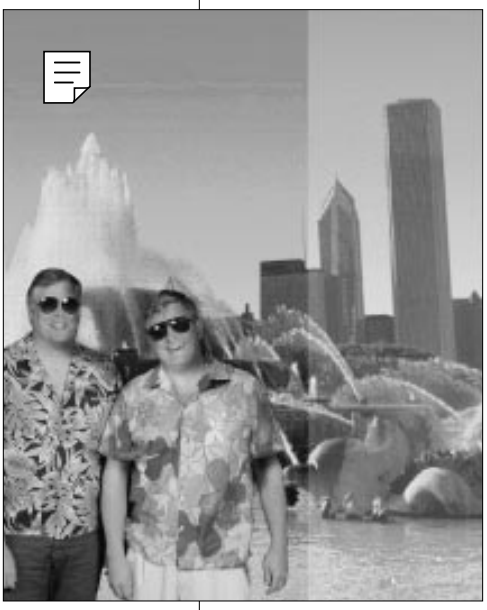
LOS ALAMOS NATIONAL LABORATORY
WHERE SCIENCE MAKES A DIFFERENCE

DATELINE
LOS ALAMOS

NEW COMPUTER SOFTWARE PROTECTS ELECTRONIC FILES FROM ALL TRESPASSERS

DATA EMBEDDING TECHNOLOGY PROTECTS, STORES, COMBINES, AND TRANSMITS DIGITAL DATA



Criminals beware. Thanks to researchers at Los Alamos, digital information sent through open communication channels can be protected from unauthorized users. The new technology, known as Data Embedding, will prevent pirating of copyrighted information and unauthorized manipulation of digital photographs.

Because people are relying more and more on electronic communication and electronic information storage, it has become increasingly difficult to prevent the piracy of digital information. Data Embedding takes a unique approach

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Los Alamos Researchers Theodore Handel (left) and Maxwell Sandford are superimposed on a photo of Buckingham Fountain in Chicago. The original file of this manipulated photo contains embedded text of a technical paper on data-embedding research.

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to preventing such incidents from occurring by enabling communicators to create a code, or key, that can open the "gateway" to the information by only those who possess the key.

The idea of embedding data into electronic files is not new. The technology has been used to add information to existing signals in radio communications and also in standard television signals. But data-embedding technology is new to digital-information storage.

Data Embedding is a spin off of a Los Alamos research project to examine image data using high-speed television systems, film systems, and long-exposure systems. The researchers realized that no matter how well they processed an image, there were still "noise" components, or unnecessary parts of the information, that could not be removed from the data. So, rather than eliminate the noise intrinsic in the electronic data, Data Embedding exploits the noise by using it as space to store additional information.

The Data-Embedding procedure is similar to sending a photo through the U.S. mail encoded with a secret message written in disappearing ink. Anyone trying to breach the package containing the photo will see only the photo. And, even if the person who steals the package knows of the secret

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A "watermark," or copyright inscription encoded in an electronic photo file mars illegal duplications of this photo. Authorized users receive the software key required to remove the watermark.

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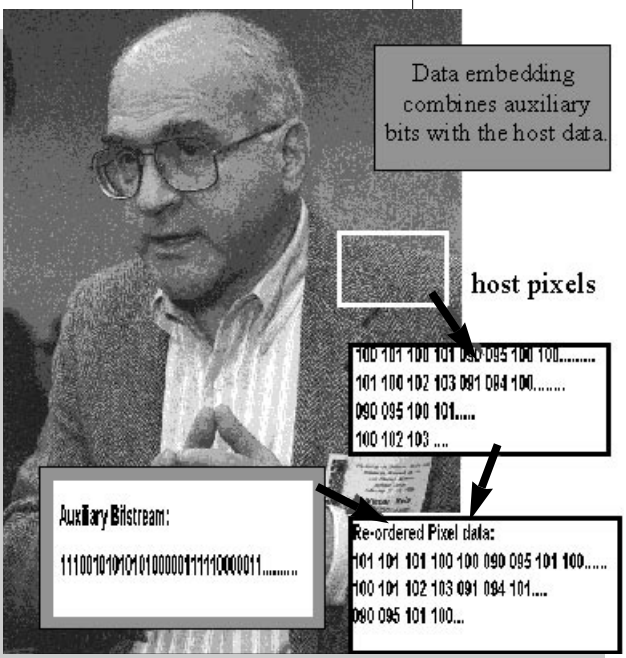
message, without a special ultraviolet light — or in Data Embedding, an electronic key — the unauthorized user cannot decode the message.

For example, the text of a five-page document can be added to a file of statistical data supporting the text and sent through existing communication channels without altering the size of the data file. And, since embedded data is contained within the noise already present in the host document, it cannot be determined through statistical analysis of the modified host data.

If a third party is involved in the communication transfer, for example, a person who must oversee all communication between the first and second parties, analysis of the file will not reveal a secret message if the overseer does not have the code to retrieve the imbedded message.

Data Embedding applications range from protecting intellectual property rights of digital information to embedding a patient's medical history in electronic records.

Personal medical information can be embedded in electronic records such as sonograms and MRIs. Databases containing records with embedded personal information will improve the efficiency of medical record keeping, while making it easier for physicians to comply with the Privacy Act by enabling them to compare related cases without compromising patients' anonymity.



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This photo of Vic Reis, Department of Energy assistant secretary for Defense Programs, illustrates how data embedding modifies the pixels in the image to encode the auxiliary information. A digital photograph consists of individual numerical values that make up the elements of the picture. The white box selecting an area of the photograph is expanded to show the values in the photograph. The digital image serves as the host for the auxiliary data, which is embedded. The auxiliary data in the box at the lower left are a stream of binary ones and zeroes (bits) conveying information that does not have to be related to the host photograph. Data embedding rearranges the pixel data in the host photograph to encode the auxiliary information. The box at the lower right shows the digital photograph data after it is rearranged to hold the auxiliary bits. In the example, the value 101 is used to represent a "1" in the auxiliary bits, and the value 100 is used to represent a "0." The distinction between the values 100 and 101 in the host picture is too small to distinguish, and the picture is unchanged to the eye, even though it contains a substantial amount of new, unrelated information.

This technology also can identify illegally copied files of digital photographs, computer-generated artwork, and audio compact disks. Data Embedding's techniques can produce a "watermark" on an illegally copied file that mars all copied images with a copyright symbol, for example, making them unacceptable for publication.

Other technologies impress visible watermarks, but only Data Embedding facilitates removing the stamp because the information for its replacement resides within the noise component of the watermarked image. A user purchasing rights to an image receives the key required to completely remove this watermark.

A music CD, or compact disc, can be embedded with copies of a score or commentary on a particular selection. Conventional CD players could play the music, but new-generation players would allow users to remove the audible watermark from the music and extract the score or commentary.

In a defense-related application, military maps sent in digital form through open communication lines could contain embedded information on targets and overlays of battle order.

Data Embedding is a software package written in the programming language "C" that conforms to virtually any digital-storage medium. It operates on PC-compatible computers run by MS DOS and requires 512 kilobytes of memory — less memory than what is needed to run most word-processing software .

Of the many future consumer applications, one might be to use Data Embedding to embed positive biometric identifiers such as iris scans or infrared thermograms of a person's face. These identifiers could help security personnel better identify potential terrorists or people requiring special security consideration. This application is under development.

The researchers are seeking an industrial partner to manufacture Data Embedding software for commercial use. Two patents are pending.

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Meet the Rickmans. This family photo obviously has been manipulated with the face of Public Affairs staff member James Rickman (top). Computer technology has made it possible to alter photographs in such detail that — unlike this photo — the changes may not be obvious to non-experts.

DATELINE: LOS ALAMOS

RESEARCHERS DISCOVER GENE FOR FATAL CHILDHOOD DISEASE

BATTEN-DISEASE GENE PINPOINTED ON LOS ALAMOS MAP OF CHROMOSOME 16

An international research consortium has identified the gene responsible for Batten disease — a fatal, inherited disease of the nervous system that begins in childhood.

The new gene, CLN3, was discovered at the Massachusetts General Hospital Molecular Neurogenetics Unit by researchers Terry Jane Lerner and her colleagues.

Norman Doggett and his colleagues at Los Alamos' Center for Human Genome Studies aided in the discovery by constructing a detailed physical map of the region where the gene is located on human chromosome 16.

Discovery of the gene may give researchers a tool with which to develop prenatal screening for high-risk families, or a test to identify whether a person in a high-risk category carries the gene.

The new gene encodes a newly discovered protein. Determining the function of the protein will give scientists their first real knowledge about what goes wrong on a molecular level in Batten disease. It may even give them insight into processes involved with other neurodegenerative disorders, including those that affect the aged and younger adults.

Los Alamos researcher Christine Munk loads an automated DNA sequencing machine, which allows researchers to determine the exact DNA sequence of a specific gene, and, more importantly, determine how the sequence has changed in a disease gene.

Batten disease, a progressive neurodegenerative disorder, leads to the accumulation of certain pigments in the brain and other tissues. Batten disease is a member of a group of inherited illnesses that occur in the United States in two to four births out of every 100,000. It may be more common in northern Europe, especially Finland and Sweden, and in the Newfoundland area of Canada. Scientists in 1989 determined that a gene for Batten disease was located on a

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segment of chromosome 16. The biological basis of Batten disease has been unknown until now.

Symptoms of Batten disease first appear in children aged 5 to 10 and usually begin with vision problems and seizures. As affected children grow older, they exhibit learning disorders, behavioral changes, and physical clumsiness. Victims of the disease eventually are robbed of their sight and mental faculties, and are condemned to a bedridden state until death — usually in their late teens or 20s. A child must inherit a copy of the defective gene from both parents to develop Batten disease.

Researchers at Los Alamos' Center for Human Genome Studies have constructed a low-resolution map of the chromosome and a high-resolution map for more than 80 percent of it. The map shows where certain base-pair sequences are located on a strand of DNA.

The base pairs, or nucleotides, are the "rungs" of the spiral ladder formation of DNA. Since the Los Alamos researchers were already working on chromosome 16 (see related article in the May 1995 issue of *Dateline: Los Alamos*), they assisted other Batten Disease researchers by making a detailed physical map of the region on chromosome 16 where the gene is located.

In 1993, five organizations established the International Batten Disease Consortium to speed up the process of isolating the gene by sharing information and research tools. The protein produced by CLN3 is found in brain cells and other tissues. The researchers found that Batten disease

Los Alamos researcher David Bruce prepares a gridding robot for its designated task of transferring bacteria cells cloned for known fragments of human DNA from their storage sites to specific locations on a grid. By dipping the grid in a chemical bath containing DNA tagged with fluorescent dye, researchers can probe the grids for specific genes.

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Bruce checks the alignment of the robot arm and vials of bacterial DNA.

patients are missing a portion of the gene. The observed mutations could lead to Batten disease through the accumulation of abnormal protein fragments in cells or tissues, or by making necessary proteins inactive.

In addition to Los Alamos, Lerner and her team's successful completion of the search was aided by colleagues at the Women and Children's Hospital in Adelaide, Australia; Leiden University, the Netherlands; and the University College of the London Medical School in England. The National Institute of Neurological Disorders and Strokes, a division of the National Institutes of Health, was a primary source of funding for Lerner's team and for several other consortium members.

The Children's Brain Disease Foundation was another major supporter of the investigations, as well as the Batten Disease Support and Research Association, the Juvenile NCL Research Fund, and the U.S. Department of Energy.

An article about the discovery of the Batten gene was published Sept. 22, 1995, in the scientific journal *Cell* by the International Batten Disease Consortium. The physical map constructed by Los Alamos researchers that includes the Batten-disease gene was published in the Sept. 20, 1995, issue of *Genomics*.

Los Alamos' contribution to this research was made possible through Laboratory-Directed Research and Development funding, a portion of the Laboratory's budget used to support outstanding science and engineering efforts.

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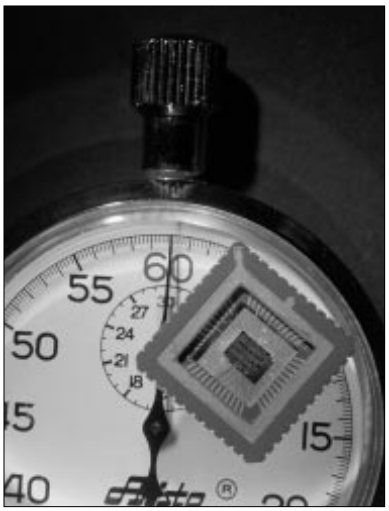
DATELINE: LOS ALAMOS

LOS ALAMOS BUILDS A BETTER STOP WATCH

NEW TIME-INTERVAL METER IS ACCURATE TO 10 TRILLIONTHS OF A SECOND

Los Alamos engineers have developed a time-interval meter that makes reliable time measurements to within 10 trillionths of a second. Their invention replaces bulky, power-hungry, temperature-sensitive circuits currently used to make ultrafine time measurements.



An integrated circuit developed at Los Alamos rests on top of a standard stop watch. The integrated circuits that comprise the Los Alamos time-interval meter are the first to successfully combine analog and digital technologies in a single silicon chip for time-interval measurements.

The need for precise time-interval measurements is greater than ever as scientists probe ultrafast processes in the physical and biological sciences. For example, precision timing is essential in the semiconductor industry where computer systems must be increasingly fast to stay competitive in such a rapidly evolving industry.

The time-interval meter developed at Los Alamos is ideal for validating computer electronics in which the generation, transmission, and arrival of ultrashort electronic pulses must be timed precisely to ensure accurate computations.

The Los Alamos meter is based on a sophisticated combination of stable analog circuitry and high-speed, low-power digital circuitry. By combining the two technologies into one integrated circuit, the researchers were able to create a time-interval meter that is just as fast as commercially available meters, with 10 times better usable time resolution.

In spite of its advanced electronics, the time-interval meter serves the same basic function as a common stopwatch — but instead of clocking racehorses, the Los Alamos meter clocks the time elapsed between two electric or other types of analog signals. Once the signal is recorded by the meter's analog circuitry, the information is translated into digital format for computers to be able to read, store, or analyze the data. It is a

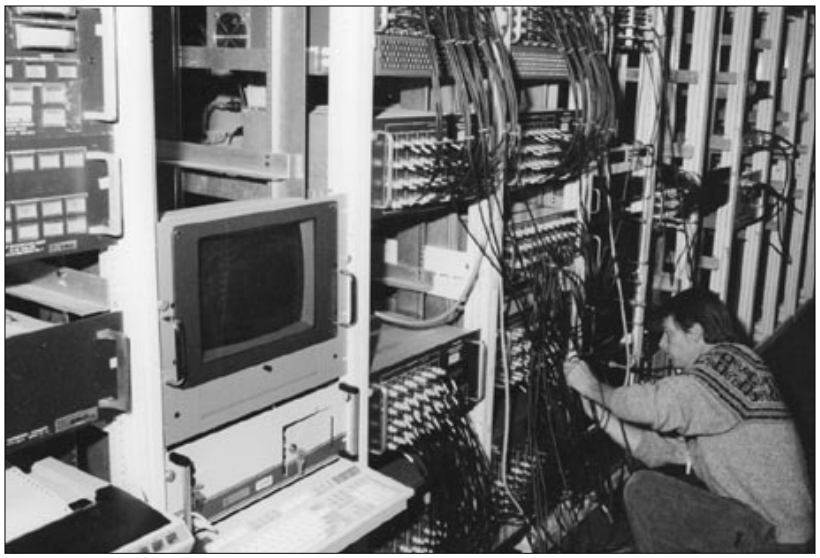
bit like transforming a gallon of water into a discrete number of ice cubes that can then be stored in the freezer and accessed as needed.

But mixing analog and digital technologies into one integrated circuit was much harder than freezing ice cubes. The integrated circuits that comprise the Los Alamos time-interval meter are the first to successfully combine the two technologies into a single silicon chip.

The challenge was not only being able to detect the millivolt "whispers" of analog signals from the volt-high amplitude of the digital signals, but to do so in a matter of picoseconds. A picosecond is equivalent to one-millionth of one-millionth of a second.

The integrated circuit chip is about the size of a standard cuff link. It takes at least two chips to make a time-interval meter. This tiny package performs the same job as a digitally based time-interval meter produced by Hewlett Packard, which is roughly the size of a household VCR. The Los Alamos meter uses 90 percent less power than the interpolator circuit in the Hewlett Packard unit, with increased reliability and thermal stability.

The integrated-circuit technology is a spin off of electronics work developed at Los Alamos for weapons research. The cost of producing one integrated circuit is about $100. The circuits perform best in a temperature range of 65 to 75 degrees Fahrenheit, which eliminates the need for expensive and bulky refrigeration equipment. The researchers recently received a patent for their integrated-circuit design.



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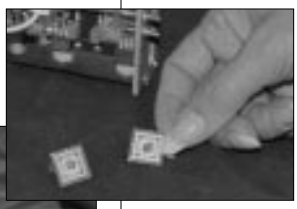
A Los Alamos researcher performs a maintenance chore on one of the previous generation of time-interval meters developed at Los Alamos. These instruments were based on hybrid — analog and digital — circuits but were huge compared to the integrated circuit chips that replaced them.

The invention could find use in a variety of time-measuring devices. Some examples include laser-ranging tools of measurement such as the those currently used by land surveyors. By sending a laser beam to a reflector at some distant point, surveyors can calculate distance from the amount of time it takes the beam to bounce off the reflector and return to the source. The Los Alamos time-interval meter would result in more accurate measurements.

Another application is nondestructive testing of materials. Currently, scientists use ultrasound signals to locate cracks in materials. The technique requires time-interval measurements of 10 picoseconds or less. The finer time resolution offered by the Los Alamos meter would enhance the existing technology.



The time-interval meter also could be used in inner-planetary studies to provide more accurate measurements between planets and satellites. Back on Earth, the meter could be used to help predict when a volcano might erupt. Using laser-ranging technology, scientists monitor expansion in a volcano's rim to help predict an eruption. In the case of dome-topped volcanoes like Mount St. Helens in Washington state, they use the same laser-ranging technique to monitor the swelling that occurs as magma builds up inside the mountain — another sign it's getting ready to blow.

The Los Alamos researchers have produced many samples of the time-interval meter. They encourage inquiries from commercial companies wishing to license the technology for time-measuring instruments.

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The top photo shows two of the Los Alamos integrated circuits. It takes at least two chips to make a time-interval meter. In the bottom photo, the chips and a circuit board from a previous-generation Los Alamos meter rest atop a time-interval meter sold by Hewlett-Packard.

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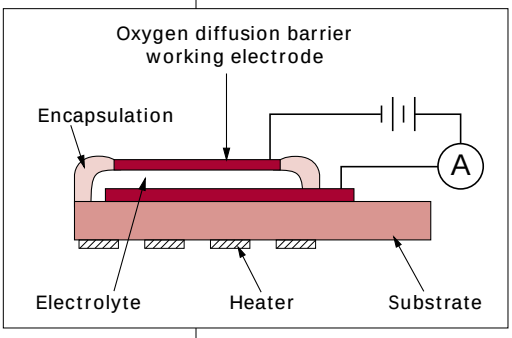
DATELINE: LOS ALAMOS

OXYGEN SENSORS CONTROL POLLUTION AND IMPROVE AUTOMOTIVE POWER AND ECONOMY

SENSOR BASED ON SOLID-STATE DIFFUSION BARRIER

A new technology is emerging to help an automobile's computer system intelligently control the air-to-fuel ratio in the internal combustion engine.



This technology involves the improvement of oxygen sensors that feed information back to the car's computer, thus allowing adjustments so that the fuel can burn more efficiently. Measuring the amount of oxygen coming out of the exhaust process and using that information to improve the way fuel burns avoids unburned hydrocarbons and greatly reduces air pollution.

Los Alamos researchers have developed a linear-response oxygen sensor based on a solid-state diffusion barrier. This sensor eliminates most of the manufacturing difficulties associated with previous diffusion barriers that use a porous ceramic covering or a pin-hole aperture.

When a bias voltage is applied to the sensor, it produces an electric current that is linearly proportional to the oxygen concentration. The sensor fabrication process lends itself to inexpensive manufacturing, and its implementation is being pursued with General Motors/GM Delphi in a cooperative research and development agreement.

In addition to reducing pollution, potential benefits of this oxygen sensor include greater horsepower and better fuel economy. Non-automotive applications include oxygen monitoring for workplaces and confined spaces, medical uses, and chemical process control.

A lean-burning linear current oxygen sensor under development at Los Alamos.

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DATELINE: LOS ALAMOS

BRIEFLY ...

LOS ALAMOS NATIONAL LABORATORY'S FIRST STEP TO MARS. Three detectors ready for space flight were recently taken to Russia by Los Alamos scientists to become part of the Mars 96 mission to the red planet next year. Mars 96 is an international endeavor built around Russia's Phobos-type spacecraft that will carry a variety of instruments for studying Mars, solar wind, and astrophysical events. The fist-sized detectors — two to fly on the spacecraft and one to serve as a backup — are designed to detect high-energy photons called gamma rays. Their measurements will help map out the elemental composition of the Martian surface and also provide valuable information about enigmatic bursts of gamma rays that come from deep space. Astronomers have been unable to determine the origin of gamma-ray bursts because they cannot penetrate Earth's atmosphere, making them difficult to study.

Photo: Los Alamos researcher John Valencia makes a final inspection of one of the three Los Alamos-developed gamma-ray detectors that were recently shipped to Russia for inclusion on the Mars 96 mission.

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