minimal 10 percent loss in performance.

Air bags, a standard feature on all new passenger cars, have saved thousands of lives. Whenever an air bag is deployed, however, the propellant used to inflate the air bag — sodium azide — leaves a toxic and corrosive residue on a person's face, hands and upper body. A nitrogen-rich fuel would offer a nontoxic, noncorrosive alternative to sodium azide.

Because the Los Alamos-developed fuel becomes unstable at 160 degrees (compared to 300 degrees Celsius for sodium azide), scientists are searching for similar nitrogen-rich fuels with better thermal stabilities.

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R&D WINNER

UNDERGROUND RADIO

PORTABLE RADIO RECEIVER SUPPORTS COMMUNICATIONS THROUGH HUNDREDS OF METERS OF ROCK

Anyone who has lost radio reception when driving around a mountain has experienced the same phenomena that workers underground do: Radio waves cannot penetrate rock.

Researchers at Los Alamos and Raton Technologies of Raton, N.M., have developed an underground portable radio receiver capable of receiving communication through hundreds of meters of solid rock.

The receiver features high sensitivity and low noise because it uses a detector made of high-temperature superconducting material, which loses all electrical resistance at liquid nitrogen temperatures.

One of the conventional ways to communicate underground has been to use low-frequency radio waves, but these waves significantly weaken as they pass through the rock and require strong transmitted signals and sensitive, low-noise receivers.

Underground Radio can be used within the deepest reaches of a mine to alert miners to conditions during fires or rockfalls.

The underground communications systems most commonly used are hard-wired links such as phone lines, coaxial cables, mining car tracks, short-range radio links or line-of-sight communication. Many of these systems restrict the mobility of an underground worker and can be disrupted by fires or rockfalls, the very circumstances where it's vital to get information to and from the miners.

The Los Alamos underground radio uses a highly sensitive, low-noise magnetic field sensor called a SQUID — superconducting quantum interference device — to measure the small changes in magnetic flux produced by low-frequency radio waves passing through the rock.

The receiver achieves high enough sensitivity and small enough size to allow portable communication, including enough signal bandwidth to make voice communication through the earth possible.

This new system can alert miners to underground conditions during fires or rock falls. It can be used to locate miners trapped underground or accurately determine the positions of underground machines.

The receiver itself consists of a SQUID sensor and components that control the SQUID and amplify and filter the signals. The prototype circuit was used to light up a miner's headlamp or flash a light-emitting diode. The prototype requires 175 cubic centimeters of liquid nitrogen to operate for 24 hours and runs off the battery in a miner's headlamp with very little power consumption.

Since the Los Alamos underground radio is completely portable and does not require hard-wire links, communication can occur within the deepest reaches of a mine. The portability and low cost of the system make it physically and economically feasible to equip a large portion of the 70,000 underground miners in the United States and the millions of underground miners worldwide with the means to receive timely information in the event of a mining emergency.

With some modification, underground radio could be used to communicate with divers or underwater vehicles to a depth of about 100 feet in seawater. The convenience and portability of the system make it possible to mount underwater radio receivers to the hulls of small submersible craft or even to allow the divers to directly communicate with each other underwater.

Another possible application is in mineral exploration. The receiver could be lowered into a borehole and measurements made of the magnetic field propagated to the receiver from the surface or from a nearby borehole. Data analysis and computer modeling would then allow researchers to use these measurements to determine the local geology.

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R&D 100 WINNER

SOLVE

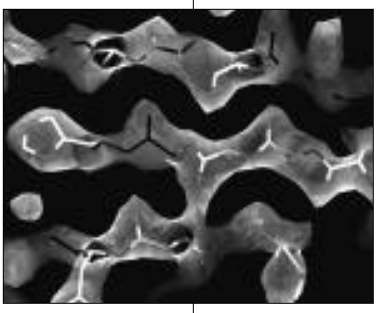
CREATING THREE-DIMENSIONAL PICTURES OF PROTEIN MOLECULES FROM X-RAY DIFFRACTION SPOTS

Proteins are remarkable molecular machines that perform numerous functions essential to life, such as the control of blood clotting and the synthesis of complex organic compounds. Pictures of proteins are in high demand in the biotechnology and health care fields because of their importance in the design of new drugs and in the engineering of new enzymes for commercial use.

SOLVE, a new technique developed by Los Alamos researchers, creates three-dimensional pictures of protein molecules faster than any other available method. And because SOLVE is automated, it is easy to use and very fast.

Constructing a picture of a protein is a formidable task because proteins are too small to be seen with a microscope. The most common way of constructing these pictures is by X-ray crystallography in which a crystal of a protein placed in an X-ray beam is measured at different orientations.

X-rays scatter off the molecules in the crystal to allow a series of measurements with intensities of thousands of spots. These spots make



A slice through a three-dimensional picture of a protein calculated by SOLVE.

up an X-ray diffraction pattern. Additional measurements, made by adding metal atoms at specific sites within the crystal or by tuning the wavelength of the X-rays, provide sufficient information to make a three-dimensional picture of the densities of electrons throughout the molecule.

This picture can be used in determining the position of most or all the atoms in the protein.

The initial and most important step in producing a 3-D picture of a protein molecule is turning the sets of raw X-ray diffraction measurements into a map of electron densities that pinpoint the exact locations of atoms within a molecule. Until now, this task could be done by only by a highly skilled protein crystallographer and took several days or even weeks to complete.

SOLVE's computer software application analyzes how X-rays diffract off crystals in a protein molecule and then draws a three-dimensional picture of the protein. It produces these pictures of protein structure by automatically solving for the missing information in X-ray crystallography.

After automatically analyzing the diffraction measurements, SOLVE generates likely starting solutions, or a series of educated guesses, about the arrangement of the heavy (metal) atoms in a protein molecule. SOLVE then evaluates and ranks each solution for consistency and compares characteristics of the picture constructed from the generated solutions with those of real pictures of proteins.

SOLVE chooses the best starting solutions, generates improved solutions and ultimately draws an accurate picture of the protein molecule. Automating the generation, evaluation and ranking of starting solutions is the most important innovation designed into SOLVE.

As a result, SOLVE can test many possible solutions and choose the best. The system is capable of finding solutions even in cases that cannot be solved by other technologies. SOLVE allows a technician with an hour of training to run and determine with confidence whether a picture of sufficient quality can be constructed from the raw data.

SOLVE is being used at more than 60 government and academic laboratories. Its technology can be applied to rational drug discovery, which is used in designing new, improved drugs; the engineering of enzymes with new catalytic properties useful in the rapid breakdown of toxic waste and in rapid chemical synthesis; and the engineering of robust, heat-tolerant enzymes useful in chemical manufacture.

SOLVE also can be applied to health-related research: Investigators ultimately will be able to identify key structural information of human enzymes and determine how these enzymes work.

SOLVE's speed and automation represent a breakthrough in the quest for new technology that can rapidly construct pictures of the thousands of proteins in a bacterium or even the tens of thousands of proteins in a human being.

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R&D WINNER

CYRAX™

PORTABLE, 3-D LASER-MAPPING AND IMAGING SYSTEM

It is estimated that of the $180 billion to $250 billion spent annually on construction, as much as 5 percent is wasted on correcting field and fabrication errors. More than 60 percent of the construction done today is either revamp or expansion work, as more owners focus on extending the lives of existing facilities.

Expansions and revamps require as-built documentation; computer-aided design files are preferable. Since the existing documentation is often obsolete, field surveys are required. Using conventional methods to update or create models of an existing facility is slow, costly and often impossible.

Cyrax™ has been developed to meet the need for a quicker, cost-effective way to create three-dimensional models. The portable integrated laser radar and modeling system produces a 3-D digital image, like that of a digital camera, but with accurate 3-D geometric information. The technology was co-developed by Los Alamos; Cyra Technologies of Oakland, Calif.; and MIT Lincoln Laboratory.

Cyrax™ eliminates the need for labor-intensive, error-prone survey methods. In addition, because of its powerful laser radar, it provides great accuracy and range (it can scan as far away as 100 meters) that is unavailable with any other laser-based system.

It is the only completely integrated system for acquiring, visualizing and modeling accurate 3-D data. The system's output is 3-D digital represen-

tations and models of large objects such as oil refineries, buildings, mines and ships.

Cyrax™ works by sending out green laser pulses that scan an object as a "cloud of points" in three dimensions. The system determines the location of a particular point by measuring the time it takes for a light pulse to travel from the laser to the surface point and back to a light detector.

An integrated circuit measures this time interval to a precision of 10 picoseconds, allowing locations to be measured to a precision of 2 millimeters. Cyrax™ then converts the thousands or even millions of data points into a 3-D surface model, which can be exported to a CAD application to create two-dimensional drawings or 3-D models. The system is portable and is simple enough to be operated by one person.

Cyrax™ was developed primarily for the architecture, engineering and construction industry to create as-built CAD drawings of buildings, ships, refineries, manufacturing operations, transportation infrastructure and mines, to name just a few.

It has been used in a pilot study with an oil company to create as-built drawings of oil field facilities, where it is estimated that Cyrax™ can save the company 30 to 40 percent in the modeling process and cut field surveying from several months to a few weeks.

In a study for the U.S. Navy, Cyrax™ performed a shipcheck in one-third the time it normally takes. The Navy spends about $100 million per year dispatching teams to survey ships in U.S. and foreign ports or at sea. These teams gather as-built data for shore-based design engineers, allowing design to proceed without taking the ship out of service or off its station. Based on the results obtained by the Cyrax™ test, the Navy is considering purchasing a system for each ship in its fleet.

Cyrax™ also can be used to create as-found and as-built drawings of historic structures and artifacts for preservation and restoration; provide robotics vision for automated welders; create catalogs of modeled parts, such as pipe fittings, that can be overlaid on existing as-built models of facilities; reconstruct accident and crime scenes; and create 3-D models of facilities, such as refineries, for virtual training.

Cyrax™ has even gone Hollywood. It has been used in the production of several movies to create 3-D models of "real-world" sets that are then combined with actors and special effects.

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Cyrax™ was used to scan the island superstructure of the U.S.S. Tarawa. From top to bottom: a photo of the island superstructure, the three-dimensional cloud of points and a textured map of the superstructure's mast.

Modified Cyrax™ systems are being tested in underwater applications, where they could be used to map the ocean floor and inspect structures below the water surface, such as oil rig foundations and ship bottoms and hulls; and terrain mapping for surveying land for construction and creating topographic maps.

In the next few years, the capabilities offered by Cyrax™ could be extremely important to many U.S. plants in light of recent Occupational Safety and Health Administration regulation calling for complete engineering documentation for environmentally regulated plants.

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PASSIVATING DETECTOR SURFACES WITH ENERGETIC OXYGEN ATOMS

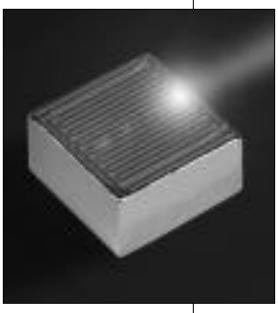
Cadmium-zinc-telluride (CdZnTe) is a semiconductor that is emerging as the material of choice for gamma- and X-ray spectrometers that operate at room temperature. Large-volume CdZnTe detectors not only provide better energy resolution than other detector types, they allow for the development of more compact spectrometers than can now be made with current detectors that may require bulky cryostats or power-hungry cooling equipment.

CdZnTe-based spectrometers are needed to measure radioactive and nuclear materials associated with weapons production.

To be competitive with other detector materials, large CdZnTe substrates with uniform electronic properties are required. Unfortunately, the uniformity of substrates produced with today's commercial processes is variable and production yields are low; fewer than 5 percent of the finished detectors can be sold for gamma-ray spectroscopy.

Los Alamos has developed a surface passivation process involving energetic oxygen atoms that renders the surface chemically and electronically inert and that dramatically improves CdZnTe detector performance and more than doubles production yields.

For the passivation process, the detector is placed in a vacuum chamber and is exposed to an energetic oxygen beam for about five minutes at ambient temperature (about 25 degrees Celsius). Exposure produces a thick layer of cadmium, zinc and tellurium oxides on the top and side surfaces.



The light beam on this detector's surface simulates the beam of energetic oxygen atoms used in the passivation process.

This process reduces surface leakage current — electricity or charge that does not contribute to a useful measurement — by more than 80 percent and improves detector resolution by 25 percent. Leakage current is undesirable since it can mask the real current the detector should measure. In addition, detector noise is reduced by more than 40 percent.

Such improvements are important, since poor performance at low energy is the major factor limiting widespread use of large CdZnTe detectors. The neutral oxygen atoms used in the Los Alamos process are energetic enough to directly induce surface oxidation but not energetic enough to inflict surface damage.

Applications for the improved material include nuclear safeguards, treaty verification, monitoring of nuclear weapons dismantlement and environmental monitoring.

Imaging spectrometers are needed in nuclear medicine for computerized axial tomography. Industrial applications include oil and mineral exploration, monitoring industrial processes with radiotracers and neutron activation analysis, and airport baggage inspection by neutron activation analysis.

The Los Alamos passivation method also will enable the detectors aboard space probes to better withstand the extreme operating conditions encountered in space. Other applications of the Los Alamos process include the growth of high-quality thin films and the selective removal of materials by carefully controlled etching with energetic atoms. In fact, the low-temperature passivation process could impact microelectronics and related fields.

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GENEFINDER — AN ULTRASENSITIVE GENE-DETECTION SYSTEM

The ability to detect a single gene is an invaluable tool for medical diagnoses and numerous types of analytical analyses. However, identifying a gene's short nucleic-acid sequence in a genome up to 3 billion

nucleotides long is a scientific search for a needle in a haystack. And when these individual genomes are present at attomolar concentrations — one genome per every 50-million-trillion ($50x10^{19}$) water molecules — the search is seemingly futile.

The detection of a single DNA sequence in complex genomic samples is the cornerstone of a large number of applications in scientific research and medical diagnosis.

Current techniques for detecting DNA or RNA sequences are rarely sensitive enough to detect minute quantities of a target sequence and often rely on a process with a high potential for producing erroneous results or a time-consuming, labor-intensive procedure that usually requires hazardous radioactive markers.

Los Alamos scientists have developed an invaluable replacement for those techniques. GeneFinder detects and counts single-copy genes (genes that appear only once per genome) in complex samples.

The system couples a two-probe hybridization protocol with advanced single-molecule fluorescence detectors to create a highly specific, sensitive and quick tool that is faster, easier to use, more versatile, capable of quantification and at least an order of magnitude more sensitive than any other instrument or technique available.

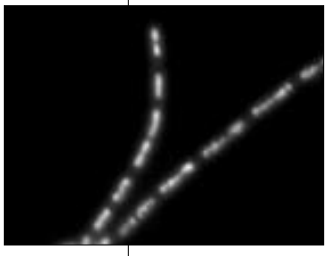
GeneFinder is posed to revolutionize health care. It has potential applications including detection of low levels of viral and bacterial infections or genetic disease in humans, forensic analysis of miniscule crime-scene samples, and detection of early stage levels of malignant transformation in precancerous or cancerous human biopsies.

GeneFinder also holds promise for use in the quality control of food products, including screening for pathogenic bacterial and viral stains such as *E. coli* and Salmonella.

With enhancements, future applications of the GeneFinder technique may include detecting not only a specific sequence within a DNA molecule in a complex sample but also determining the size distribution of DNA fragments after the original molecule has been cut by restriction enzymes.

This data could be used for many applications in analytical genetics, the most important being physical genome mapping — finding the chromosomal positions of genes on the human genome. GeneFinder may also be able to detect minute amounts of a given protein in complex serum

These Bacillus anthracis organisms are an example of the pathogens that can be detected at very low concentrations with GeneFinder.



samples, which could have numerous applications in cancer researching, aging and drug discovery.

Finally, although the current instrument is designed for use in a laboratory setting, it can be converted into a more compact version that can be used in the field. As part of a mobile unit, a compact GeneFinder will be ideal for outdoor applications, such as continuously monitoring the air for biological-warfare agents.

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NTVISION — A BREAKTHROUGH CAMERA TECHNOLOGY

As children, many of us loved pondering those puzzles that had us compare two seemingly identical pictures to find the differences. A new Los Alamos technology — NTvision — takes that idea to a higher level.

Instead of a human looking at two images to find the differences, NTvision's surveillance camera system both records and analyzes images to detect changes in the number, characteristics or position of objects in a scene.

By constantly analyzing the images it records, NTvision creates a visual key pinpointing every changed object, formats the information in hypertext markup language, and makes it available to authorized users through an intranet or Internet connection only seconds after the event occurs.

NTvision can be programmed to ignore inconsequential changes in a scene such as shifting light and shadow and discard the images of events that produce no lasting effect such as a passing car or person. It can alert the user of changes by cell phone, pager or e-mail. NTvision also can encrypt image data or restrict access to particular users, not just particular computers.

Named for the Microsoft Windows NT 4.0 operating system on which it is based, NTvision is a combination of imaging software from Los Alamos and a ruggedized image server built by National Instruments Corp.

Although other surveillance camera systems are in wide use, NTvision is superior in several ways. It's intelligent; it can make decisions about

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NTvision records and analyzes an event in real time and pinpoints any changes for the user. It does this by comparing a pre-event image (top) with a post-event image (middle) and creating an object key (bottom) that shows only the items that have been added, removed or altered.

what it sees. It's adaptable; additional features can be added as they are developed, much like a computer user can upgrade software. It's timely; events are viewed in real-time and data is available within seconds. It's efficient; one person can monitor a large number of scenes. And it's easy to use.

The speed of NTvision permits it to record a variety of high-speed, random events such as lightning.

NTvision was originally developed for safeguarding nuclear materials. For this purpose, the system is being tested in mockup vaults at Los Alamos and at the European Safeguards Directorate (Euratom) in Luxembourg.

However, the use of NTvision doesn't have to remain exclusively with nuclear safeguards. It is an equally useful surveillance technology for any site that has a valuable or sensitive inventory requiring a high degree of physical security, such as at medical and pharmaceutical laboratories, office buildings after hours, construction sites, and warehouses and factories.

Future applications may include early detection of mechanical or physical abnormalities in large industrial rotating machinery replacing conventional means such as vibration analysis, animal behavior studies, microscopic studies, lightning studies, automated forest fire watch system and residential security.

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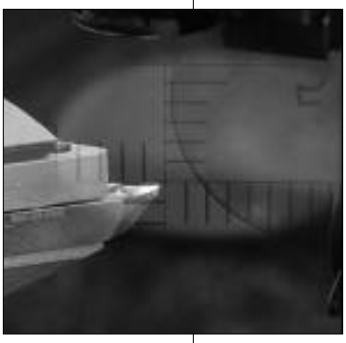
OPTICAL TOOL LOCATOR

It should be possible with state-of-the-art lathes to make parts with a precision that is limited only by the smallest motion increment that the machinist can move the lathe's cutting tool. That increment is on the order of 10 millionths of an inch, about 1/400th the thickness of a dollar bill or about half of a wavelength of visible light.

However, it is difficult to take advantage of this precision that at great expense is built into the lathe because there are many other factors that must be controlled to a comparable level of precision to make super-precision parts.

For example, to make parts with precision limited by the smallest machine motion increment, the radius of the cutting tool tip and the



The Optical Tool Locator provides magnified views of a tool's cutting edge and the OTL cross-hair alignment system on a video monitor. A machinist adjusts the tool until it is aligned to the cross hairs, thereby setting the tool to within 10 millionths of an inch of the lathe's cutting path.

method to put the tool's cutting edge on the correct tool path must all be accurate and known to within ±10 millionths of an inch. It is difficult to achieve that precision for these necessary setup procedures.

Commonly used systems to set the tool on the correct tool path only set tools in two dimensions, they do not measure tool radius and they are not that accurate. These touch-probe systems can only be trusted to position tools on the correct tool cutting path to within about ±500 millionths of an inch. Consequently, the current contact tool setting systems are simply not accurate enough for some applications.

A Los Alamos-developed noncontact tool setting system is being developed to improve the tool setting accuracy for making precision parts. This system, called the Optical Tool Locator or OTL, is an easy-to-use, noncontact system with a three-in-one capability. It allows tools to be set, measured and inspected, all at the machine.

The OTL is at least 10 times more accurate than the best contact tool setting system. It locates the cutting edge of a tool in three dimensions within ±10 millionths of an inch and measures the radius of the round tool tip to within ±50 millionths of an inch. With this new level of precision, machinists avoid costly, time-consuming and frustrating rework on parts that do not pass a final inspection.

Operating the Optical Tool Locator is simple. It provides magnified views of a tool's cutting edge and the OTL's cross-hair alignment system on a video monitor. A machinist adjusts the tool until it is aligned, i.e. until it touches the cross hair. The magnified views of the tool also allow the machinist to inspect a tool for wear, dirt and damage, and to accurately measure the tool radius.

The current version of the system depends on the operator to set the tool and measure the tool radius, but researchers are working on an implementation that will automatically and even remotely perform these operations. Although the OTL was designed for defense applications, it could widely be used in the machine tool industry, especially the high-precision end, which manufactures delicate parts for the automotive, aerospace, telecommunications, electronics, medical, and oil and gas industries.

The OTL is a noncontact visual system that can be set up inside a glovebox containing a lathe. This would allow hazardous or high-explosive materials to be machined more safely because tool setting, tool

measurements and tool inspection are controlled and viewed on a monitor at a safe, remote location.

Researchers have concentrated on using the OTL on lathes, but believe it could also be used on other types of precision machines, such as milling machines. Features could be added to the OTL to set tools even more precisely for machining optical components or for making tiny target parts for laser fusion experiments.

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RADNET — A PROTOCOL FOR COMMUNICATING WITH REMOTE DETECTORS

Various types of radiation detectors are used to measure radiation levels in the workplace. Not too long ago, technicians made their rounds in nuclear facilities, clipboard in hand, to record radiation levels and ensure that detectors were working properly. Today, obtaining such information over computer networks considerably improves their ability to respond quickly to alarms or instrument malfunctions.

Over the last decade, radiation-instrument manufacturers have developed ways of networking their equipment to make remote monitoring possible. Without a standard protocol to draw on, however, they developed proprietary protocols, usable only with their instruments. Moreover, these protocols were designed to run on dedicated networks, which can cost millions of dollars.

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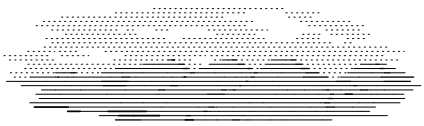
Researcher Brian Rees steps into a personnel contamination monitor to demonstrate RadNet, which can link hundreds, even thousands, of differently manufactured instruments to networked computers.

Los Alamos and Eberline Instruments of Santa Fe, N.M., have developed the RadNet protocol to allow for real-time, remote monitoring, control and calibration of radiation detectors, pollution detectors and other sensors.

RadNet is the first protocol that allows thousands of differently manufactured instruments to communicate data over a standard local network. It can link hundreds — even thousands — of instruments to networked computers, allowing two-way communication between instruments and computers.

For the past year, the protocol has been adopted as the nuclear industry standard for three groups of radiation detectors —



contamination, area and air monitors — and for generic sensors that measure temperature, volume, pressure, flow, vacuum, wind speed and wind direction. RadNet specifies the format in which data from different instruments should be transmitted; assigns numerical designations for the type, location and operational status of each instrument; and establishes the rules for sending data and commands.

Once the data from an instrument have been coded in RadNet format, they are transmitted through local networks in a User Datagram Protocol packet, a standard protocol.

When a UDP packet is broadcast over a local network, any computer or instrument on the network can listen and read the data, just as anyone with a radio can listen to a radio broadcast. Because these broadcasts transfer data efficiently, RadNet can be run on local networks shared with other users.

Many existing instruments can be reprogrammed to broadcast their readings in RadNet's format, and, alternatively, any instrument can be plugged into a commercially available conversion box that reorganizes its output in RadNet format and broadcasts the message in a packet over a local network. Other facilities that can benefit from RadNet include hospitals, accelerators and hazardous-waste facilities.

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RAFEL — A REGENERATIVE-AMPLIFIER FREE-ELECTRON LASER

RAFEL employs a unique optical feedback scheme to produce infrared laser light at the highest peak power achieved in a compact free-electron laser. The result is a rugged source of coherent light — light with narrow ranges of wavelengths and phases — with a peak laser-beam power at least 100 megawatts, 10 times higher than that of the nearest FEL competitor.

The high power levels produced by the RAFEL can be used to cut, drill or weld either single-component or composite materials, to perform laser surgery with minimal collateral tissue damage, to produce pure starting materials from which isotopes can be made for treating cancer, for medical imaging or for making high-quality semiconductors.

The RAFEL also can be used to provide an understanding of how high-temperature superconductor materials work, to measure greenhouse

gases to monitor the causes and effects of global warming, and to measure temperatures and wind velocities in the upper atmosphere, providing data for computer modeling of Earth's climate.

A free-electron laser accelerates a beam of electrons to speeds close to that of light and passes them through a periodic magnetic field called a "wiggler," which makes the electrons oscillate — or wiggle — and radiate light. When this light is intense enough, its electric field enhances the wiggling and causes the electrons to form microscopic bunches.

As each microbunch passes through the wiggler, it emits coherent laser radiation that further compresses the micro-bunches, intensifying the emitted light, until the electrons cannot be bunched any more tightly. At this point, the FEL has reached saturation and attained the highest peak power.

In a conventional FEL the light interacting with the electrons is intensified by reflecting it between two mirrors placed at the ends of the wiggler to form a resonator. The light beam in a resonator can reach power densities high enough to damage the surface of a mirror, which limits the peak power that can be obtained.

The primary challenge in making a compact, high-average-power FEL is to generate high peak power within a short wiggler without damaging the system's mirrors. The RAFEL meets this challenge by using a high-gain wiggler and a unique optical feedback scheme in which about 90 percent of the light generated leaves as useful laser radiation.

As with other FELs, the RAFEL can be tuned continuously to emit radiation over a large range of wavelengths, but the RAFEL is also compact, rugged and reliable enough to be used in applications currently barred to other FELs because of their size, delicate optics, expense and poor reliability.

If an X-ray RAFEL can be perfected, it could be used to produce three-dimensional, holographic images of proteins and other molecules and to improve ways to determine the structures of these molecules using coherent X-ray diffraction. These improvements could allow the RAFEL to contribute significantly to the basic understanding of the dynamics of biological molecules.

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The RAFEL is the first free-electron laser to incorporate optical feedback, a technique allowing compact, high-power FELs to be built that emit coherent light in the infrared spectrum. The optical feedback path is created by a system of mirrors contained within the long pipe above the wiggler (the long, rectangular box), and the boxlike optical connections at each end of the pipe.

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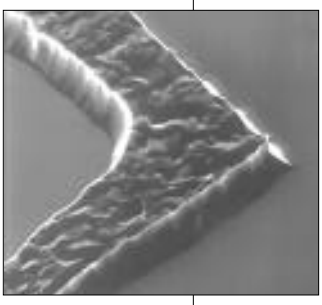
SCORR — THE PATH TO LEAST PHOTORESISTANCE

From personal computers to cellular phones and from autos to household appliances, the most common consumer products that we depend on could not function without microchips. And yet, ironically, the larger the semiconductor manufacturing industry grows for the benefit of us all, the greater its toll on the environment and on worker safety and health.



↑ A highly magnified image of one of the aluminum metal lines towering above the flat silicon substrate after treatment with SCORR.

Los Alamos and Hewlett-Packard Co. have developed a new process — SCORR — that uses a nonflammable, nontoxic, biodegradable, virtually inexhaustible solvent based on carbon dioxide. Using the SCORR process eliminates the need for costly, environmentally hazardous organic solvents, thus eliminating worker exposures, hazardous waste accumulations and harmful emissions in the manufacture of integrated circuits.

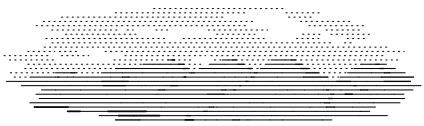
The manufacture of these circuits, commonly known as chips, relies heavily on photolithography to define the shape and pattern of individual chip components. In photolithography, a polymer photoresist film is applied to the surface of a semiconductor wafer and is cured by heating.

Exposure to high-energy light on specific regions of the photoresist makes it soluble and uncovers the wafer surface where the chip structures will be developed. The wafer is then baked at high temperatures to harden the remaining photoresist.

After fabrication into chip components, the hardened resist must be removed, which requires the use of aggressive solvents, which are often toxic and hazardous. Carbon dioxide, by contrast, has proved to be an effective, environmentally friendly replacement for the hazardous solvents required by numerous manufacturing processes.

By replacing water with CO^2 in the final rinse step, SCORR significantly reduces the amount of water used in the chip manufacturing process and thus lowers the amount of time, energy and money that must be dedicated to acquiring water use licenses and discharge permits as well as to treating the water.

SCORR also eliminates the need for multiple cleaning techniques. It is the only nonhazardous, nontoxic photoresist-removal system fully compatible with existing integrated-circuit-manufacturing processes. It effectively cleans most organic contaminants (oils, greases, lubricants



and residual solvents) from inorganic substrates (silicon, glass, metals and ceramics) without altering the substrate surfaces.

SCORR is also applicable to other manufacturing processes requiring photoresist masking, such as the production of optical waveguides and flat-panel displays. SCORR can help the semiconductor industry comply with federal and state environmental regulations by significantly reducing hazardous emissions while producing only nonregulated, nonpolluting wastes.

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SEALED CONTAINER SAMPLING TOOLS

Sampling the contents of a closed container is a problem when toxic or flammable chemicals are inside. Most sampling techniques require opening the container or its bung (access port) and using a chemical-laden — often dripping — tube or scoop to transfer the sample to a storage bottle.

The few sophisticated devices that exist to breach a sealed container are expensive, not fully portable, difficult to use in confined spaces, and may release volatile container contents to the environment.

To answer this problem, Los Alamos has developed three sealed-container sampling tools that allow the user to drill into a closed container, extract a sample (liquid, gas or free-flowing powder) and permanently reseal the point of entry without ever exposing the container's contents. Almost any kind of container can be sampled (even with thick walls) from the top, bottom or sides.

One of the models drills, samples, and reseals in a single step and can be reused on different containers. The other two models stay in place in the container wall, allowing multiple samples to be taken from the same container without redrilling.

All three models work with a common, battery-powered hand drill. The tools are fast and easy to use — it takes about 15 seconds for drilling and sampling from conventional 55-gallon storage drums.

Developed to fill a specific need for the military, the tools will play an important role in checking the proliferation of weapons of mass destruction.

One model of the sealed-container sampling tool breaches a container, extracts a sample and reseals the entry hole in a singled step.

The tools also have many other potential applications. Personnel at storage and industrial sites can use the tools to quickly and safely verify contents, perform quality-control checks on chemicals before they are used, transfer liquids in or out of a container, monitor the condition of materials in storage, obtain archive samples of materials before they are incinerated, and check the unknown contents of abandoned or poorly marked containers.

Emergency-response, law-enforcement and governmental personnel can use the sampling tools to discover drugs during customs inspections, or during raids on suspected illegal drug-production facilities.

The tools may also be useful in environmental enforcement raids and to investigate the contents of sealed containers found at fires or other disaster scenes.

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WAND — WASTE ASSAY FOR NONRADIOACTIVE DISPOSAL

Disposing of low-level radioactive wastes is an expensive problem for nuclear facilities worldwide. Government research laboratories and commercial power companies alike produce such wastes, and space in landfills is both costly and scarce. To compound the problem, some of this waste is clean enough to be disposed of in public landfills; its contamination level is below the threshold set for posing a hazard to humans.

But to segregate such “clean” waste has required swiping all waste surfaces and measuring the contamination in each swipe — a time-consuming and expensive sorting process.

For the first time, WAND technology provides a hands-off, automated waste inspection system with the required sensitivity, reliability and

throughput volume to screen the clean low-density waste, allowing it to be recycled or deposited in local sanitary landfills.

The WAND system combines the Phoswich scintillator, a detector that has been in use for more than 30 years, with a newly designed multiplexer unit and innovative computer analysis techniques. The six shielded detectors scan a 12-inch-wide layer of low-density waste (stacks of paper, rubber gloves, shredded material) as it passes on a conveyor belt.

The multiplexer processes and routes the signal from each crystal in each detector in real time. The combined signals are sorted for pulse-shape analysis and fed into the computer, which further analyzes the signals for pulse height, while controlling the waste-scanner system. When the instrument detects contamination, the waste is automatically re-examined. If the presence of contamination is verified, the contaminated material is removed from the conveyor belt.

The belt itself can be swiped or assayed with the detectors to determine whether it in turn has been contaminated. If it has, then it will need to be decontaminated before examining additional waste.

Because it detects a wide range of alpha, beta and gamma emitters, WAND can be used for waste inspection and radiation surveys at a variety of nuclear facilities, including nuclear research labs and nuclear power reactors.

In the private sector, WAND can be used to segregate waste from nuclear-medicine operations and radioisotope-production facilities. Worldwide, about 400 million nuclear medicine procedures are performed annually, creating a substantial waste stream. With modification, WAND technology may eventually be used to measure waste in containers, for remote detection and for personnel monitoring.

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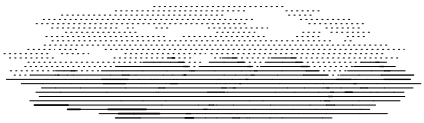
Researcher Steve Myers places mock waste on the conveyor belt to demonstrate the WAND system.



DATELINE: LOS ALAMOS

BRIEFLY . . .

USER FACILITIES AVAILABLE. From Fiscal Year 1996 through Fiscal Year 1998 to date, the Laboratory has executed 70 user facility agreements. As of April of this year, Los Alamos has 64 staffed user facilities with equipment and laboratories available to researchers from outside the Laboratory. User facilities are powerful and efficient vehicles for gaining access to the scientific and technical resources found in the Department of Energy's national laboratories. Users include scientists and engineers from universities, other governmental agencies and the business community. Some facilities are "mega" facilities and comprise several smaller facilities with a common purpose, for example, evaluating superconducting materials. Others are specifically focused on a particular process or technology. The Civilian and Industrial Technology Program Office can help users gain access to these experimental facilities at the Laboratory for the purposes of fabrication, calibration, testing and evaluation of products and processes. The partner directs the activity that occurs within the framework of the agreement. The partner must pay for the cost of using the facility, but a waiver of DOE added factor cost and depreciation cost is readily available for nonprofits and small and minority- or woman-owned businesses. CONTACT: KIM SHERWOOD (CIT-PO), 665-1305, E-MAIL: ksherwood@lanl.gov

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