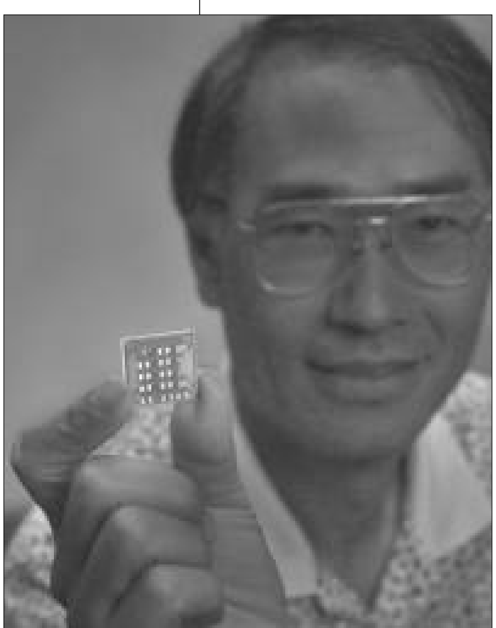
AUGUST ISSUE 1995

LOS ALAMOS NATIONAL LABORATORY
WHERE SCIENCE MAKES A DIFFERENCE

DATELINE LOS ALAMOS

# LOS ALAMOS RESEARCHERS DEVELOP MULTI-CHIP MODULE

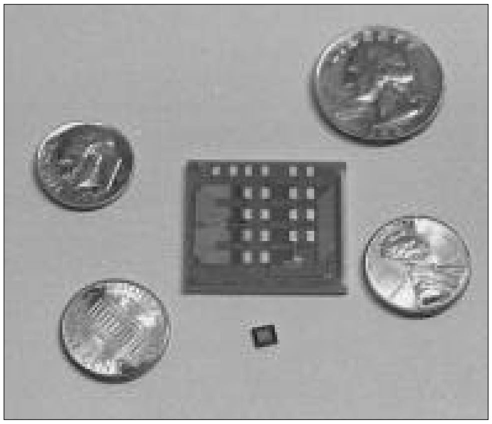
## MICROELECTRONIC MODULE OUTPERFORMS AND OUTLASTS CURRENT SATELLITE CHIPS



Sangkoo Hahn holds the multi-chip module developed at Los Alamos. The chips and circuits have been compacted to allow for more complex functions and less power consumption.

Just as a person can't function without a brain and nervous system, a satellite can't function without micro-circuit chips. A typical satellite may need thousands of these chips to perform its many information-gathering and disseminating jobs. Los Alamos researchers, working with Texas Instruments of Dallas, have developed an advanced electronic module that houses many of these chips in a small package. The module demonstrates better performance, lower power consumption, and higher reliability than what were previously possible.

# DATELINE: LOS ALAMOS



➔

The multi-chip module next to coins shows its diminutive size. The tiny square below the module is one of eight chips that comprise the module.

Satellites are by no means cheap. Even small, relatively inexpensive ones cost millions of dollars to build and launch. The weight of a satellite has direct bearing on its cost — the heavier the satellite, the more expensive it is to launch and operate. So there is a strong incentive to build satellites as light as possible without sacrificing functionality. The key to constructing a small, inexpensive spacecraft is to design it to run on low power, because components that generate, store, and distribute power aboard a satellite take up a large portion of the total weight.

Another important aspect of satellite operation is reliability. Once launched, a malfunctioning satellite is usually too costly and risky to retrieve and repair, so a great deal of work goes into ensuring its reliability in orbit. Toward that end, Los Alamos researchers have developed a multi-chip module in a smaller package that will perform better at higher reliability than other available technologies.

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Satellites are used for many purposes, including communication, weather study, navigation, and military observation. Various scientific research satellites from nearly 30 nations and international organizations are orbiting Earth, the moon, the sun, Venus, and Mars. Currently, hundreds of functioning satellites circle Earth alone.

A satellite gathers and stores information in the form of electronic signals and communicates with ground stations through radio link. Satellites have on-board computers that not only receive, store, and transmit information, but also control the satellite's operation and orbit. This is why electronic chips are vital for satellite operation.

↑ Researcher Max Katko uses a scaled-up model to demonstrate chip layout and module design.

The Los Alamos multi-chip module is composed of several integrated circuit chips. The module is slightly larger than an array of individual chips and performs more powerful functions than a single chip.

The multi-chip module consists of four analog and four digital chips mounted on the same substrate, or material. The analog chips receive signals from silicon strip detectors that generate charge pulses from high-energy particles randomly "hitting" the detectors. An analog chip amplifies the charge pulse signals and decides if a "hit" has occurred. The digital chip stores the "hit" information in temporary memory until an external command requests a readout. Measuring only 1 square inch, the module has 256 analog input lines and 60 digital interface connections.

Together with Texas Instruments, Los Alamos has produced a prototype of the multi-chip module, known as SDC-1. Los Alamos supplied the chips and layout designs, while Texas Instruments worked on the fabrication. Ultimately, High-Density Interconnect, or HDI, multi-chip technology is going to allow for cheaper, faster, and more reliable electronics. The outcome — smaller and smarter satellites.

The multi-chip module developed at Los Alamos achieves at least twice the density of circuit interconnections found in other multi-chip module technologies. Los Alamos has achieved the higher density as more

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Researcher Maureen Cafferty performs a quality control step on a new multi-chip module. Inset: The needle monitors voltages injected into the module.

interconnections between circuits are compacted into a smaller space. Another technology, surface mount, allows the module to be connected to an external printed circuit board to interface with the rest of the electronics. Conventional printed circuit boards would need up to 20 times more board area than that needed by the HDI multi-chip module.

The HDI multi-chip module is not limited to space applications. It can be used wherever there is a demand for computer chips with tight volume, low mass, low power usage, and fast operation.

The SDC-1 design is a spin-off of the Superconducting Supercollider Project. Los Alamos researchers, including David Lee and Geoffrey Mills of the Physics Division, were developing a detector subsystem for the SSC, and the use of a multi-chip module was the only approach feasible to accommodate the extremely large number of signals and very high speed needed to process data at low overall power.

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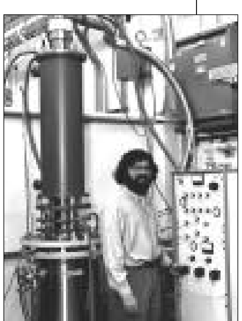
# PHYSICISTS HIT NEW LOW IN HIGH-MAGNETIC GAME

## REFRIGERATION COOLS SAMPLES TO NEAR ABSOLUTE ZERO FOR STUDY IN HIGH MAGNETIC FIELDS

A new refrigerator at Los Alamos can cool a sample down to a world-record-breaking few thousandths of a degree above absolute zero and hit it with an extremely high magnetic pulse at the same time.

Scientists will use the technology to investigate materials and organic structures that are otherwise difficult to study. The research has applications, for example, in the development of new semiconductor materials and superconductivity.

Researcher Alex Lacerda makes adjustments to the dilution refrigerator attached to the 50-tesla magnet on the left.



The National High Magnetic Field Laboratory, or NHMFL, at Los Alamos achieved the record using an Oxford Instruments dilution refrigerator. The unique non-metallic design of the Oxford Instruments device eliminates eddy currents in the pulsed magnetic fields that would raise the temperature.

The refrigerator's base temperature is twenty-five-thousandths of one degree above absolute zero, in Celsius units — about minus 460 degrees Fahrenheit. Tests were conducted with a magnetic field of 50 tesla, more than a million times Earth's magnetic field.

NHMFL was the first laboratory in the world to use the innovative technology. Dilution refrigerators and pulsed magnetic fields are now compatible tools for the discovery and study of new phenomena in the realm of high magnetic fields and low temperatures.

NHMFL is a consortium that includes Los Alamos, Florida State University, and the University of Florida. It is funded by the National Science Foundation. Los Alamos' magnetic facility makes possible research in pulsed magnetic fields — high-intensity fields that last up to a few seconds. As a national user facility, the NHMFL is available to all qualified academic and industrial users. (See related article, March 1995.)

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# COMPUTER MODEL HELPS MASTERCARD FIGHT CREDIT CARD FRAUD

## FINANCIAL INSTITUTIONS USE ADAPTIVE COMPUTING METHODS TO PREDICT FRAUD, ASSESS RISK

Fraud costs the credit card industry an estimated $1 billion annually, and much of that cost is ultimately passed on to the cardholders. Many financial institutions already use sophisticated computer programs to identify fraud by analyzing cardholder information. Researchers at Los Alamos are working with MasterCard International to develop a new computer model that uses different data to identify new classes of fraud.

The model uses advanced computer technologies Los Alamos developed for the U.S. Department of Energy to detect signs of nuclear proliferation, process anomalies in satellite images, and search an archival database from nuclear weapons tests conducted by the United States.

Pick a card, any MasterCard. Thanks to a sophisticated computer model being developed at Los Alamos, merchants and their customers can rest easier over costly credit card fraud.

Adaptive computing and neural networks play key roles in the system under development. These are computer programs that mimic the human brain by identifying patterns through positive feedback and can actually "learn" from trial and error. They are particularly useful in handling massive amounts of data that would otherwise require much more time and effort to analyze in conventional ways.

Credit card companies are already using standard neural networks. Extensive data on cardholders' credit histories, including where people use their cards and how much they usually charge, go into the system, and if anything changes dramatically the computer flags it as a potential stolen credit card. Banks then call the cardholder to verify the transaction. MasterCard estimates that neural network technology has already saved its member institutions more than $50 million, a significant reduction in fraud loss.

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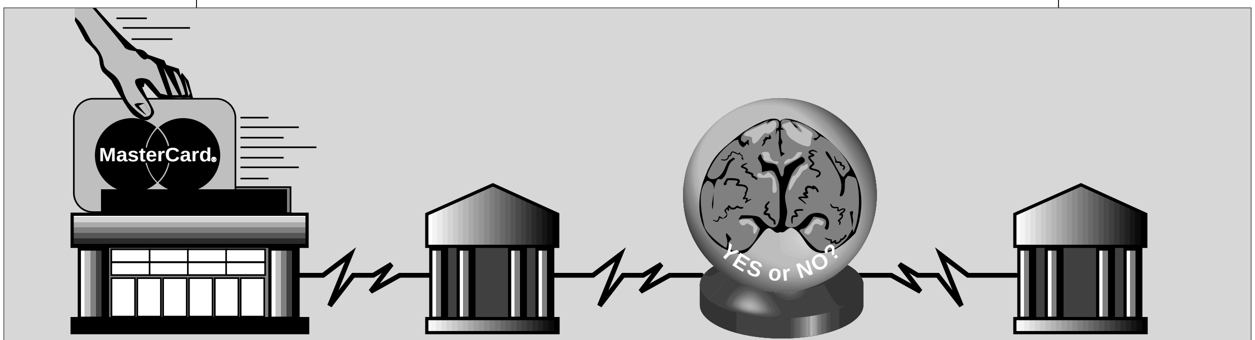


So when MasterCard executives decided to take current technology a step further to incorporate new kinds of data, they turned to Los Alamos because of the Laboratory's ability to invent and combine technologies to investigate high-risk, high-payoff approaches to complex problems. In addition to neural nets, researchers are working with fuzzy logic, a form of artificial intelligence that makes decisions by reading shades of gray rather than strictly black-or-white situations, and genetic algorithms, evolutionary mathematical processes that find the best results by selecting and combining competing solutions.

The new system, exclusive to MasterCard, will allow its member institutions to factor in even more information, such as merchant locations and transaction category codes. After Laboratory researchers test the computer model this summer, MasterCard will conduct its own analysis and begin pilot tests with selected members in 1996.

Over the past two years, the Adaptive Computational Group at Los Alamos has worked on several financial industry problems with clients ranging from large banks to governmental organizations. Besides fraud detection, the team is looking at customer behavioral patterns, operations scheduling, and financial derivatives modeling. Although details of these projects remain proprietary, the team's results to date have been promising, and Los Alamos welcomes inquiries from other companies that can benefit from applying adaptive computation to financial analysis.

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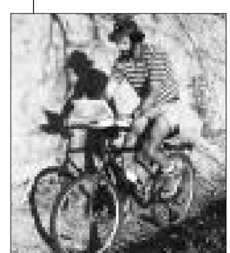
# E-PRINT ARCHIVES SPEED COMMUNICATION OF RESEARCH RESULTS

## LOS ALAMOS ELECTRONIC ARCHIVAL EFFORT FUNDED BY THE NATIONAL SCIENCE FOUNDATION

Los Alamos scientists recently received more than $1 million from the National Science Foundation for a three-year effort to advance the concept of "electronic print archives," a form of scientific communication that already has supplanted traditional research journals in some fields of physics.

Pioneered by Los Alamos theorist Paul Ginsparg, an electronic print archive provides an interactive repository where researchers can post their latest articles and preprints or search for information from others. The archives are available at http://xxx.lanl.gov/ on the World Wide Web.



↑ With tongue in cheek, Paul Ginsparg takes to his bike with a laptop computer to demonstrate how electronic print archives are changing the way scientific information is exchanged.

In 1991, Ginsparg developed an electronic archive specific to his field of high-energy particle theory research. Since then, the archive has expanded to include 25 other fields, and it now processes more than 45,000 electronic transactions per day and serves 25,000 users worldwide.

The heavy usage demonstrates how electronic archives are changing the way scientific information is exchanged. An e-print archive gets information into the hands of more researchers quicker than traditional journals, whose lengthy review and publication schedules dictate that research appears in print long after it was completed.

An e-print archive is also cheaper because it eliminates much of the waste of the hard-copy distribution system, and it will always be easier and less expensive to connect a computer to the Internet than to build, stock, and maintain conventional libraries.

At the end of the three-year, NSF-funded effort, the researchers expect to have expanded the database to cover all fields of physics and as many other scientific fields as appropriate. They also expect to improve the software to give a wider network of researchers access to the e-print archives.

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# LOS ALAMOS, HOUSTON COMPANY STUDY NEW HEAT TREATMENT PROCESS

## CERAMIC MICROBEADS HEAT AND COOL METALS MORE EFFICIENTLY

Heating and cooling metals under controlled conditions are critical to the manufacturing process for auto and aircraft parts, appliances, machine tools and dies — virtually everything made of metal. Under two cooperative research and development agreements, Los Alamos researchers are working with Kemp Development Corp. in Houston to refine a new automated machine that promises to bring greater precision and thermal control to the heat treatment industry.

Traditional heat treatment furnaces change the properties of metals by thermal radiation much like a household oven transforms batter into a cake. In contrast, the Mechanically Fluidized Vacuum, or MFV, machine treats metals by immersing them in a bed of preheated ceramic beads the size of dust. These microspheres act like a fluid, transferring heat to the metal parts faster and more efficiently than traditional radiation or convection heat. The effect is like dropping something in a hot tub of water rather than putting it in a sunny window to warm.

W.E. "Bill" Kemp, who calls himself a "wild-eyed inventor," demonstrates his innovative heat treatment machine. Los Alamos is helping Kemp test his machine against conventional heat treatment methods. Photo courtesy of the Houston Chronicle.

After a metal part is immersed, the MFV chamber rotates so the parts "float" in the microspheres. The movement allows even closer contact between the metal part and the heat which allows for consistent heating. In a traditional furnace, the part must "sit" on some kind of surface. When heat or gases are applied, the bottom of that part is not going to receive the

same exposure as the other surfaces. In the MFV machine, the fluidized beads cover all surfaces evenly.

Some heat treatments require that a part be cooled rapidly at extremely cold temperatures. The MFV machine is ideal for those processes because the ceramic beads can be brought to the desired temperature in a separate chamber and then blown into the furnace chambers by pressurized, inert gas. Hot microspheres can be exchanged for cold ones and vice versa.

Kemp Development Corp. came up with the idea behind the MFV machine but turned to Los Alamos for the in-depth performance analysis required before commercial production becomes a reality. Researchers in the Laboratory's Materials Technology: Metallurgy Group are compiling baseline data that compares the quality of metals treated by the MFV machine to those treated in conventional furnaces. Detailed metallurgical analyses will tell scientists whether the new process produces different properties in the final product.

At the same time, researchers in the Energy and Process Engineering Group are studying how temperature changes over time affect the new process. They will attach a gas chromatograph and other instruments to the MFV machine to study the composition of the gases in the furnace chamber and the effect of the gases on the surface chemistry of the parts.

Another question is whether the ceramic beads can introduce impurities to the materials being treated. Composed of zirconium oxide, the microspheres should not react chemically with anything in the furnace. But because they are somewhat sorptive, researchers want to see if the beads' surfaces pick up impurities from prior furnace runs and transfer them to subsequent runs.

The new machine lends itself to a variety of treatments: steel tempering; annealing, which removes internal stresses and makes parts less brittle; surface hardening of metals and alloys; diffusion hardening; and converting metallic powders to true ceramics. Kemp executives are optimistic that the Laboratory's research will confirm the MFV machine's commercial promise.

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# RESEARCHERS USE SUPERCOMPUTER TO STUDY HEAT TREATMENT AND MODEL A BETTER GEAR

Los Alamos researchers are also taking a look at how heat treatment affects the steel gears that make automobile transmissions work. The American auto industry needs millions of gears for the estimated 15 million cars and trucks that come off domestic assembly lines every year. Giants like Ford and General Motors know how to make those gears quickly and cheaply, but in auto parts where metal meets metal even subtle variations in high-precision gears can make them unusable.

To improve part quality and manufacturing efficiencies, an industry-led program through the National Center for Manufacturing Sciences asked researchers at four national laboratories to help study exactly how heat treatment changes the common gear. Using three-dimensional modeling codes on a Cray supercomputer, Los Alamos researchers are helping to develop a computational model that can predict the stress and distortion caused by heat treatment.

As part of the manufacturing process, gears are heated to 1,544 degrees Fahrenheit, then dropped into a cooling bath. The tremendous heat transfer hardens the surface of the steel, but it can also create distortions. Researchers are pushing the frontiers of computational modeling by looking at chemical changes, heat transport, and mechanical stress in a single calculation.

The project also uses neutron and X-ray diffraction techniques available at the Los Alamos Neutron Scattering Center to measure residual stresses in manufactured gears. Researchers use the test data to evaluate the computer models.

Because the modeling requires a great deal of computer power, the challenge to researchers is to come up with software that can one day be run on a computer work station at the gear plant. Engineers on site will be able to change the parameters of heat treatment during the process and make a better gear.

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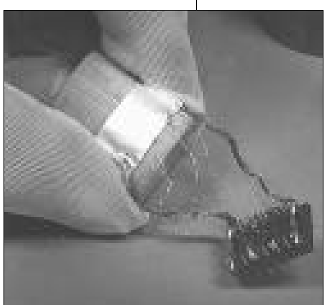
DATELINE: LOS ALAMOS

# SUPERCONDUCTIVITY BREAKTHROUGH HAS HUGE COMMERCIAL POTENTIAL

## THREE-LAYER, FLEXIBLE TAPE CARRIES WORLD-RECORD CURRENT



A short segment of the Los Alamos-developed thick-film superconducting tape is flexed around a spool.

Since the concept of superconductivity, or zero electrical resistance, was discovered in 1911, it has challenged science to come up with technologies to make effortless transmission of electricity a reality. In a major breakthrough, researchers at Los Alamos National Laboratory have taken a giant step in that direction with the development of a flexible metal-ceramic tape that can carry record-breaking levels of electric current at relatively high temperatures.

Because it can carry a great deal of current in a very small area, the thick-film superconductor created by researchers at the Los Alamos Superconductivity Technology Center could eventually lead to superconducting power lines, magnetically levitated trains, and even toaster-sized magnetic resonance imaging machines (MRIs) in every doctor's office. The potential energy saving is significant in a nation that expects to double its demand for electricity by the year 2030.

The researchers began with a superconducting ceramic called yttrium-barium-copper-oxide, or YBCO. They already knew that YBCO, unlike an earlier class of superconductors, loses its resistance to electricity at the relatively balmy temperature of minus 320 degrees Fahrenheit — the temperature of liquid nitrogen. Before YBCO and its class of ceramic materials, superconductivity was achieved only by using liquid helium to chill certain metals to absolute zero — about minus 460 degrees Fahrenheit. In practical terms, liquid nitrogen is superior to liquid helium because it's easier to handle, plentiful, and cheap — about 7 cents a liter.

But YBCO superconductors had some problems as well. They were brittle and difficult to make into wire. So the researchers turned to a technology used in semiconductor manufacturing that layers thin films of atoms. Starting with an inexpensive, malleable nickel metal tape, the superconductivity team applied a layer of cubic zirconia, the same material used for artificial diamonds. Next they added a layer of YBCO crystals. Superconducting crystals must be aligned like rows of bricks for current to flow smoothly through them. But if YBCO were deposited directly on the nickel, the crystals would align themselves randomly, making a poor superconductor. The zirconia provides a textured surface on which to deposit YBCO crystals.

Led by Xin Di Wu, Paul Arendt, and Steven Foltyn, the Los Alamos team uses Ion-Beam Assisted Deposition, similar to spray-painting at the atomic level, to deposit the cubic zirconia layer on the nickel. Then a pulsed laser process deposits the YBCO on top of the cubic zirconia. The resulting tape can carry one million amperes of electricity per square centimeter, a current density nearly 100 times greater than other high-temperature superconductors and 1,250 times greater than the copper wire standard in houses.

One of the most remarkable things about the ceramic-metal tape is its flexibility. It can be wrapped tightly around an object as thin as a soda straw and stands up to repeated twisting and bending without cracking, and unlike other superconductors in its class, the Los Alamos tape loses none of its superconductivity in strong magnetic fields. That's important because so many electrical applications, from motors to medical devices, require wires to function in magnetic fields.

Paul Arendt (left), Xin Di Wu (center), and Steve Foltyn of Los Alamos' Superconductivity Technology Center stand in front of an Ion-Beam Assisted Deposition machine, which deposits one of two layers of superconducting material onto a thin, nickel-alloy tape.

Although researchers have so far produced the ribbon-like tape only in 2-inch lengths, they predict it could one day be used in power-conserving industrial motors, small MRI machines, and even portable magnetic soil separators that remove contaminants from soil right at the site. The Superconductivity Technology Center is working on prototype motors, an underground transmission line program, and other projects. Los Alamos is looking for corporate partners to help develop commercial applications for the superconducting tape.

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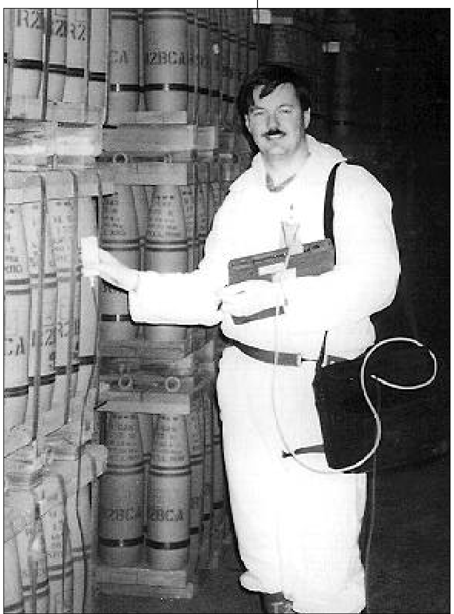
# TOOL RAPIDLY IDENTIFIES CHEMICALS IN CLOSED CONTAINERS

## NEW TECHNOLOGY ELIMINATES DANGERS ASSOCIATED WITH MONITORING CHEMICAL WEAPONS MUNITIONS

Los Alamos researchers have developed the Acoustic Resonance Spectroscopy, or ARS, Chemical Fill Detector that identifies chemicals inside closed containers. This portable detector is the first acoustic-based system that provides a quick, safe, and easy way of identifying the chemical contents of a closed container. Inspectors will no longer run the risk of being exposed to chemicals in containers because identifying the chemicals will no longer require extracting samples. Eliminating the extraction process will also prevent chemical leaks into the environment.

Traditional methods of verifying the contents of chemical munitions require the "drill and tap" procedure, which involves drilling a hole into the container, extracting a sample of the fill, and analyzing the sample in a laboratory. This method is time-consuming and can expose workers to chemical weapons agents such as nerve gas. The ARS system relies on the acoustic resonances of the container's contents rather than on drilling and extracting samples of the fill material.



➔ Researcher Paul Lewis demonstrates at a stockpile in Utah how the ARS Chemical Fill Detector analyzes the vibrations of munitions for identification.

The acoustic resonance technique in the ARS system looks for the natural vibration frequencies of a container and relies on the changes induced by different fill materials to identify chemical contents. Two transducers are connected to a munition or container by magnets. One transducer induces vibration while the other analyzes the vibration pattern. They are then matched with a chemical fill's signature pattern for identification. In less than a minute the detector identifies the fill material.

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↑ Top photo: Components of the ARS Chemical Fill Detector include a computer notepad, digital analyzer and synthesizer, and a pen. Two test munitions sit behind the components. Lower photo: A researcher analyzes a container's contents.

This method of measuring the vibrational modes of objects is a well-established technology; however, the use of acoustic signatures to identify fill materials and the software algorithms that implement this identification put this instrument ahead of traditional technologies.

The ARS system consists of a few electronic pieces such as a digital synthesizer and analyzer, and a notepad computer for readouts. These components make the detector efficient because it is battery powered, lightweight, and user friendly. A shoulder tote carries the entire system, and the operator can remove and replace the notepad before and after use.

The ARS system is one result of the Defense Nuclear Agency's funding of work on nondestructive evaluation technologies at Los Alamos and other laboratories. The impetus for a field instrument came after the Persian Gulf War when United Nations inspection teams were scheduled to go into Iraq to locate and destroy Saddam Hussein's chemical weapons munitions. The Defense Nuclear Agency asked Los Alamos to develop a field instrument using the ARS technology. In October 1991, a United Nations inspection team used an early prototype to examine Iraqi artillery shells and rocket warheads.

In December 1994, the ARS system was tested at the Tooele Army Depot, a U.S. chemical stockpile site in Tooele, Utah. Personnel from the U.S. Army Dugway Proving Ground analyzed a set of 155-mm artillery shells containing the blistering agent mustard gas and nerve agents GB and VX. The detector successfully identified the fill of these chemical weapons munitions.

The ARS system supports the Bilateral Chemical Weapons Agreement between the United States and Russia, and the Multilateral Chemical Weapons Convention. These treaties require site inspections and verification of munitions. The detector also has civilian functions. It can function as a quality-control tool in the manufacturing and packaging of chemical products, detect salmonella in eggs, and measure intraocular pressure — an indicator of glaucoma — within the eyeball.

A patent has been granted on one application of the ARS technology, and another is pending. Researchers are preparing to transfer this technology to a commercial company for manufacturing and distribution worldwide.

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# DATELINE: LOS ALAMOS

## BRIEFLY ...

Los Alamos scientist receives E.O. Lawrence Award. Gregory Kubas (in photo at left) received a gold medal and a $10,000 check presented by Department of Energy Secretary Hazel O'Leary at a May ceremony in Washington, D.C. Kubas' award was in the chemistry category. He discovered a new kind of chemical bonding — the stable hydrogen-metal complex — that has revolutionized the way scientists think about how hydrogen interacts with metals and improves the prospects for hydrogen's use as an energy source. Established in 1959, the award is named after Ernest Orlando Lawrence, who invented the cyclotron, a particle accelerator. Two major DOE labs are named after Lawrence. Kubas was one of eight E.O. Lawrence winners for 1994.



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