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DATELINE LOS ALAMOS

U.S. DEPARTMENT OF ENERGY
UNIVERSITY OF CALIFORNIA

MINE BLAST OR NUCLEAR EXPLOSION?

U.S. SCIENTISTS CONDUCT EXPERIMENTS AT FORMER SOVIET TEST SITE IN SUPPORT OF TEST BAN TREATY

The U.S. Senate has not yet ratified the Comprehensive Test Ban Treaty, which prohibits all nuclear testing. But for the past two years, Los Alamos researchers have been participating in a unique program in support of the CTBT by conducting tests designed to more accurately locate underground events and distinguish underground nuclear explosions from other types of man-made and natural phenomena.

The tests are taking place at a former Soviet underground nuclear test site in Kazakhstan. They are a multiagency collaborative effort among the Defense Special Weapons Agency (now part of the Defense Threat Reduction Agency), Department of Defense, Department of Energy and the National Nuclear Center of the Republic of Kazakhstan under DoD's Cooperative Threat Reduction Program.

DATELINE: LOS ALAMOS

"DSWA was tasked with helping the Republic of Kazakhstan close the testing infrastructure at one of the former Soviet weapons test sites near Semipalitinsk, located in the southern part of Siberia in Kazakhstan," said Los Alamos researcher Craig Pearson, leader of the project. "We proposed to the DOE's Nonproliferation and National Security Research and Development Office in charge of CTBT research and development that we concurrently conduct a series of experiments to better understand explosion phenomena."

Large mine blasts can produce ground motions similar to those of underground nuclear tests, therefore scientists must be able to differentiate between the two. In addition, seismic waves travel through mountain ranges, faults, basins and other natural environments, which modify the signals and make it more difficult to characterize them and locate their origins, Pearson explained.

"This is a very complicated situation. We have to be able to separate nuclear explosions from mining explosions and explosion signals from natural signals such as earthquakes," Pearson said.

To study the problem, Laboratory researchers have conducted two separate series of experiments, the first series involving depth-of-burial detonations using vertical boreholes at a site called Balapan at the Semipalitinsk test site. The site has 108 such boreholes that originally

DATELINE LOS ALAMOS

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DATELINE: LOS ALAMOS

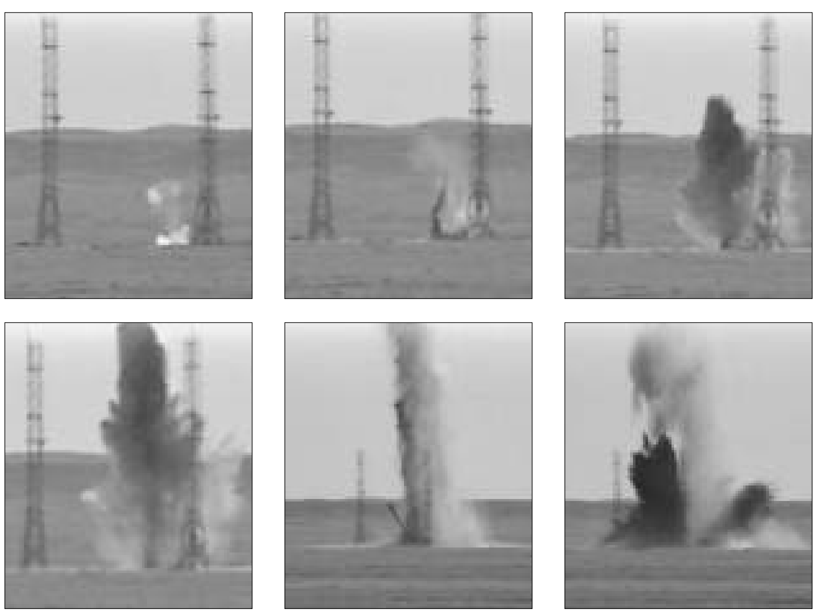
were drilled for placing nuclear weapons underground for testing, but some were never used. Four boreholes were used for the experiments.

Laboratory researchers filled the boreholes with 25 tons of high explosives at depths of 50, 300 and 550 meters. The theory was that at greater depths, explosions of equal strength would produce smaller seismic impulses. The 50-meter test was conducted in shale, with the other tests conducted in granite. Three tests were conducted in 1997, with an additional 50-meter test in granite conducted last year. The tests substantiated the researchers' theory.

Los Alamos researchers recorded signals generated from the explosions using eight portable seismic stations situated at ranges up to 20 kilometers from the shots. This helped the researchers better understand what the explosions look like up close from a physics standpoint. Scientists from Lawrence Livermore National Laboratory recorded signals at ranges of 100 to 1,100 kilometers from the test site.

The second series of experiments began last year. These involved conducting large contained chemical explosions inside tunnels located at Degelen Mountain, a tunnel complex at the Semipalitinsk test site. The first explosion was conducted at Tunnel 214 which, like the boreholes, was intended for underground nuclear testing but was never used.

For this experiment, DSWA and Kazakhstan researchers placed 100 tons of high explosives at the end of the approximately 1.2 kilometer-long



← A series of frames from a film of the September 1997 550-meter-deep blast at the Semipalitinsk test site. The explosion was followed by a series of gushes of water and ejection of the borehole casing (seen falling to the left at the bottom of the water geyser in frame 5). The tops of the nearby towers are 25 meters high.

tunnel and sealed the explosives in place with concrete plugs. For the test, DSWA placed shock gauges within 5 meters of the explosives. The gauges measure the acceleration of the rock mass as the explosion displaces it; by knowing the speed at which it was displaced, researchers are able to deduce the amount of stress imposed on the rock mass. The first test occurred in August; Pearson said he hopes similar tests will occur sometime this year and in 2000.

The depth-of-burial and tunnel tests will allow DSWA and Kazakhstan researchers to account for the geology along seismic wave paths from known source points to regional seismic stations.

Using what are called ground truth calibration events, in which the exact location, time and depth of the event are known, scientists can use the information to improve velocity and structure models for specific regions of the world. Then when a seismic event takes place in that region and the exact time and location aren't known, the models can be used to deduce these parameters with greater accuracy.

The calibration information will aid in characterizing suspicious seismic disturbances once the International Monitoring System is operational, and any data obtained from IMS stations will be made available to all the countries that have signed the CTBT.

There are 50 primary and 150 auxiliary seismic stations, which are one component of the IMS, a global system of sensors defined within the CTBT that will be used to verify that all signatory countries are abiding by the terms of the treaty. Of the 10 regional stations located in Kazakhstan, two are primary and three are auxiliary seismic stations in the IMS. There are thousands of non-IMS seismic stations worldwide as well.

To help determine whether an underground blast is a nuclear blast or some other type of explosion, researchers from Los Alamos and Lawrence Livermore national laboratories have developed — and continue to improve on — special computer algorithms that can help distinguish between different types of explosions. They also can look at historical data of nuclear shots as a guide. Researchers note, however, that determining the location of an unknown signal — particularly its depth — goes a long way toward helping researchers determine the nature of a particular blast.

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DATELINE: LOS ALAMOS

CHEMIN: A PATH TO UNDERSTANDING OUR SOLAR SYSTEM

SODA-CAN SIZED INSTRUMENT DETERMINES CHEMISTRY AND MINERALOGY OF SAMPLES

It's a bit more than simple coincidence that David Bish and his team chose the name CHEMIN for their prototype analytical instrument. In French, the word "chemin" means path and by all indications the CHEMIN instrument may very well be the path to a greater understanding of our solar system.

The miniaturized X-ray diffraction/X-ray fluorescence instrument is named CHEMIN to reflect its ability to determine both the CHEmistry and MINeralogy of a sample. It was designed to remotely analyze both the elemental composition and constituent mineralogy of fine-grained soils, rock and even ice samples. Given the opportunity, the CHEMIN instrument will find its way to other planets and beyond.

↑ A comparison of the tiny X-ray tube that will be used in the next-generation CHEMIN instrument and an X-ray tube from a commercial diffractometer.

There are roughly 100 naturally occurring elements in our universe. These elements can combine to form more than 3,800 known minerals.

The genesis and histories of the planets, asteroids and comets are reflected in their constituent minerals. Origins of intense pressure and extreme temperatures are intertwined with histories of sedimentation, metamorphism, collisions and weathering. All this is part of the complex structure of our solar system. CHEMIN is designed to help unravel that complex structure.

According to David Vaniman, a geologist at the Laboratory, "Scientists have been sending instruments to planets and other bodies in our solar system for many years, but none of that instrumentation could do both chemical and mineralogical analysis. Using the CHEMIN instrument, not only can we now determine what elements are present in a mineral, rock or ice sample, but we can also analyze the sample's crystalline structure or mineralogy. That's helpful because knowing the sample's crystalline structure can tell us how the sample's elements first came together and if they have been changed. It gives the sample's life history, if you will."

CHEMIN provides chemical information similar to that provided during the recent Martian rover mission, but it also provides information on the types of minerals present in a powder sample using a technique known as X-ray diffraction.

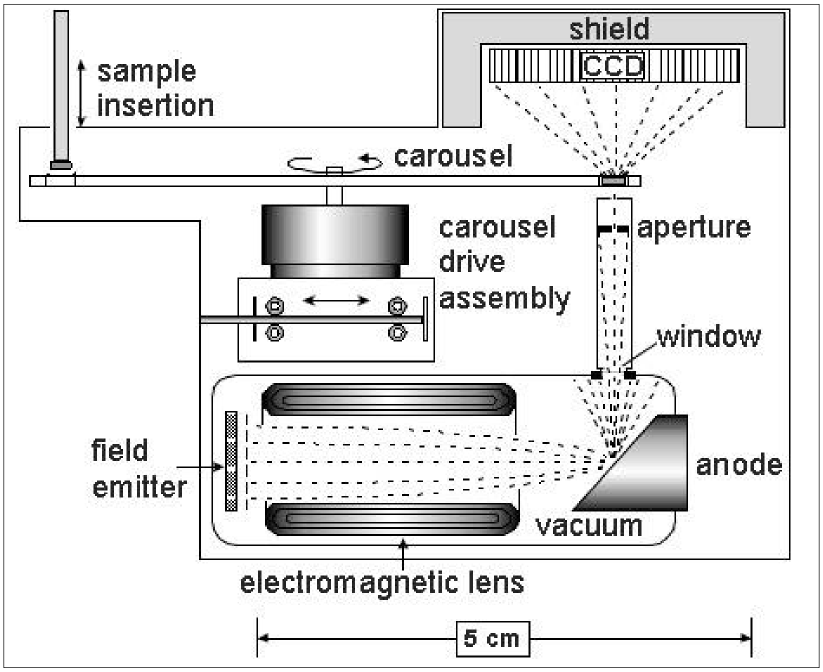
Each mineral has a characteristic X-ray diffraction pattern, much like a fingerprint. CHEMIN uses a single CCD (a charge-coupled device similar to those used in modern video cameras) as a detector to determine both chemistry and mineralogy at the same time.

Geologists use information on the particular types of minerals present to determine how rocks formed and what processes have shaped planetary surfaces. Bish explains why having both chemical and mineralogical information is so important. "If a sample containing only silicon and oxygen were chemically analyzed, we might know, for example, that the material's chemical composition is SiO_2.

"However, a number of different minerals have this same composition. One of them is quartz, which is quite common on Earth's surface; another is opal, which is comparatively rare. With chemical information alone it would be almost impossible to determine which form of SiO_2 the sample represents," explained Bish.

A view of the Martian surface taken on NASA's recent mission to the red planet. On such a mission, CHEMIN not only could provide chemical analysis, it also could analyze the types of minerals present in the Martian soil,

DATELINE: LOS ALAMOS



←

This schematic shows the three components that are critical to the operation of CHEMIN: the X-ray tube source, a sample manipulation system and a CCD detector that discriminates both energy and position of X-rays.

Geologist Steve Chipera echoes the thought. “In some cases this (the CHEMIN data) will be the best information you can collect because any planetary, asteroidal or cometary body with mineral constituents that contain water (including ices), sulfur or halogens requires X-ray diffraction in addition to chemical analysis for adequate understanding of origin and evolution.”

What makes the CHEMIN instrument so unique, however, is not just its ability to analyze the elemental composition and mineralogy of a particular sample, but rather the fact that it does so in a very small size. Necessitated by the fact that it is designed to fit into a spacecraft payload or onto some kind of planetary rover, a flight-ready CHEMIN would weigh less than a kilogram, be about the size of a soda can and consume only 2 watts of power.

Overall, flight-instrument data-collection times of 1-2 hours are expected, with sample collection systems that could hold more than 25 samples. In other words, this small instrument could gather a great deal of important data in a relatively short period.

Near the beginning of the project there had been some concern about the quality of the data collected by a CHEMIN device, but extensive testing has shown that the instrument is capable of gathering data on a quality level near that of laboratory diffractometers 50 times CHEMIN's size. This ability to gather high-quality data with such a compact and lightweight instrument is finding many uses.

In fact, not only can it be used to answer questions about extraterrestrial mineralogy, but it could be used here on Earth in field applications requiring a small, low-power instrument, such as geological sampling at remote or dangerous sites or where soil has been contaminated.

CHEMIN is the product of years of collaborative work by scientists at Los Alamos, NASA's Ames Research Center in Mountain View, Calif., and the Jet Propulsion Laboratory in Pasadena, Calif.

Vaniman, Bish and Chipera recently received an award for a poster on the CHEMIN technology presented during an international conference in Colorado Springs, Colo. (See *Dateline: Los Alamos*, January 1999.)

More information on CHEMIN is available at the following address on the World Wide Web: http://www-geo.lanl.gov/chemin/chemin.html.

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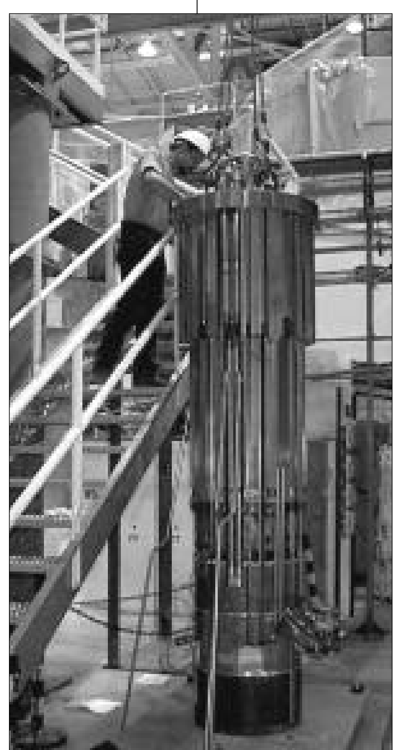
DATELINE: LOS ALAMOS

WORLD RECORD SHATTERED FOR PROTON BEAM OUTPUT

TECHNOLOGICAL BREAKTHROUGH OPENS NEW WINDOWS OF RESEARCH OPPORTUNITIES

Los Alamos recently shattered the world record for peak proton beam output by delivering pulses of 31 trillion 800-megavolt protons to a target for neutron production. Twenty pulses per second were delivered, for an average current of 100 microamperes.

The increased beam output capability at the Los Alamos Neutron Science Center opens new windows of research opportunities in the fields of physics, chemistry, biology, geology, engineering and material sciences.



➔ Dennis R. Martinez of LANSCE works on the target/moderator/reflector system insert. A new approach to the construction, installation and replacement of the TMRS has reduced the replacement time from 10 months to approximately five weeks. The TMRS is now a single module that can be installed or removed in a single operation.

The technological breakthrough is the result of major new additions and modifications to the center's proton storage ring, target and moderator assembly, and many other components made over more than four years as part of the Department of Defense-funded LANSCE Reliability Improvement Project, or LRIP.

The achievement marks the completion of a long-standing promise to provide 100-microampere average beam currents to the target at the Manuel Lujan Jr. Neutron Scattering Center.

It also demonstrates success for the many upgrade projects that were implemented during the past year. LANSCE is now ready to demonstrate the scientific potential that it holds for neutron science and to make productive contributions to both defense and civilian research.

Neutrons are uncharged elementary particles slightly more massive than protons and present in all known atomic nuclei except the hydrogen nucleus. To free neutrons, the proton storage ring ejects high-intensity proton beam pulses toward a heavy-metal object such as tungsten. As the pulses strike the target, they drive neutrons from the nuclei of the

DATELINE: LOS ALAMOS

target atoms — called spallation neutrons — at the rate of about 20 neutrons per proton. The more intense the proton beam, the more neutrons released. These neutrons then are used in neutron scattering and nuclear physics experiments.

Neutron scattering is a primary tool for studying the structure of materials. By increasing the number of neutrons, studies can be made more sensitive to small changes in structure that can significantly affect material properties, such as strength or electrical conductivity.

Increasing beam intensity allows scientists to do more and different kinds of experiments. For instance, the center's new beam output capability means researchers now can perform such things as measuring the magnetism of thin films and analyzing the structural transformation of steel in real-time experiments. These experiments were not possible before because the beam's earlier output could not produce enough neutrons.

Until recently, the top proton beam output for the facility was 70 microamperes; so peak intensity has been increased by 43 percent. The new beam capability should please researchers in the materials science community who had been dissatisfied with the reliability of accelerator-driven neutron spallation sources. Their availability and predictability, compared to neutron scattering done at nuclear reactors, were not as good.

LANSCE also hopes to attract more biologists, chemists and others with the increased beam output. LANSCE already attracts about 400 researchers from industry, universities and other federal laboratories annually.

Los Alamos currently is working on ways to increase beam output even further, to 200 microamperes, by 2001. Some technical issues still need to be resolved to achieve this goal.

Additional information about the Lujan center and the LRIP is available at http://lansce.lanl.gov/facilities/upgrades.htm#lrip.

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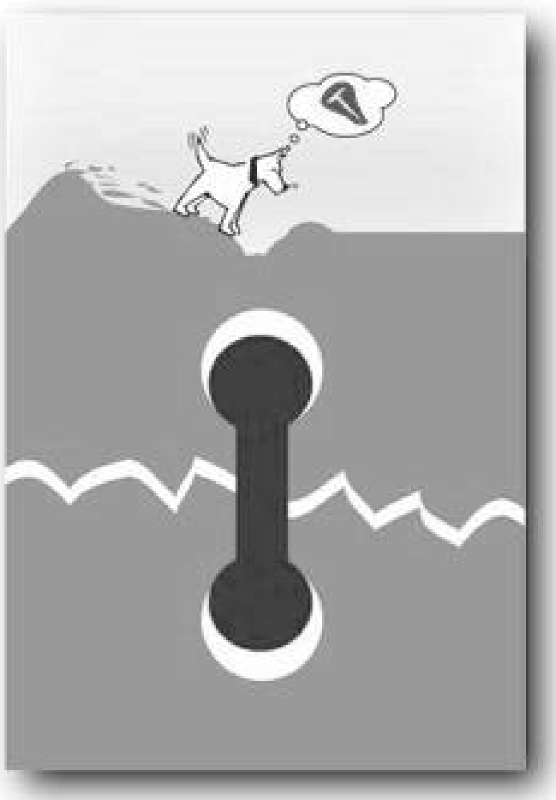
DATELINE: LOS ALAMOS

BONE-SHAPED FIBERS INCREASE STRENGTH AND TOUGHNESS OF COMPOSITE MATERIALS

RESEARCH COULD IMPACT AEROSPACE, AUTOMOTIVE, CONSTRUCTION INDUSTRIES

Researchers have shown that enlarging the ends of short fibers used in composite materials simultaneously increases the overall toughness and strength of the material.



Composite materials are used widely in the automotive, aerospace, civil engineering and other industries requiring lightweight but structurally sturdy parts.

The Los Alamos finding impacts a problem material scientists have been trying to solve for decades: how to get effective load transfer between fibers and the surrounding matrix without making the composite more brittle, as happens when the fibers are tightly bonded to the matrix.

The special fibers, shaped like a cartoon dog bone, anchor into the matrix at each end because of their shape but bond only weakly with the matrix along their length. This allows the fibers to help carry the load.

The experimenters designed the shape and size of the enlarged fiber ends so they don't experience the stresses that usually snap fibers and limit a short-fiber composite's performance.

"People have been trying to solve this problem for the last couple of decades," said Los Alamos' Yuntian Zhu, who leads the research effort.

DATELINE: LOS ALAMOS

"We've shown that this fairly simple mechanical approach can provide a solution."

Zhu and his colleagues in Los Alamos' Material Sciences and Technology Division developed the bone-shaped fibers from commercially available polyethylene stock and mixed them in a polyester matrix. They made another composite from the same materials, but without enlarging the ends of the fibers.

Standard, straight fibers can pull free of the matrix material if the fibers bond weakly with the surrounding matrix. If, on the other hand, the fibers bond strongly with the matrix, they can snap under the high stresses generated by a crack in the matrix.

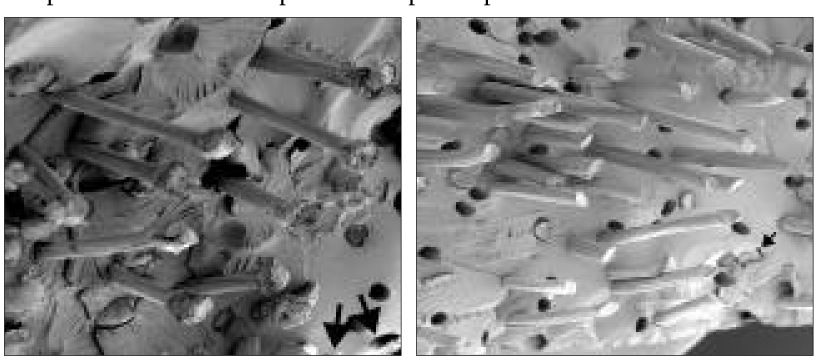
The bone-shaped fibers connect mechanically with the matrix predominantly at their ends. They have a weak interface, and so don't experience extreme stress, but remain anchored at their ends and so still help carry the load felt by the composite.

The composites developed for the experiment were subjected to forces to the point of failure and examined microscopically.

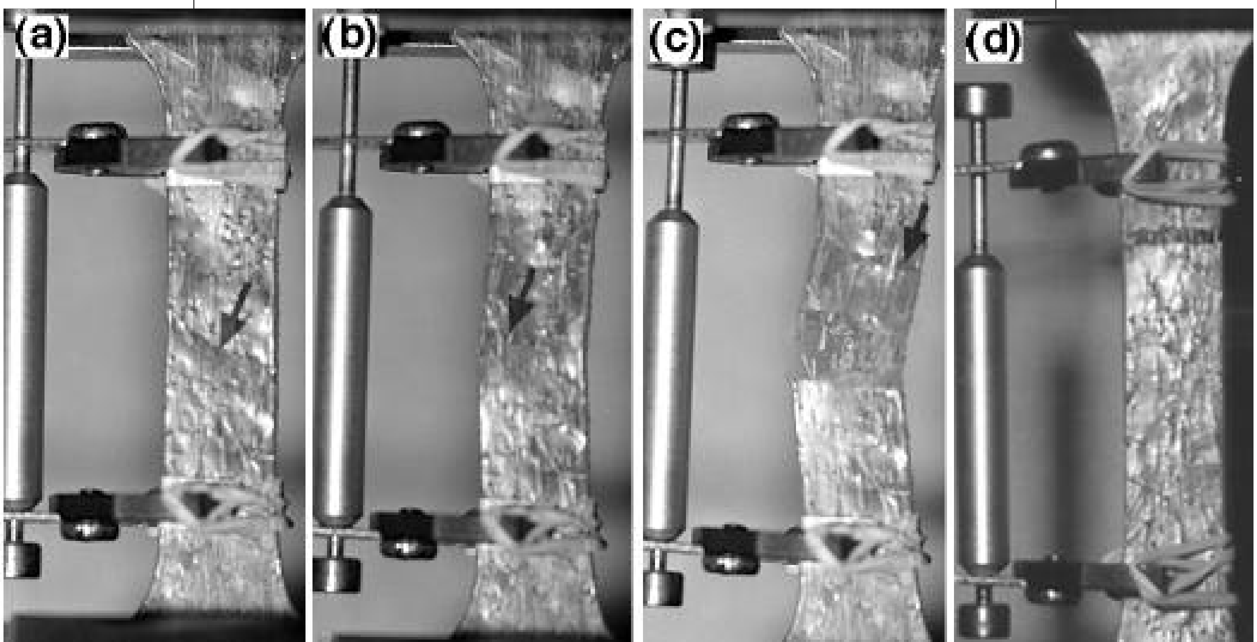
The composite with the bone-shaped fibers significantly outperformed the straight-fiber composite for both toughness and strength (toughness measures the amount of energy required to damage the composite; strength measures the composite's resistance to pressure, or force spread over a given area).

The bone-shaped fiber composite was much more resistant to the propagation of cracks; the fibers would actually bridge the crack, refusing to let go. Inspection showed that even though a crack in the matrix had snaked through the sample, the sample remained intact overall.

The researchers are conducting additional experiments to adjust the shape of the fibers for optimal composite performance. One member of



→ Highly magnified images of fracture surfaces of a bone-shaped short fiber composite (left) and a conventional short straight fiber composite.



the team, Irene Beyerlein, is using computer modeling to better understand the experimental results and predict the outcome when the researchers use different materials or change the fiber design.

Composite makers have successfully used long, continuous fibers to increase strength and toughness, but these materials require special, more expensive manufacturing techniques. Short-fiber composites have been long preferred because they are compatible with standard manufacturing processes.

The Los Alamos team expects its bone-shaped fiber approach also could be used in reinforced concrete structures, such as roads, bridges and buildings.

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↑ Tensile tests show better crack bridging by bone-shaped short fiber composites (A, B and C). D shows a crack formed in a conventional short straight fiber composite in which the test material has fractured completely across the sample.

DATELINE: LOS ALAMOS

AIRPORT MONITORS MAY THWART NUCLEAR THIEVES

DOE LABORATORIES PROVIDE EXPERTISE FOR RUSSIAN ANTI-SMUGGLING EFFORT

Preventing the spread of uranium and plutonium materials that could be used in a nuclear weapon is a principal component of U.S. nonproliferation policy. The first line of defense is securing the materials at the facilities where they reside. Detection equipment at major travel hubs and border crossings are part of a so-called "second line of defense."

←

A collaborative effort between DOE national laboratories and the Russian customs agency to thwart nuclear smugglers was unveiled last fall. Energy Secretary Bill Richardson, left; Sen. Pete Domenici (R-N.M.), center; and Valeriy Draganov, chairman of the Russian Federation State Customs committee, were on hand to cut the proverbial ribbon on the portal monitors at the Sheremetyevo airport in Moscow.

Incidents in the last few years have heightened concerns about nuclear materials being pirated out of Russia, although to date it does not appear that any significant quantities of material have left the country, U.S. and Russian officials agree.

To thwart would-be nuclear smugglers, the Russian customs agency has installed a set of monitors in a major Moscow airport. Los Alamos was the lead Department of Energy laboratory to work with Russia on this project and provided significant technical assistance to this effort to increase global security.

The Sheremetyevo airport in Moscow, where the monitors are installed, supports flights to other parts of Russia and to other countries, making the airport a potential route for nuclear smugglers. Last September a ribbon-cutting ceremony was held to inaugurate the Second Line of Defense Program. Department of Energy Secretary Bill Richardson, Sen. Pete Domenici (R-N.M.) and Russian Federation State Customs Committee Chairman Valeriy Draganov attended the ceremony.

"We concentrated our efforts on a major choke point for people and luggage," said Sara Scott, who initiated Los Alamos' involvement. The effort is governed by a formal protocol between Russia's customs agency and DOE's Nonproliferation and National Security Office.

Scott and others from Los Alamos assisted the Russian Federation State Customs Commission in identifying a system of portal monitors and video surveillance equipment that can detect nuclear smuggling activity. The nuclear monitoring and video surveillance system installed at the

Sheremetyevo Airport was evaluated during a technical demonstration of the equipment last October.

A Russian company called Aspect built the portal monitors; Los Alamos previously worked with Aspect to test and evaluate the equipment for portal monitoring and other applications. Los Alamos has long been a leader in developing nuclear monitoring equipment for international inspections and other uses.

In addition, the presence of the detection system alone could be a deterrent to would-be smugglers.

"This collaboration started in March, but we've had a concentrated technical effort going only since June," Scott said. "We focused on the airport installation as a first step because we wanted something that would give us an immediate and very visible result," and thereby demonstrate that the collaboration between the DOE and the Russian customs agency is a productive one.

The overall collaborative program between the DOE and the Russian customs agency includes participation from Lawrence Livermore, Pacific Northwest and Oak Ridge national laboratories. Livermore, for example, is overseeing an effort to install nuclear monitors in customs areas of a principal Russian seaport on the Caspian Sea.

Russia plans to purchase 500 vehicle radiation monitors in all to cover various points of entry and egress from the country.

Phil Hemberger, project leader at Los Alamos, and his colleagues are looking at future and more extensive efforts even while they are actively completing the effort in the Sheremetyevo airport.

For example, they want to make sure a process is in place to ensure an effective response in case the portal monitors detect nuclear materials. They also are working with Russia's customs personnel to develop sensible export guidelines, train border guards and customs officials in the guidelines and educate them on any "triggers" to be alert for.

Los Alamos staff members also are looking at a variety of technology improvements to increase the sensitivity of portal monitors and other detection systems. Los Alamos currently receives about $1.5 million in annual funding from the DOE for the second line of defense project.

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DATELINE: LOS ALAMOS

BRIEFLY ...

ROBERT KARL, A LOS ALAMOS RESEARCHER IN ADVANCED CHEMICAL DIAGNOSTICS AND INSTRUMENTATION, RECENTLY RECEIVED A U.S. ARMY DISTINGUISHED SERVICE AWARD for his efforts in developing a laser system for remotely detecting and characterizing clouds of biological agents. Karl has been working since the early 1990s on a light detection and ranging, or LIDAR, system that mounts in a helicopter and provides rapid detection of airborne biological agents at distances up to 18 miles. In all, Los Alamos has built three deployed production units and delivered them to the Army's 310th Chemical Detachment in Fort McClellan, Ala. Called Biological Standoff Detection Systems, the units are maintained in a high state of readiness for deployment anywhere in the world. The units are mounted on skids for easy insertion and removal from Army UH-60 Blackhawk helicopters; they can search about a million acres per hour.

IN THIS ISSUE:

Mine Blast or Nuclear Explosion?
PAGE 1

CHEMIN
PAGE 5

World Record Shattered
PAGE 9

Bone-Shaped Fibers
PAGE 11

Thwarting Nuclear Thieves
PAGE 14

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