Gamma-Ray Imaging Spectrometry

Laboratory scientists have developed an imaging instrument for locating and identifying nuclear materials by taking "photographs" of the gamma rays emitted by these materials. This instrument, the gamma-ray imaging spectrometer, has many potential applications as wide ranging as treaty verification, environmental cleanup investigations, gamma-ray astronomy, and nuclear medicine.

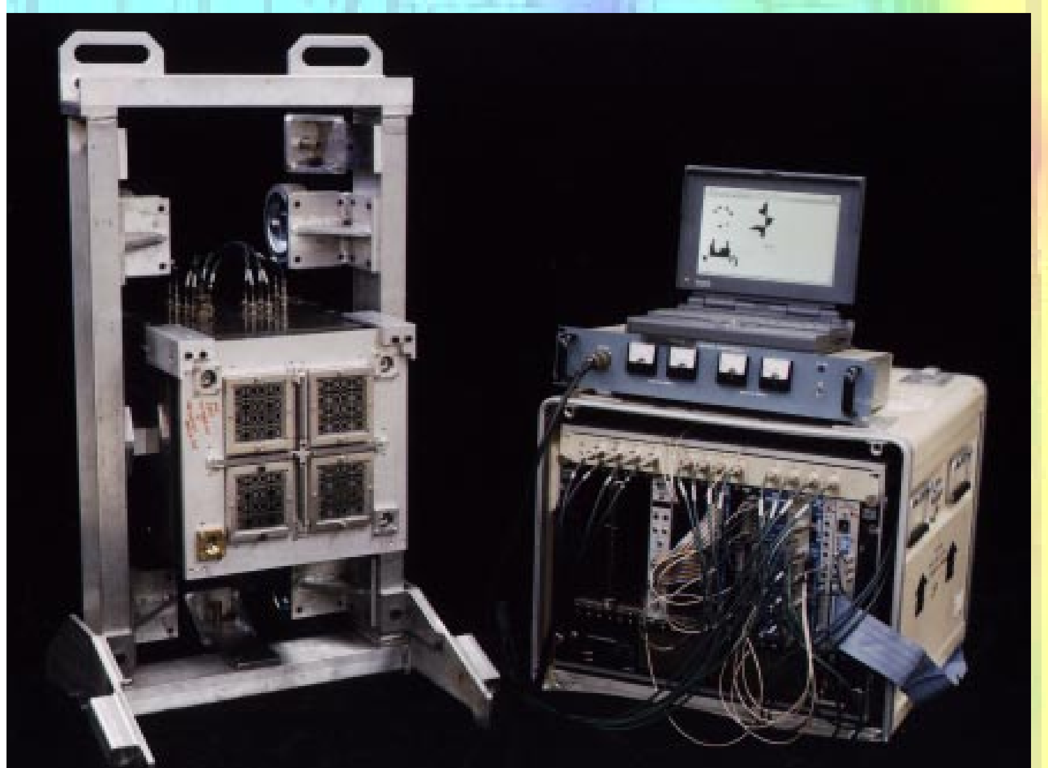


Figure 1. A Gamma-ray imaging spectrometer (GRIS) configured for work in gaseous diffusion plants. On the left, the GRIS imager head has four independent gamma-ray imagers. On the right is its data-acquisition system.

ONE of the challenges facing today's world is to keep track of the nuclear material generated during the Cold War. Some of the materials are radioactive isotopes that fuel nuclear weapons; others are used in the nuclear power industry. At Lawrence Livermore National Laboratory, we have developed an instrument that can help locate and identify these materials.

One of the characteristics of many nuclear materials, including those used in weapons, is that they emit gamma radiation. Each isotope emits a unique spectrum of gamma rays that can penetrate substantial amounts of ordinary matter without being scattered or absorbed like visible light. This radiation is imagable and can be used to indicate the presence and specific type of nuclear material.

Although nonimaging, nondirectional gamma-ray radiation detectors have long been used to monitor the presence and general location of nuclear materials, gamma rays have been poorly exploited to provide information about the precise location of the nuclear material. Recent advances in position-sensitive detector technology, coupled with advances from gamma-ray astronomy, have allowed researchers to design and build a gamma-ray camera capable of taking gamma-ray "photographs" that quickly characterize radiating materials. When these images made with invisible radiation are combined with visible-light images, they clearly show the exact location of the gamma-ray emitting materials.

Looking at Gamma Rays

The gamma-ray imaging spectrometer (GRIS) we have assembled comprises four coaligned, independent imagers, each with its own detector and coded-aperture mask (Figure 1). Each detector "sees" incoming gamma rays only through its mask, which serves as the imaging optic for the gamma rays (see box, pp. 18-19). This mask is mounted on a movable mask plate in front of the detector plane; moving the plate provides different levels of zoom for the gamma-ray images.

At the back of the housing are the electronics that take the relatively weak signals from the detectors and amplify them before they are sent to the data-acquisition system, which can be located remotely. Our system currently consists of a commercial electronics module, whose data are read out by a notebook computer (Figure 1). Coaligned with the gamma-ray imagers is a video camera. Images from this provide both a visual aim point and visible light images that can be overlaid with the gamma-ray images to pinpoint the location of the radioactive material.

Applications and Results

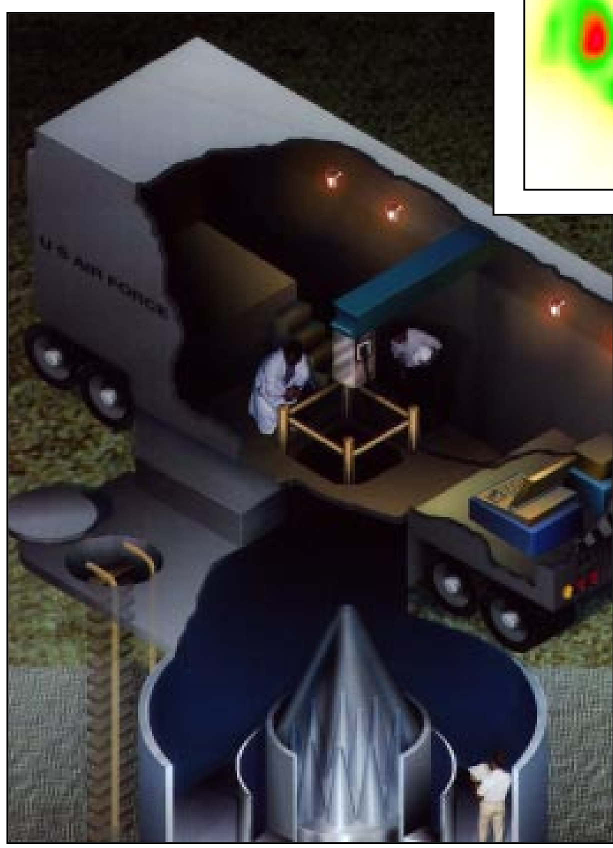
Although the spectrometer was developed to control the special nuclear material (SNM) associated with nuclear weapons, there are a myriad of applications in other areas, including environmental cleanup, astronomy, medicine, the nuclear power industry, and any other enterprise where radioactive sources are used.

Arms Inspection

GRIS was initially designed for use in arms inspections called for by the Strategic Arms Reduction Treaty (START)—specifically, to count the number of warheads on board a missile without requiring either close access to the missile or its disassembly. Inspections would be conducted remotely, based on the premise that the gamma-ray signature from the on-board warheads, although weak, is strong enough to be detected through the top of the missile. GRIS was constructed with four detectors to decrease the time it takes to obtain a good image approximately 10 m from the source. Figure 2 shows GRIS being used to inspect a Peacekeeper missile in its silo; the missile's ten warheads in the GRIS image are easily seen in Figure 3.

Confidence through Transparency

As the U.S. and Russia strive to reduce their respective nuclear stockpiles, each must have the ability to identify and verify the location of the other's weapons components throughout the demolition process. Each



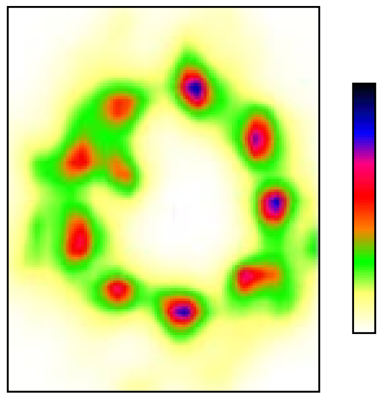


Figure 3. This enhanced gamma-ray image is from an emplaced Peacekeeper missile. The warheads are shown in a ring of nine, with the tenth inside the ring at the 10 o'clock position. The colors represent radiation intensity contours.

Figure 2. Rendering of the configuration used for gamma-ray imaging of a Peacekeeper missile. The GRIS imaging module is suspended above the open silo door and generates an image from the radiation given off by the warheads at the top of the missile.

must have confidence that the SNM in the other's storage vessels is associated with nuclear weapons components but must be able to develop that confidence without performing an inspection that is sufficiently detailed to raise classification issues. This ability, or confidence, is called transparency.

In a recent joint U.S.–Russian demonstration at LLNL, we obtained data with a conventional, nonimaging gamma-ray detector and with GRIS. The data were collected from a radioactive source hidden inside a typical weapons component storage container. Both detectors possessed similar energy resolutions and could identify the type of material present. However, in a single measurement, the non-imaging detector could not verify the quantity of SNM present or the likelihood that the material was a weapons component. Such information could only be obtained from the nonimaging detector by scanning it across the storage vessel in small steps. Although this generated a crude image of the object that allowed identification, it also required most of a morning to complete. By comparison, the inspection with GRIS took half an hour—a time which could be easily reduced to a few minutes. The GRIS images taken from two directions 90 degrees apart (Figure 4) clearly show that a disk of plutonium and not a weapons component is in the storage container.

Related applications that take advantage of GRIS's ability to "see" behind shielding occur in nuclear waste disposal and in the characterization of nuclear weapons. Figure 5 illustrates such an application. Here, we placed a rectangular shape made from plutonium

rods inside a storage drum. To simulate shielding, we placed a depleted uranium plate about 3 mm thick outside the drum. The uranium serves as shielding, as a source of confusing radiation, and as a different radioactive isotope.

Figure 5 indicates both the energy resolution of the system and how images using data from different spectral regions can show the locations of different materials. The image obtained using only the data in the region of the spectrum shaded blue is on the left. This image represents emission from uranium and shows only the large uranium plate. On the right is the image obtained using data in the region of the spectrum shaded pink. These data are characteristic of plutonium and reveal the rectangular figure behind the uranium inside the container.

Safeguarding Weapons

When nuclear arms and their components are secured and stored, the primary concern is to verify that no material is removed from a storage area. In addition to armed guards, an inventory control system that constantly

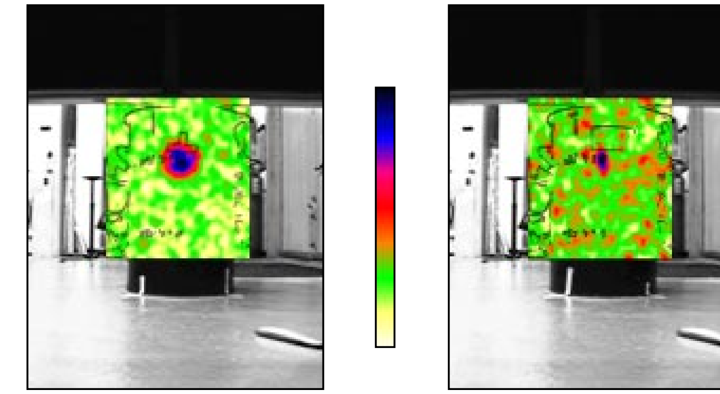
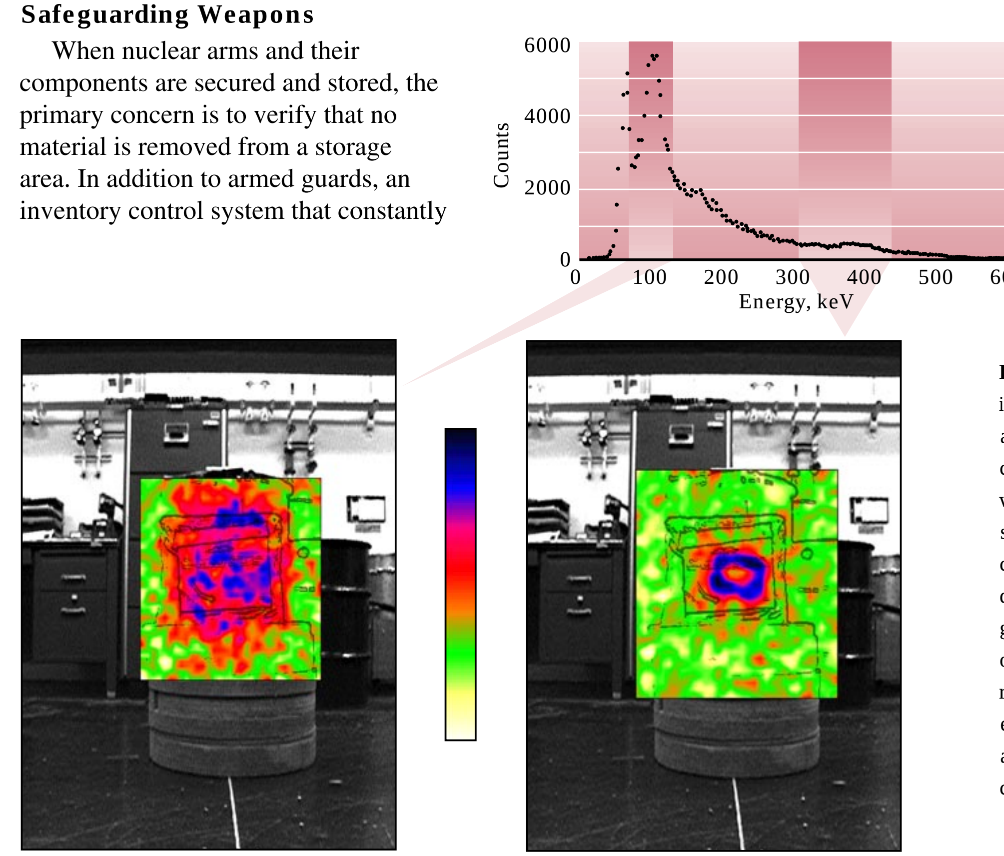


Figure 4. Overlaid on a video picture, a color gamma-ray image shows the difference between a face-on (left) and an edge-on (right) image of a plutonium disk. The images were obtained at a distance of 1.8 m and a position resolution at the source of 3.8 cm. Black represents the highest radiation intensity.



Depleted uranium source

Plutonium source

Figure 5. Demonstration of gamma-ray imaging and energy discrimination in applications for arms control transparency, contaminated waste identification, and weapons forensics. The plutonium source is distributed inside a storage drum can be clearly seen, even through 3 mm of depleted uranium. The image at left is generated from 100-keV gamma radiation of the depleted uranium; the image on the right is generated from the plutonium energy band at about 400 keV. With the appropriate energy selection, the plutonium can be seen through the uranium.

How the Gamma-Ray Imaging Detector Works

Astronomers have worked on the problem of imaging gamma rays for about 30 years. Although cosmic sources of gamma rays are extremely bright, they are also exceedingly far away, so the problem is how to image dim sources in a relatively large background. In principle, a pinhole camera could be used, but only a small fraction of the available radiation would reach the film or detector. In the late 1960s, it was recognized that one could improve the pinhole camera by punching more holes in the blocking sheet. Each hole projects its own image on the detector, and the different images overlap. If the hole pattern is known, one can mathematically recreate a faithful reproduction of the scene.

Although initial attempts showed that the technique worked, they also showed that the pattern had to be selected carefully, or false sources would appear in the image. The research on pattern effects was largely completed in the 1970s when a class of patterns called uniformly redundant arrays was created. These patterns possess a unique property: the information present in the shadow pattern from any one source in the image is not affected by the presence of gamma-ray sources in other parts of the image.

In the schematic of the imager (see the illustration below), we assume that radiation is coming from a very distant source. The light rays from this source are parallel, so a shadow of the mask is projected on the detector much the way it would be projected by the sun. Each pixel (the smallest picture element) in the image is represented by parallel gamma rays incident from one direction that project a detector-sized portion of the mask pattern onto the detector. The pattern is selected such that each projection is unique and independent of all other projections.

The image is recreated by a cross-correlation technique: the complete detector pattern is summed against each unique mask position by adding counts to the sum if the mask is open at this position and subtracting them if it is closed. Physically, counts are added if they could have come from that direction and subtracted if they could not. If no source is present, any detector-sized portion of the mask pattern has the same fraction of open and closed area relative to all other portions of the mask of that same size, so the sum is zero (except for statistical fluctuations). If a source exists at the particular location being summed, then every time there is an opening there will be counts, and the sum will recreate the true flux (amount of signal per unit time) from the source.

The advantage of this technique is that half the detector area is exposed to each of the sources in the field of view. The rest is behind closed mask elements. Compare this with a pinhole camera, in which the open area is only one pixel's worth. For a point source, the signal-to-noise ratio increases as the square root of N, where N is the number of open holes. For our system, N is approximately 200, meaning a 14-times-greater signal strength and significantly reduced data-acquisition time.

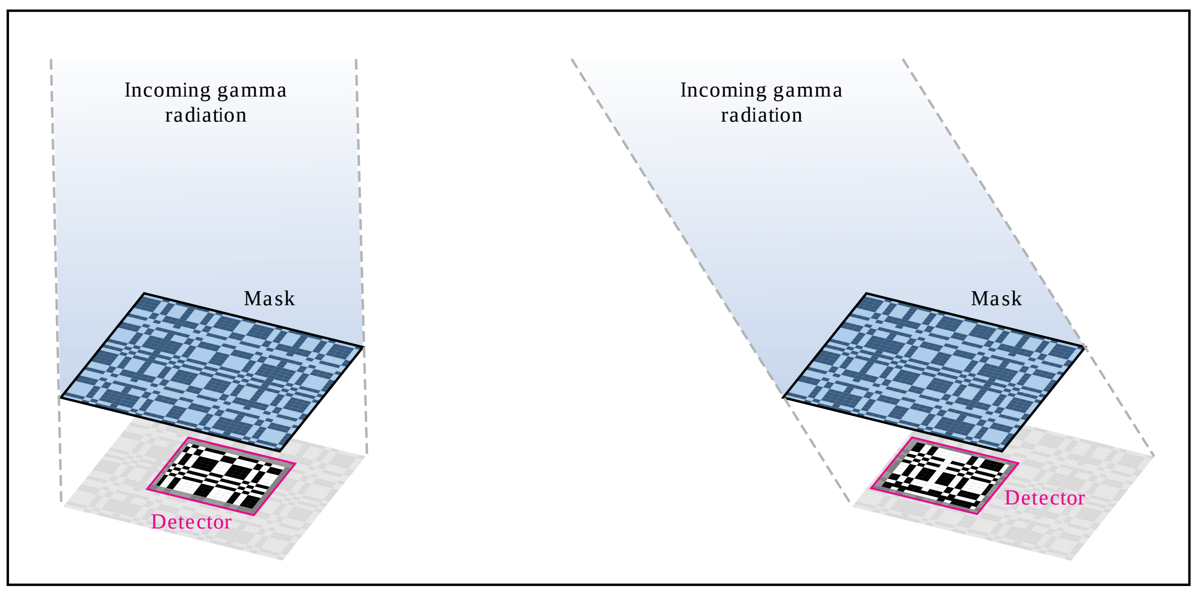
Unfortunately, because all the counts in the detector are used at each image location, the more sources there are in the field of view, the less one gains from this technique. It reverts to one with the same sensitivity as a pinhole camera if the whole field of view glows at the same intensity.

The resolution of a coded-aperture camera is just what it would be for a pinhole camera. For each pixel, the angular offset in incoming radiation is the basic hole size divided by the focal length (detector-to-mask spacing). To obtain the resolution at the source, one must multiply this angle by the distance to the source.

Position-Sensitive Detector

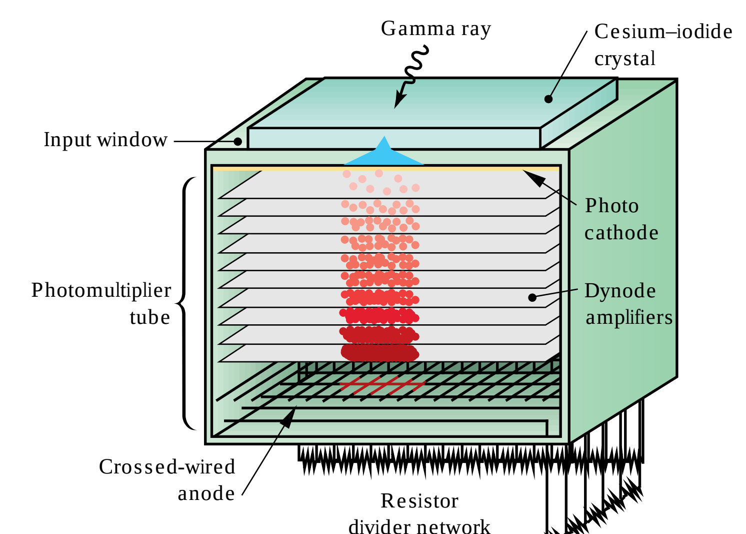
Converting the signal to a visual image requires a position-sensitive detector. Moreover, the position resolution must be comparable to the mask hole size; otherwise the pattern washes out. Because typical position-sensitive detectors (known as Anger cameras) for gamma rays of energies from 20 kiloelectron volts to greater than 1 megaelectron volt have position resolutions of the order of 1 cm, an imager must be quite large to have a reasonable number of pixels across the detector. An imager made with such a detector must also have a long focal length to achieve even modest position resolutions at the source

Our development of a gamma-ray detector with a position resolution of about 1 mm allowed the full exploitation of the coded-aperture technique in a compact system. In the schematic of the detector at the left, a position-sensitive photomultiplier tube is combined with a thin cesium–iodide crystal. When a gamma ray hits the crystal, it causes a brief flash of light, which is converted to an electronic signal by the photomultiplier tube. The tube is unique in that it allows the position of the light flash to be determined from its four output signals. The amount of light is proportional to the energy of the gamma ray and is also measured by the photomultiplier tube. The 4- × 5-cm active area of the detector yields about 40 pixels across its face, allowing for a mask pattern about 20 × 20 pixels (ideally, one oversamples by a factor of two.)



Uniformly redundant-array coded apertures produce an image by having each source pixel cast a unique mask shadow pattern on the detector. The mask is four times the area of the detector. On the left is the system response for a source in the center of the field of view. On the right, is a response for a source near the left edge of the field of view.

This schematic of the GRIS detector shows how it locates gamma radiation. A sodium-doped cesium–iodide crystal emits a flash of light when struck by a gamma ray. This light is converted to electrons and amplified by the photomultiplier tube on which the crystal is mounted. The tube uses a unique mesh dynode structure and a crossed-wire anode to determine the location of each event over the face of the tube.



monitors the radiation from each radioactive component is desirable. However, such a level of security is not always possible. Particularly in establishing an interim storage area, the costs and time required to make individual security monitors for each location can be prohibitive. However, the need for such facilities will be particularly important as U.S. and states of the former Soviet Union dismantle nuclear warheads. In this case, a GRIS-type imager can be a relatively inexpensive and very rapid way to establish inventory control.

Although we have not fielded such an application, the implementation is straightforward. The gamma-ray imager is installed so that it can "see" all sources, and a baseline image is taken. Then, the imager is set on a timer to take that image over and over again. A mathematical comparison of each successive image to the original can be used to sound an alarm should something be moved; we developed suitable algorithms to do this in the course of analyzing the Peacekeeper data. The advantages of using an imager in this case are that it can be set up very quickly, personnel need not leave the room, and visible light is not required.

Locating SNM in Process Plants

GRIS has been demonstrated at two U.S. gaseous diffusion, uranium-enrichment plants—K-25 at Oak Ridge, Tennessee, and the Portsmouth plant near Portsmouth, Ohio. The images we obtained from these plants demonstrate the utility of gamma-ray imaging in a number of complex situations.

Gaseous diffusion is used to separate the useful uranium-235 isotope from the predominant uranium-238 isotope present in natural uranium. Uranium-235 is the fissionable material used both as nuclear fuel in reactors and as weapons components. In the gaseous diffusion process, uranium metal is combined with fluorine to make uranium hexafluoride (UF_6), which is a

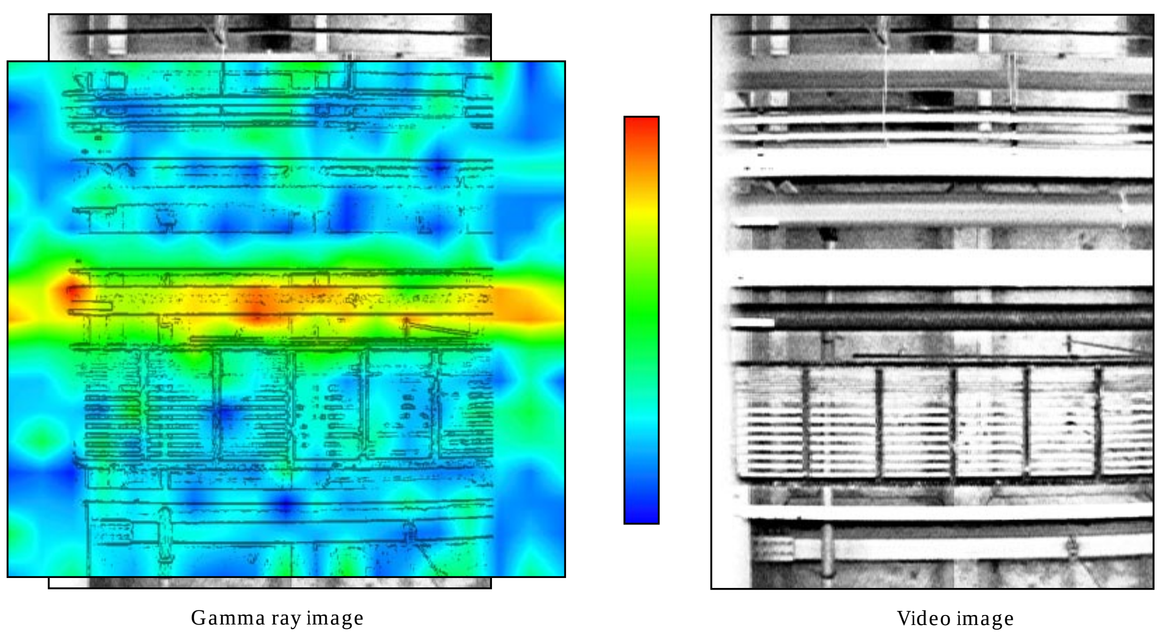


Figure 6. Video (right) and composite gamma-ray/video overlay (left) of a contaminated pipe at the K-25 gaseous diffusion plant at Oak Ridge. The gamma-ray image clearly shows which of the pipes overhead is contaminated.

gas at elevated temperatures. Separation takes advantage of the fact that the gas, composed of the lighter uranium-235 isotope, diffuses at a slightly higher rate than the gas containing heavier uranium-238. The UF_6 is enriched in heated equipment and piping contained within insulated housings.

Occasionally, because of leakage of wet air or environmental changes in the housing, solid UF_6 deposits develop. Such deposits routinely occur in an operational plant and must be located and identified. This task is not trivial. Many different pipes share the same heat shielding in the miles of pipe galleries. To enter these enclosures, workers must don protective gear to avoid radioactive contamination from possible residual leaks from more than 30 years of operation. In addition, some facilities—including those going through decontamination and decommissioning—contain highly enriched uranium, which could cause a criticality accident if a deposit of uranium-235 becomes too large.

Current characterization of the uranium deposits in these plants is performed primarily using sodium-iodide-based radiation detectors. These are carried through the plant, and readings are taken at fixed intervals to map the radiation fields. If a "hot" region is found, workers must either enter the heat-shield-enclosed area or take many measurements with a collimated version of the detectors to try to locate the deposit. Both are time-consuming, expensive, and potentially hazardous tasks. GRIS avoids these problems by generating images from outside the heat shielding that definitively locate the hot material.

Our first use of GRIS in this environment was at the idled K-25 plant. GRIS was mounted on a cart to look up some 4 m at the pipe galleries overhead that range in width from a few meters to more than 12 m across. Each gallery, enclosed in heat shielding, contains pipes ranging in size from a few centimeters to more than a meter in diameter. The building had been entirely scanned by K-25 personnel walking under and on top of the galleries using an uncollimated radiation detector; the results from this survey were used to select sites of interest for application of the GRIS imager. The first image was a pipe used to exhaust the building's many vacuum pumps. We selected this pipe because the lack of heat shielding allowed us to verify that the gamma-ray and video images identified the hot pipe (Figure 6).

A second exposure was taken of a more representative location where an isolated deposit of material was known to exist. After an initial wide-field image was taken to see the complete deposit, we moved the imager under the hot spot and zoomed in on this region. Figure 7 shows a deposit in a 1.2-m-diameter pipe, where an expansion joint exists. The deposit is probably uranium oxide, formed when a leak developed in the expansion joint.

The images from the next location, although they are nearly featureless, clearly demonstrate the power of the technique. We took GRIS to a location where we expected to find a series of radioactive pipes running the length of the area covered in the image. Two exposures were needed to cover the full width of the 12-m-wide pipe gallery. The resulting images (Figure 8) revealed only a few hot spots, not the contamination expected from the standard analysis.

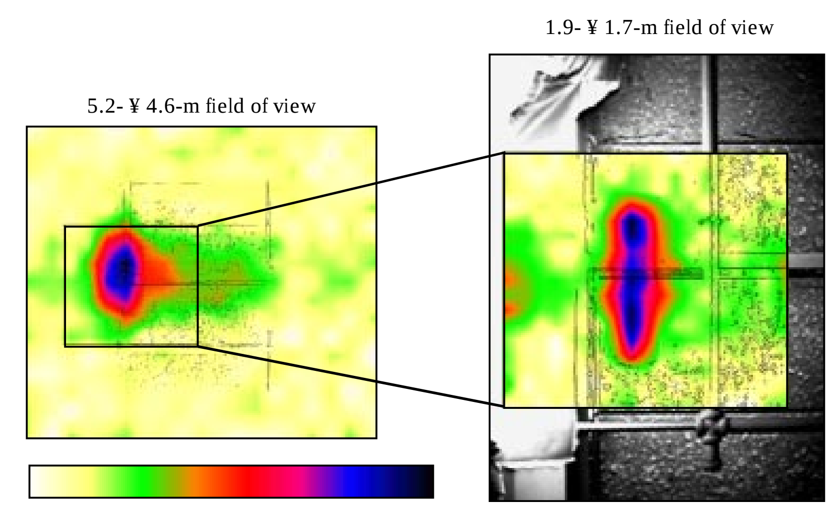


Figure 7. Overlay of gamma-ray intensity as a function of position for wide-field (left) and zoom views (right). The gamma-ray image on the right, which is overlaid on a video image, was taken after the imager was moved under the hot spot initially identified from the image on the left. The radiation is emitted by a uranium deposit inside a 1.2-m-diameter steel pipe hidden behind heat shielding.

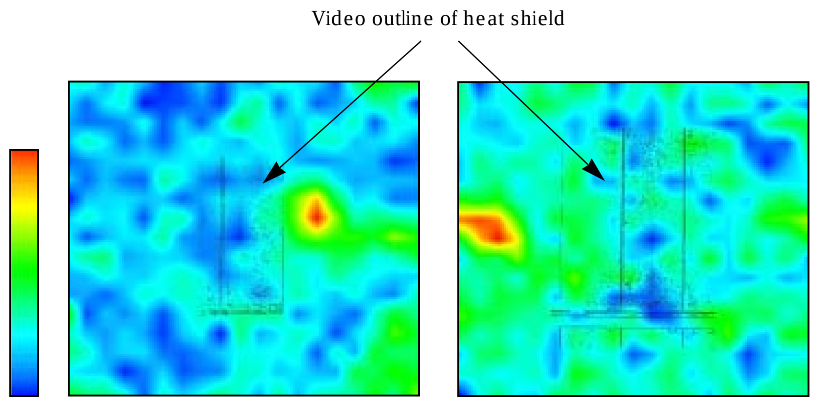


Figure 8. A powerful example of the advantages of gamma-ray imaging, this image shows little contamination within the heat shield. Instead, the image shows that the contamination is in a nearby area.

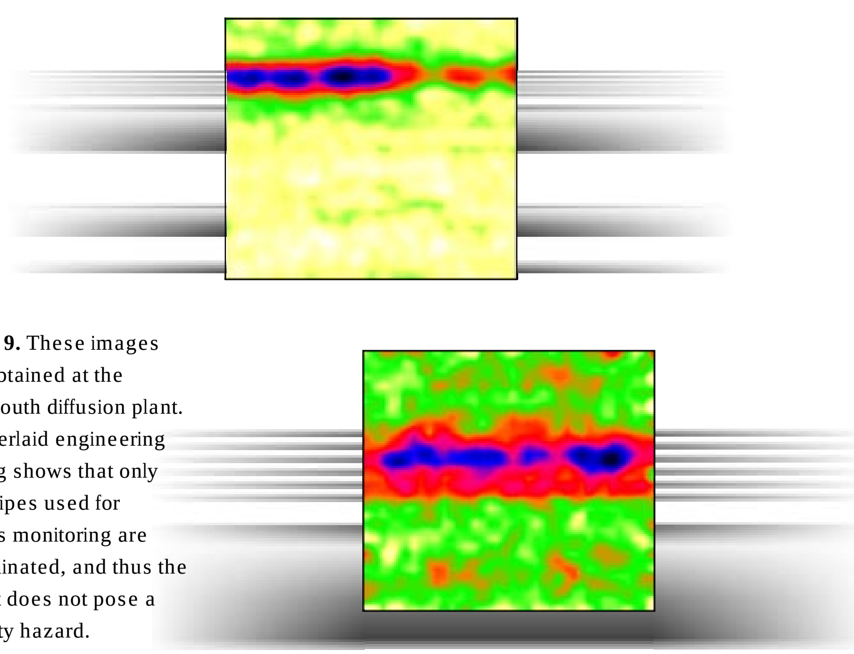


Figure 9. These images were obtained at the Portsmouth diffusion plant. The overlaid engineering drawing shows that only small pipes used for process monitoring are contaminated, and thus the deposit does not pose a criticality hazard.

Following the K-25 visit, we took GRIS to the diffusion plant at Portsmouth. There we made two measurements of note. The first was taken to determine the exact location of a known deposit of highly enriched uranium. There were concerns that a criticality accident was possible if the deposit was in the main 20- or 30-cm-diameter pipes of the gallery. One image (Figure 9) shows that this was not the case and that the deposit was in much smaller instrumentation pipes. The second image (Figure 10) shows a deposit in a diffuser cell, a large heat-shield-enshrouded area about 25 m × 6 m. The image, overlaid onto a plant blueprint, clearly shows plant personnel where the deposit is located before someone enters a cell.

In addition to its usefulness to personnel who operate and clean up these facilities, gamma-ray imaging also promises to be very useful to the International Atomic Energy Agency's safeguards programs for monitoring reactor fuel production facilities around the world. One of the major uncertainties in inspecting such plants is the nuclear material remaining in the process equipment. The ability to take images of both deposits and gas in the equipment can significantly increase the accuracy of the estimates of the quantity of material present. In addition, the settings of valves and the flow of gas through a plant can be independently verified.

Other Applications

Other GRIS applications are being considered. For example, a private company working for the nuclear power industry is studying the feasibility of using the gamma-ray/video overlay imagery to direct workers away from

areas of particularly intense radiation.

In a similar application, GRIS could be used to find "lost" radioactive sources. Intense radioactive sources are sometimes used for materials characterization in construction and maintenance. If these sources are lost from their holders, they present a significant radiation hazard.

Finally, nuclear medicine could potentially benefit from application of a gamma-ray imager with capabilities similar to those of GRIS. The gamma emissions of several well-known radionuclides used in medicine fall within the range of energies GRIS exploits.

Spectrometry and the Stars

In addition to the programmatic imaging work described so far, we have collaborated with the University of California at Berkeley and at Santa Barbara to combine our unique detectors with a novel implementation of coded-aperture imaging to build the world's highest angular-resolution, gamma-ray telescope (Figure 11). Constructed with Laboratory Directed Research and Development funding, GRATIS (gamma-ray arc-minute telescope imaging spectrometer) comprises 36 individual imagers specifically tailored to work in the astronomical energy band from 20 to 200 keV. Our high-position-resolution detectors combined with a 4-m focal length allow GRATIS to achieve an unprecedented angular resolution of 2 arc-minutes (arc-min). By providing each of the 36 detectors with its own one-dimensional coded-aperture mask (Figure 12), we provide better overall performance at lower manufacturing cost than a more conventional telescope of similar size. Every one of these

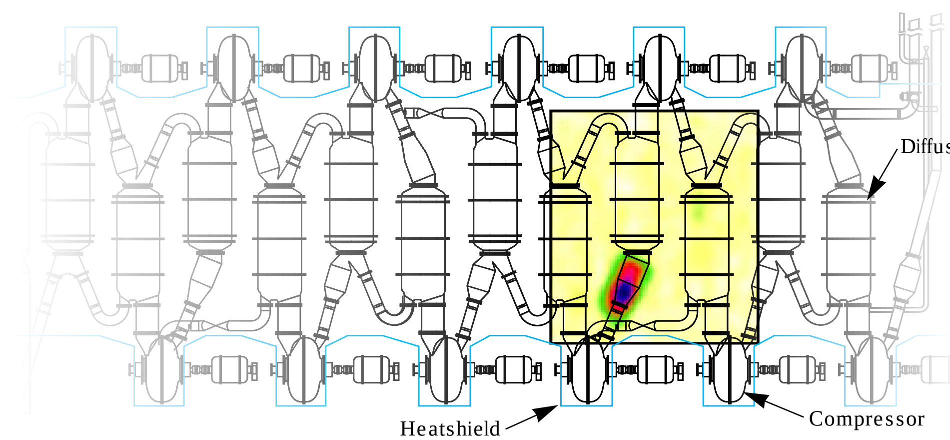


Figure 10. Overhead view of process equipment at the Portsmouth, Ohio, facility overlaid on engineering drawings of the area. The gamma-ray image clearly localizes the deposit to one length of pipe. The cylindrical diffusers are spaced about 2 m apart.

Figure 11. GRATIS is held by the launch vehicle as it is transported to the launch site at Palestine, Texas. Although significantly larger in size, the telescope is operationally very similar to the GRIS system developed for LLNL programmatic work.

telescopes produces a one-dimensional picture of the sky; the images are combined mathematically to give a full two-dimensional image.

GRATIS provided a special challenge because viewing radiation from the cosmos requires that the telescope be above all but the most tenuous portions of the atmosphere. Thus, GRATIS is hung from a helium balloon, and the pointing system is operated by remote control. To keep a source in the center of the field of view requires that the pointing system be stable to 1 arc-min. To reconstruct the images properly requires that we know where the telescope is pointing to an even higher accuracy, which is obtained by using a coaligned star camera and a gyroscope system that allow us to reconstruct the pointing after the flight to approximately 20 arc-seconds.

GRATIS was first flown successfully in spring 1994 from Palestine, Texas. During its 11-hour flight, we observed three scientific targets: Cygnus X-1, Cygnus X-3, and Her X-1; we are in the process of analyzing the data. Meanwhile, GRATIS is on the ground in Alice Springs, Australia, ready for its next flight this fall, when we will observe the center of our galaxy.

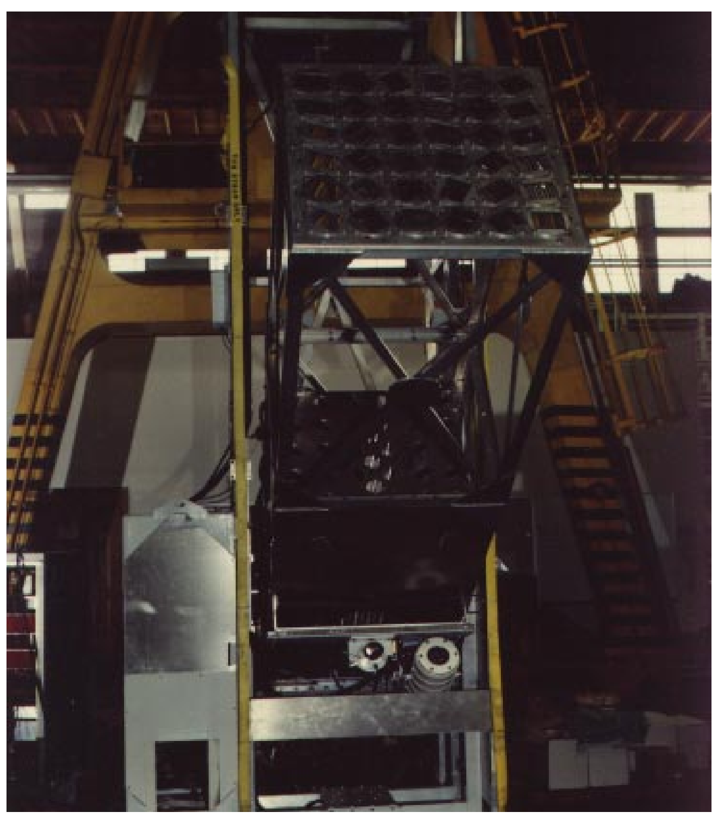


Figure 12. Close-up view of the GRATIS mask plane. There are 36 individual one-dimensional masks, each rotated with respect to all the others. The resulting rotated individual images are combined mathematically to give a two-dimensional image.

Continuing Development

Our ongoing efforts in gamma-ray imaging include improvements in the detectors and in image-generation techniques. We are building a new detector that takes advantage of the rotated one-dimensional imaging used in GRATIS to extend the useful energy range of this work and to significantly lower the cost per unit area of detector. Called the Gamma-Ray Bar Imaging Telescope (Figure 13), GRABIT achieves these advances by separating the energy- and position-resolving functions of the detector.

A series of scintillator bars is mounted on a nonimaging photomultiplier tube. Most of the scintillation light from a gamma-ray event is collected by this tube, the signal from which is used to determine the energy of the gamma ray. To determine where the gamma ray hits, we pick off a small fraction of the light with a fiber-optic bundle and transmit it to an imaging device such as the photomultiplier tube used in GRIS. By observing which fiber end glows and knowing its arrangement on the imager, we can determine which bar is hit by the gamma ray.

To understand how this feature improves the system performance, note that the GRIS detectors determine an event's position by finding the center of the light footprint at the input to the photomultiplier tube. However, as one makes the crystal thicker, the average event size will increase because the light spreads out more before it reaches the tube, thus decreasing the ability to find the flash location. By dividing the crystal into bars, we remove this problem: the position resolution is limited only by the width of the bar. The costs are lower because the unit area of nonimaging tubes is only about one-tenth that of imaging tubes. By reading out a bar with a fiber optic, we effectively increase the expensive imager area some 40 times. We are currently assembling a laboratory prototype of this detector system.

Our previous imaging work clearly demonstrates the advantage of generating images using different parts of the energy spectrum. Unfortunately, the energy resolution of the cesium iodide currently used is only about 10%, not enough to distinguish commercial (reactor-grade) plutonium from weapons-grade plutonium. Higher energy resolution makes this distinction possible because it separates the different gamma-ray energy lines of the various plutonium isotopes.

Another advantage of improved energy resolution is the ability to obtain information from a strong source that lies behind a significant thickness of other material. In such a case, the overlying material acts much like the diffuser in front of a light, scattering the radiation and blurring the image. However, unlike visible light, the scattered radiation at these higher energies is also shifted to a lower energy. By restricting the image to photons, which are in a known spectral line from the source, one can remove this type of blurring. With these advantages in mind, we plan to develop position-sensitive, solid-state detectors such as germanium- or zinc-doped cadmium telluride, both of which provide much better energy resolution.

Because it was developed for gamma-ray astronomy, the coded-aperture imaging technique as it has been applied by others assumes that the source is very far away. In the close imaging work we have described, this assumption does not hold. We have applied several techniques to compensate for this difference and are continuing to make improvements to the imaging techniques.

We are investigating the application of more advanced imaging algorithms to the coded-aperture data. These techniques rely on iterative approaches, based on Bayesian logic, that seek the

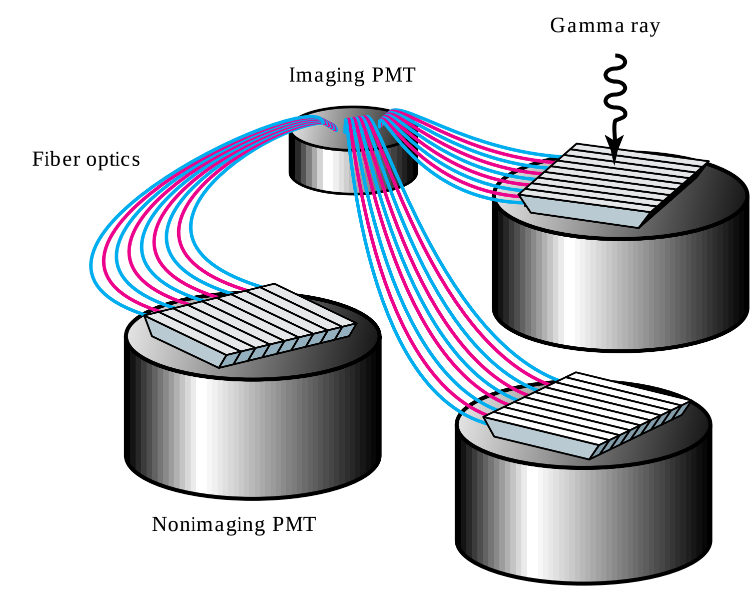


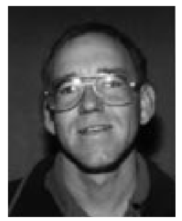
Figure 13. This schematic of the GRABIT detector shows how the position- and energy-resolving functions are separated. The light collected from the bottom of the bar arrays provides the energy information for an event. The small amount of light transported to the image tube by fiber optics allows one to determine which bar was struck.

best image on the basis of prior knowledge of the source and instrument. We are already applying one such technique, known as maximum entropy, to obtain the two-dimensional image from our set of one-dimensional images in GRATIS data. This technique selects the “flattest” image (the one with the least structure) commensurate with a statistical goodness-of-fit indicator based on the known instrument properties. In this case, we assume that the scene nature supplies will not have a lot of rapid variations in counts versus position.

Key Words: gamma rays—gamma-ray arc-minute telescope imaging spectrometer (GRATIS), gamma-ray astronomy, gamma-ray bar imaging telescope (GRABIT), gamma-ray camera, gamma-ray imaging spectrometer (GRIS); special nuclear material (SNM); Strategic Arms Reduction Treaty (START).

For further information contact Klaus-Peter Ziock (510) 423-4082 (kpziock@llnl.gov).

About the Scientist



KLAUS-PETER ZIOCK came to Lawrence Livermore National Laboratory 10 years ago as a post-doctoral scientists in V Division. Since 1988, he has been a staff scientist in V Division’s Laboratory for Experimental Astrophysics. He received his Ph.D. in Physics from Stanford University in 1985 and his B.A. from the University of Virginia in Physics and Chemistry in 1978. His primary area of scientific research is low-energy gamma-ray astrophysics. He has been involved in the development of GRIS, GRABIT, GRATIS, GRB (a gamma-ray burst detector), and SXRP (an x-ray polarimeter).

His numerous publications to date (about 40) are in the area of atomic physics, including high-atomic-number systems, positronium spectroscopy, and instrumentation development for astrophysical research.

Positioning Health Care Technologies for the Needs of the 21st Century

LAST year, expenditures for health care reached about 14% of the U.S. gross domestic product, or a staggering $1 trillion. Many experts agree that the annual bill for health care will grow even larger in the next few years. Moreover, the effects of escalating costs extend beyond the domain of health care per se; they are reflected in added costs of U.S. manufactured products, in labor–management relations, and in many other ways that are not always obvious.

Can the trend be reversed? In some industrial fields, such as electronics, technological innovation is part of an effective strategy to reduce costs without decreasing quality. In marked contrast, investment in technology development accounts for only a tiny fraction of national health care spending, and even medical research and development represents only about 3% of its overall spending. LLNL is marshaling its world-class technology base to help the nation to contain escalating costs for health care.

Over the last decade, a broad spectrum of Livermore research projects has explored new or improved health care technologies that can potentially reduce health care costs. We are developing better imaging systems, such as pulsed x-ray lasers, improved instrumentation and information systems, and advanced sensor and detection systems, such as accelerator mass spectrometry. Other efforts around the Laboratory—often interdisciplinary and involving external collaborators—are already having an impact on the frontiers of research or treatment in maladies such as cancer, heart disease, stroke, diabetes, osteoporosis, and repetitive strain injury as well as in specialties such as ophthalmology, dentistry, and prosthesis design and manufacture.

To coordinate these activities, we established the Center for Healthcare Technologies at LLNL. Its goals are to:

- Continue to pursue the high-quality science and technology efforts that are already directed toward improved health care.
- Become better known in the health care community.
- Propose LLNL initiatives in health care that are more integrated than others’.
- Promote a national focus for federal activities in health care technology.

The Center has an external advisory committee of senior health-care professionals and an internal coordinating and advisory committee.

Perhaps most importantly, the Center represents a single point of contact through which interested organizations outside the Laboratory can gain access to the LLNL individuals or groups that are most appropriate for addressing specific health-care needs.

Our current strategy entails three phases of activities, which we have launched in parallel.

In Phase I, we are delivering results on current projects and gaining recognition for our accomplishments in health-care technologies. More than two dozen projects at the Laboratory are currently funded at about $6 million per year. The box illustrates developments from one of our most recent and exciting initiatives—the prevention of hemorrhaging in stroke-damaged blood vessels.

During our first year, we contacted more than 80 medical, industrial, and governmental organizations. We are identifying and coordinating projects that extend LLNL core competency in the multidisciplinary focus of biotechnology, helping to meet future DOE Defense Program requirements and providing cost-effective medical technology at the same time.

In Phase II, we are initiating and participating in larger health-care projects through multidisciplinary teams of collaborators. For example:

- Digital Mammography Systems is a proposed team of military, government, and industrial partners led by an Army medical center. Livermore would be responsible for system integration at 14 sites, for data integrity and archiving, and—with Sandia National Laboratories, Livermore—for new algorithms for computer-assisted diagnosis.
- This year, we have been asked to define and coordinate potential roles for the DOE laboratories in Testbed’95, which will set up a telemedicine system. The Center is a partner in the health-care working group of the National Information Infrastructure Testbed (NIIT), a consortium of telecommunications, computer, and other companies. In September 1994, we participated in a successful, one-day NIIT telemedicine demonstration, Testbed’94, held at the Congressional Office Building in Washington, D.C.