DOE/NN/ACNT-95D

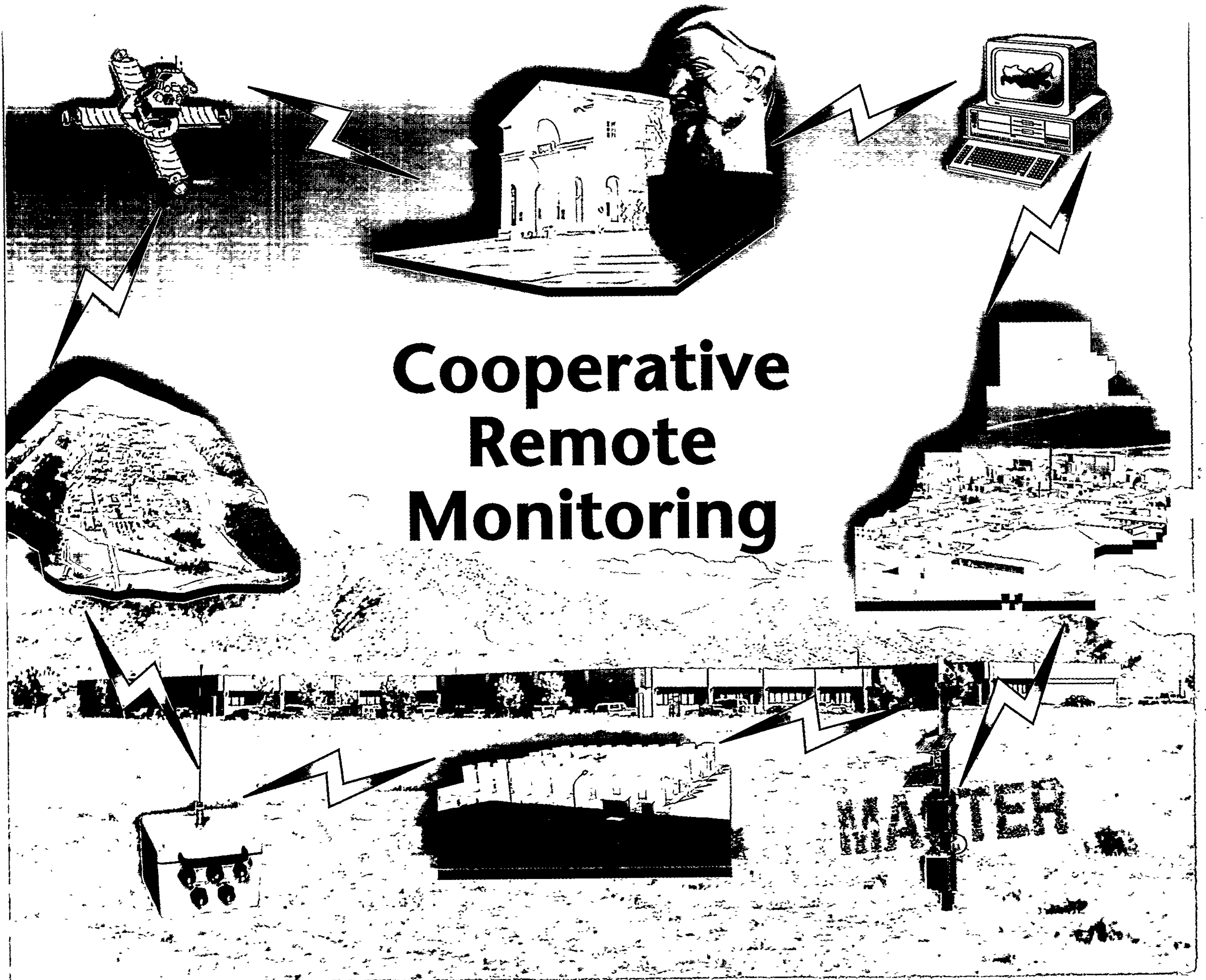
Department of Energy

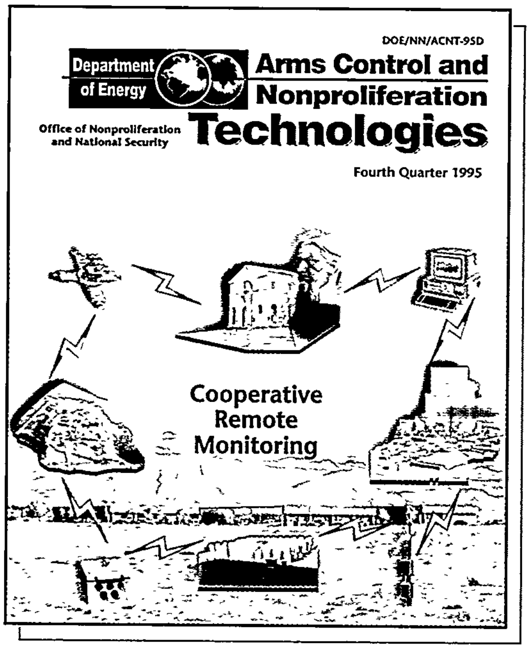
Arms Control and Nonproliferation Technologies

Office of Nonproliferation and National Security

Fourth Quarter 1995

Cooperative Remote Monitoring





About the cover

The Department of Energy's (DOE) Cooperative Remote Monitoring programs integrate elements from research and development and implementation to achieve DOE's objectives in arms control and nonproliferation. Clockwise, starting at the top, we show four sites described in this issue: the Kurchatov Institute, Argonne-West in Idaho, the Embalse Nuclear Power Station in Argentina, and the Y-12 Plant at Oak Ridge. The four hardware items alternating between these sites are among many described in this issue that play roles in the programs. Sandia National Laboratories' Cooperative Monitoring Center is in the background.

About the card and envelope

It is extremely important that the enclosed Reader Verification card is returned to the ACNT office. If the card is missing, please call at 510-424-6100.

The purpose of *Arms Control and Nonproliferation Technologies* is to enhance communication between the technologists in the DOE community who develop means to verify compliance with agreements and the policy makers who negotiate agreements.

Published by
U.S. Department of Energy, Office of Nonproliferation and National Security
Joan Rohlfing, Director

DOE/ACNT Project Manager
Michael F. O'Connell

Issue Editor
Carl Friesen

Scientific Editor
George Staehle

General Editor
Gorgiana M. Alonzo

Art/Design/Layout/Copyediting
Kirk Hadley, Lead Designer
Nancy Compton
Carolin Middleton
Kelly Spruiell
Leonard Walton
Molly Glen, Sandia National Labs
Dave Cunnington, Sandia National Labs

Production Office
Arms Control and Nonproliferation Technologies
Lawrence Livermore National Laboratory
7000 East Ave. (L-389)
Livermore, CA 94550

Correspondence
George Staehle or Gorgiana M. Alonzo

Phone
(510) 424-6100
Fax
(510) 423-9091
E-mail
acnt@llnl.gov

Arms Control and Nonproliferation Technologies

Fourth Quarter 1995

Contents Page

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

Cooperative Remote Monitoring—Trend for Arms Control and Nonproliferation

The Risk

Secretary Hazel O'Leary, in remarks at the International Atomic Energy Agency's (IAEA) General Conference, addressed a new paradigm where nuclear risks created by the Cold War are being defused at the same time a darker nuclear danger is emerging: the proliferation of and the loss of control of fissile materials. This danger includes the proliferation of all weapons of mass destruction—nuclear, biological, and chemical—and the missiles and other delivery systems for such weapons.

Minimizing the Risk

The lessening of superpower rivalries has produced a climate more conducive to using technology to verify bilateral, regional, and multinational arms control agreements. The "trust but verify" position has evolved to cooperative technical solutions for the on-site verification of such agreements.

The Department of Energy's (DOE) approach to strengthening nonproliferation through cooperative remote monitoring is illustrated in Fig. 1. The inner two rings represent DOE's role in developing cutting-edge technology to support cooperative monitoring agreements. Remote monitoring—one aspect of DOE's cooperative monitoring research program—is accomplished by deploying sensors and cameras that can operate unattended at the location of interest to detect and monitor declared activities. This information is recorded and can be accessed from anywhere in the world by authorized individuals. DOE's research focuses on developing low-cost, flexible, and robust remote monitoring systems that can be easily customized to monitor numerous types of facilities and activities, including the tracking of items of interest from one location to another.

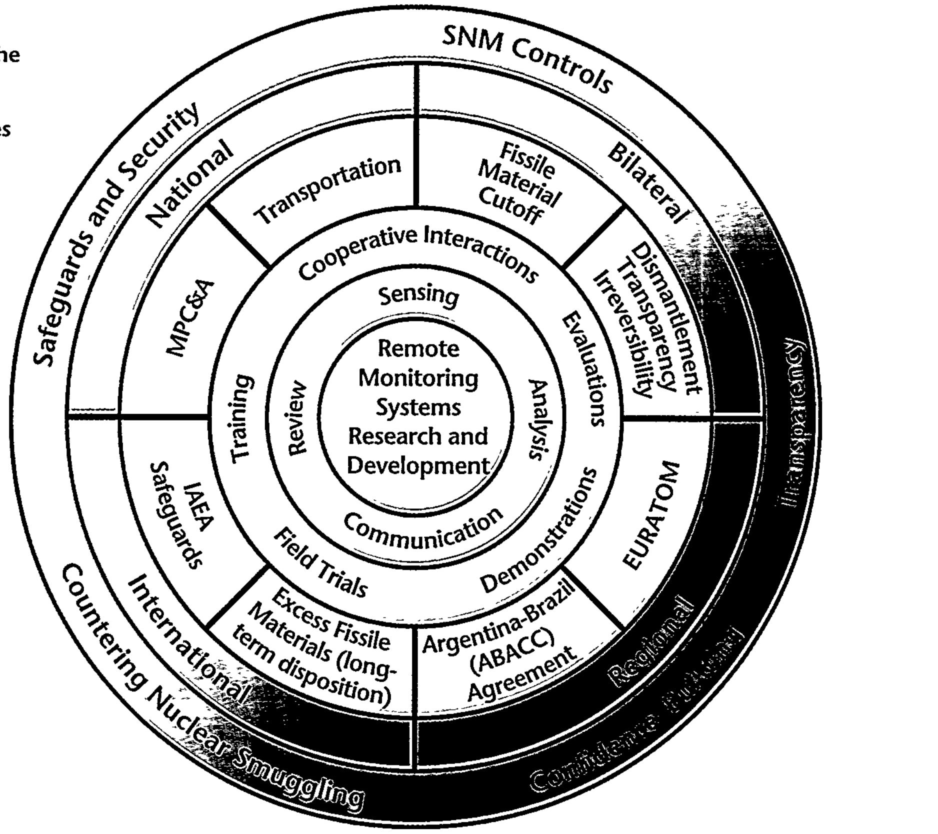
The middle two rings represent DOE's implementation of remote monitoring technologies through cooperative interactions, evaluations, demonstrations, field trials, and training.

Pictured below: Department of Energy (DOE) Secretary Hazel O'Leary met with Academician Nikolai Ponomorov-Stepnoi during the Cooperative Remote Monitoring Demonstration in March 1995.

Developing innovative technologies to meet the future needs of remote monitoring

Implementing remote monitoring technologies

Improving the capabilities to prevent the proliferation of weapons of mass destruction



▶ **Figure 1.** DOE sponsors the research and development of technologies for cooperative remote monitoring systems to support national, bilateral, regional, and international nonproliferation objectives.

DOE sponsors the International Remote Monitoring Program, tasked with working closely with international agencies that will use remote monitoring to enforce safeguards agreements.

The outer two rings represent the objectives of DOE's cooperative remote monitoring programs: building confidence, promoting transparency, improving controls of special nuclear materials (SNM), countering nuclear smuggling, and enhancing safeguards and security.

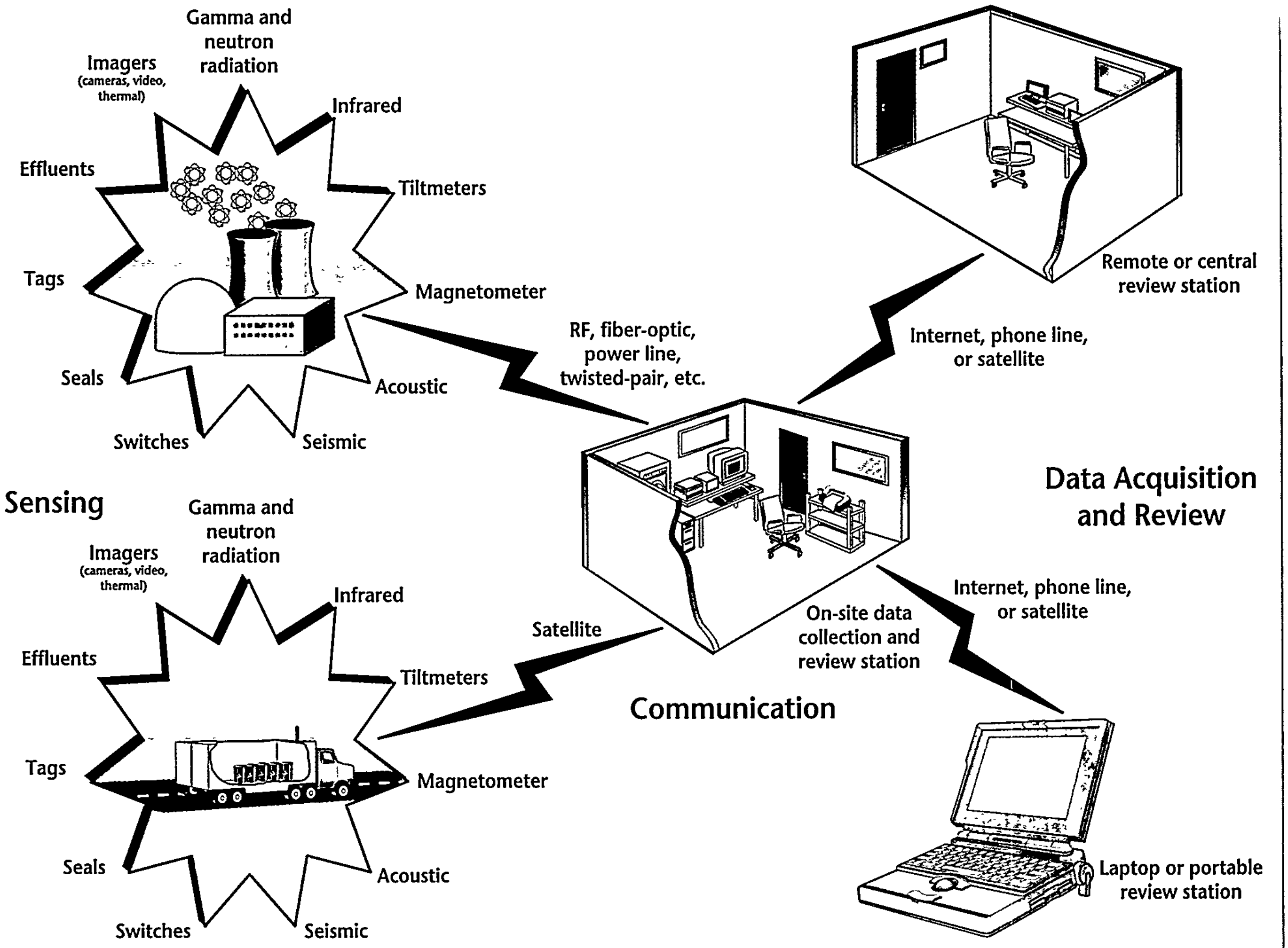
In This Issue

This issue of *Arms Control and Nonproliferation Technologies* highlights DOE's technology development efforts related to on-site remote monitoring and also projects associated with DOE's international remote monitoring programs. In addition, four DOE national laboratory projects are described where remote monitoring systems for practical applications have been successfuly implemented. For more information, contact any of the individuals listed below. ❖

CONTACT: **Mike O'Connell**
DOE/Office of Research and Development
PHONE: 202-586-1766
FAX: 202-586-2612
EMAIL: Mike.O'Connell@HQ.doe.gov

CONTACT: **Ken Sheely**
DOE/International Safeguards Division
PHONE: 202-586-1620
FAX: 202-586-0936
EMAIL: ken.sheely@hq.doe.gov

CONTACT: **Ed Fei**
DOE/Office of Arms Control and Nonproliferation
PHONE: 202-586-2124
FAX: 202-586-2323
EMAIL: ed.fei@hq.doe.gov



Modular Integrated Monitoring System (MIMS)

The reliability of new technologies and the current trend of using new technologies to implement international agreements make it practical to use on-site, unattended remote monitoring to augment or even replace on-site inspections. One example of unattended remote monitoring implemented for the latter reason is Project Dustcloud (see page 30). Implementing systems of this nature is technically challenging because of the differing requirements of each monitoring scenario. For this reason, the Department of Energy (DOE) is building the foundation for flexible and robust unattended remote monitoring systems that can be easily adapted to as many monitoring scenarios as possible. The Modular Integrated Monitoring System (MIMS) research and development (R&D) program is this foundation.

Pictured above: The Modular Integrated Monitoring System (MIMS), based on a common architecture, includes a sensing component, a communications component, and a data acquisition-and-review component.

MIMS Architecture

The MIMS architecture includes three major components: sensing, communication, and data acquisition and review (see picture above). The sensing component consists of sensors interconnected by a commercial Local Operating Network, or LON. By exploiting LON technology, sensors are connected to each other

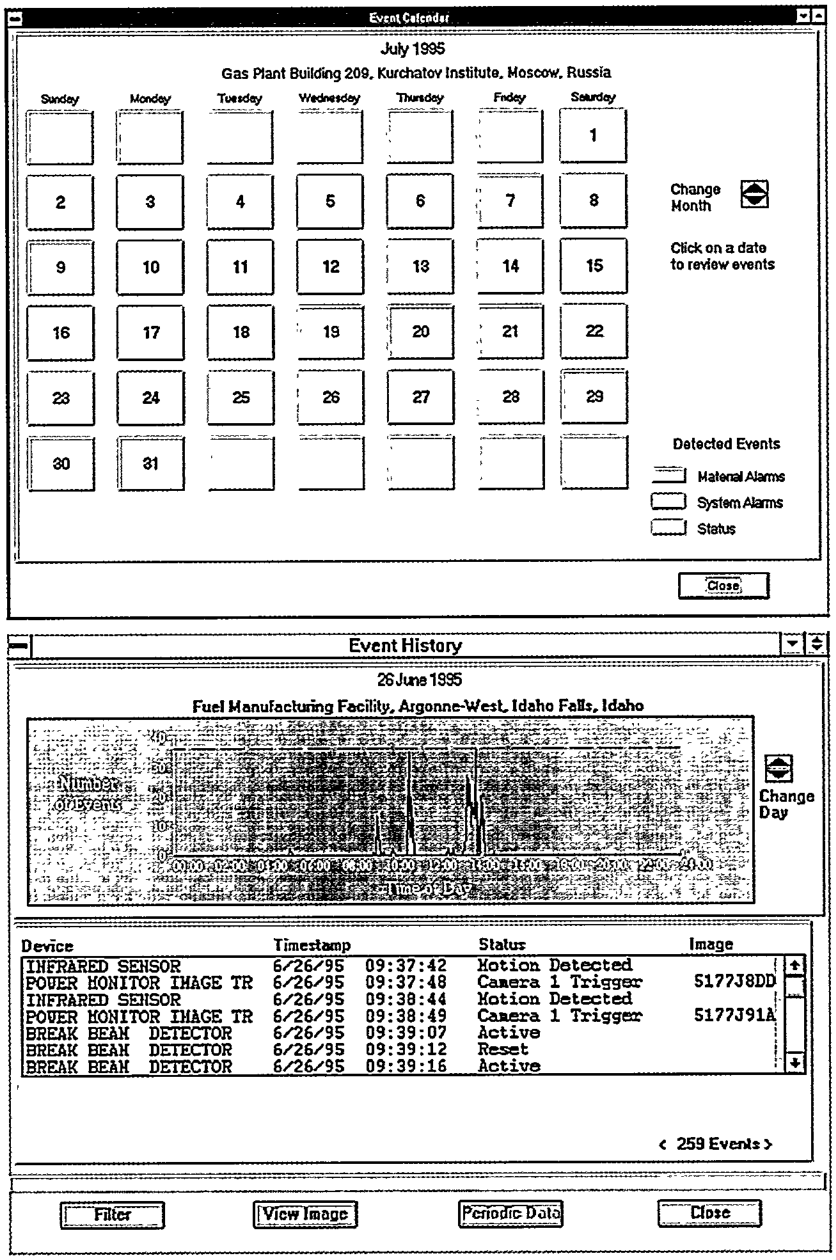
DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

through an assortment of media (e.g., twisted-pair wire, coaxial cable, AC power lines, radiofrequency signals, fiber-optic lines). Authentication hardware and soft-ware ensure integrity of the data and images collected by the sensors. A network management system configures and evaluates the performance of the sensor network. The combination of these modules creates an adaptable, on-site sensing system. The MIMS architecture is flexible enough to handle a variety of sensor types, allowing for easy adaptation to future nonproliferation monitoring scenarios.

The communication component incorporates commercially available hardware and software to connect local monitoring sites with remote sites using telephone lines, the Internet, and satellites. TCP/IP—which stands for Transmission Control Protocol/Interface Protocol—together with exportable authentication, encryption, and key management systems create a media-independent, communication network compatible world-wide.

MIMS efforts include developing a robust data acquisition system that can quickly adapt to data formats of existing sensors and cameras as well as to those anticipated for the future. This data acquisition system interfaces with the sensor LON to capture and store sensor and image data, events, and state-of-health information. Because the data acquisition-and-review system is easily re-configured, it is being developed as a single, scalable system, minimizing development costs while maximizing functionality.



▲ **Figure 1.** Sandia National Laboratories (SNL) developed two-dimensional displays to show data gathered by sensors for cooperative remote monitoring scenarios.

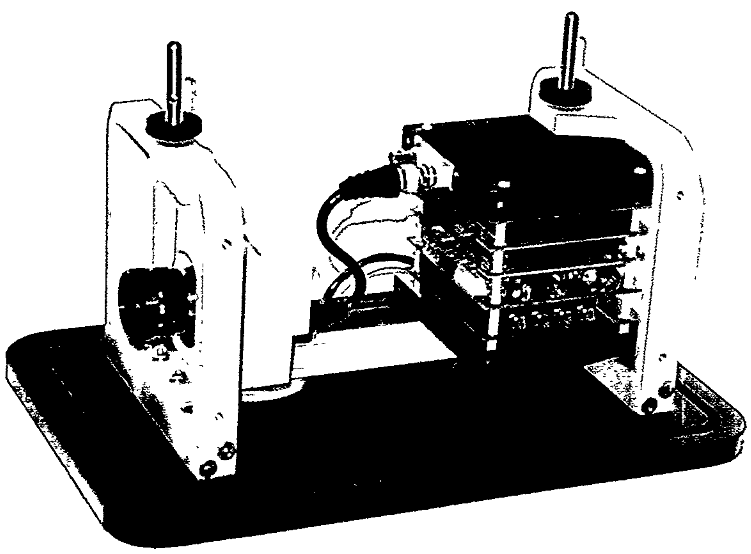
Advanced Data Visualization

Advanced data visualization concepts are being researched to identify efficient and effective methods for displaying sensor information. Currently, site information and sensor arrangements are displayed by means of site pictures and sensor layout diagrams. Event information is depicted in calendar and graphical form to quickly direct users to days and times when specific types of events have occurred; tables identify occurrence and sequence (Fig. 1). In addition, available images associated with these events can be displayed. Sensor data, such as radiation and temperature information, are displayed in two-dimensional graphs.

Three-dimensional interactive displays that provide more intuitive data visualization are being used commercially in manufacturing, modeling and simulation, and accounting. MIMS researchers are investigating ways to apply these and other advanced data visualization concepts to cooperative remote monitoring.

Analysis

Analysis algorithms to assist users in making decisions based on sensor data are being developed for MIMS. The goal is to reduce the vast amount of data that must be manually reviewed. In most cooperative monitoring scenarios, events, sensor data, images, and state-of-health information are collected continuously. The amount of data associated with this continuous data collection exceeds the amount that any human can effectively and efficiently review without the support of automated analysis capabilities. The MIMS algorithms review state-of-health, event information, sensor data, and images together with known facts about the monitoring scenario to determine if an event is authorized or unauthorized. For example, if a motion sensor trips an alarm in a room, the MIMS algorithms can answer questions that an analyst or inspector might have—verify the state-of-health of the sensor and other related sensors, check to see if entry has been indicated or if other motion sensors have been tripped, analyze images to determine if the motion detected can be verified by change detection algorithms, and check radiation values to determine if materials have been moved.



◀ **Figure 2.** The Image Compression and Authentication Module (ICAM) integrates cameras with compression and authentication algorithms and a control subsystem to support International Atomic Energy Agency (IAEA) requirements for authenticated images.

Sensor Development and Integration

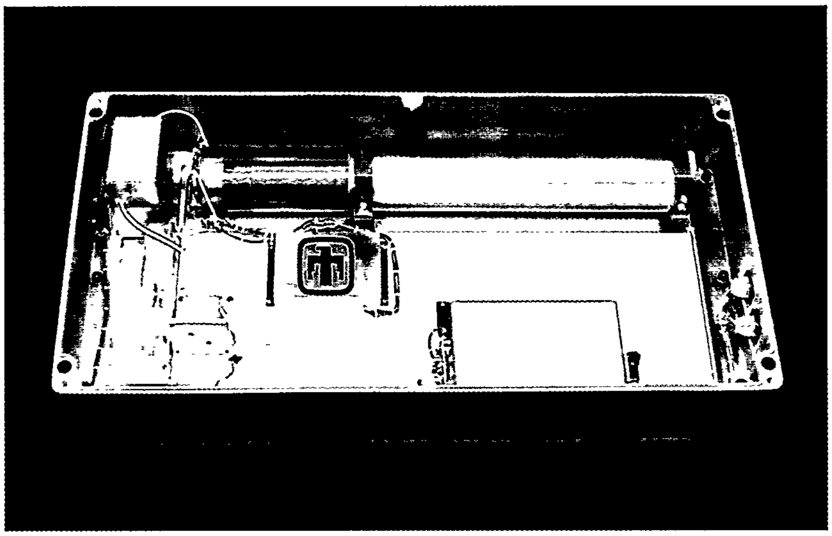
Drawing on many sensor development programs, DOE national laboratories are integrating their available sensors into the MIMS architecture to show the flexibility of and to test and evaluate MIMS. New sensors are also being developed for unique unattended monitoring capabilities. Some of these development and integration activities are described next.

Image Compression and Authentication Module

The Image Compression and Authentication Module (ICAM), developed by Sandia National Laboratories (SNL) as part of the MIMS research program, can be a building block for many digital video-surveillance systems (Fig. 2). The ICAM uses a set of video-compression cards and a controller board that protects the transmission and storage of video images. The ICAM works with both 525-line NTSC and 625-line PAL cameras for U.S. and European compatibility. Interfaced to a MIMS network, the ICAM can receive commands from a central controller or from any sensor on the network. A digital authentication algorithm protects the images as they are transmitted from the cameras to a data storage location.

Nuclear Sensor

SNL's battery-powered nuclear sensor detects intrinsic radiation. The sensor uses a 5 × 30-centimeter NaI scintillator for gamma-ray detection and ^{3}He tubes for neutron detection (Fig. 3). A palmtop computer integrated in the package controls collection and connects to the LON. Separate software compares the triggering data to a library of radiation values to determine the type of the radiation source. Also, a digital geophone sensor that detects vehicle motion is being integrated into the nuclear sensor.

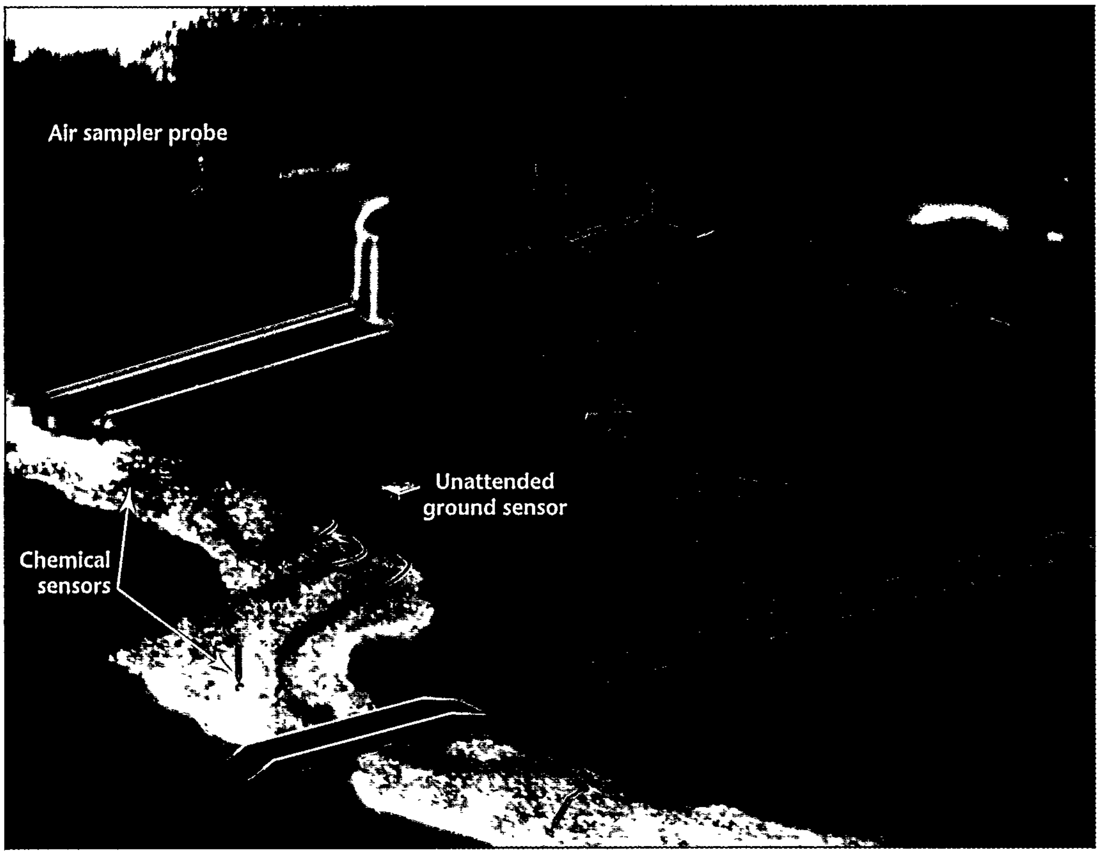


▲ **Figure 3.** SNL developed a nuclear sensor for MIMS integrated with a digital geophone to detect vehicle motion.

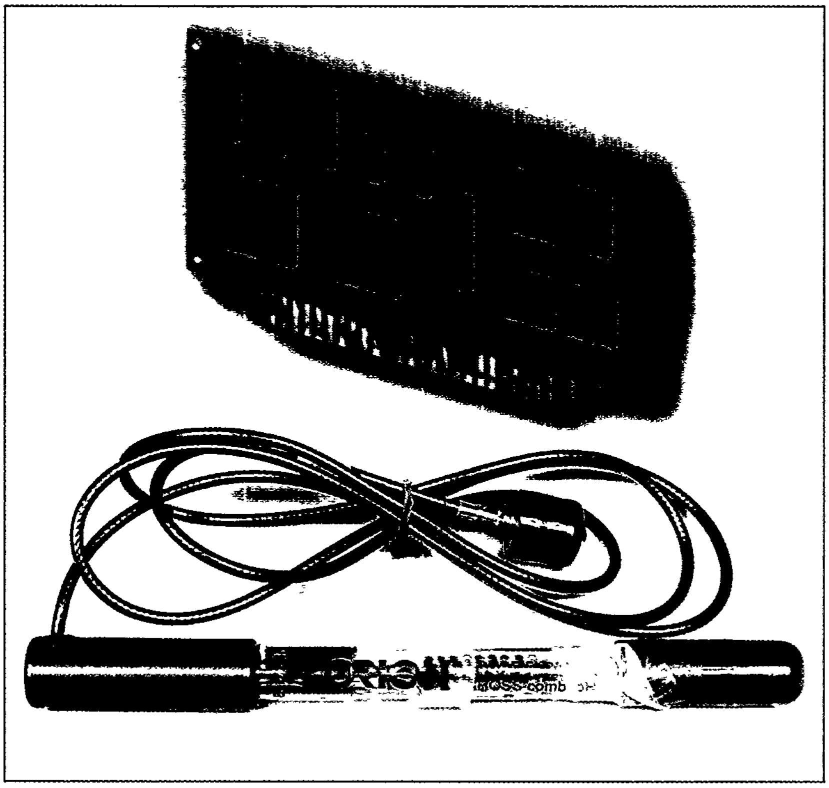
Chemical Sensor Interface

The Chemical Sensor Interface project was initiated to integrate chemical sensors into MIMS networks (Fig. 4). The interface, being developed by Lawrence Livermore National Laboratory (LLNL), will handle commercial units and those sensors developed by DOE national laboratories as prototypes become available.

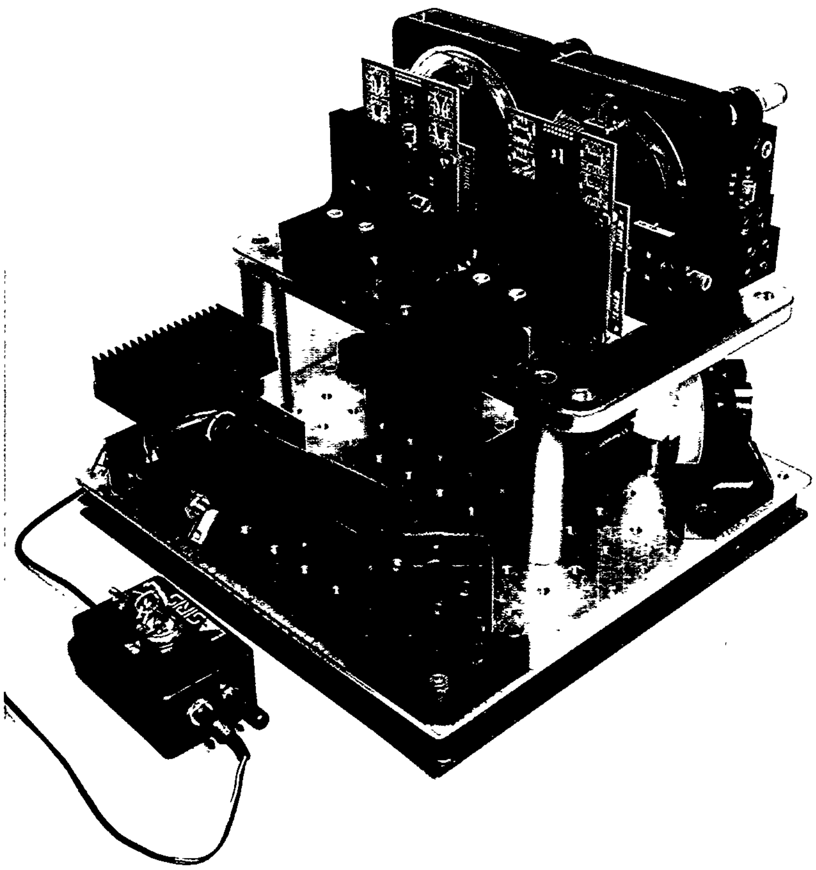
LLNL's intelligent, multi-purpose interface will accommodate a variety of sensors; the interface will acquire signals in various forms, analyze data, and identify



◀ **Figure 4.** Several sensors identifying and measuring chemicals, conductivity, pH, and gases can monitor the discharges from a manufacturing facility, in this case, a chemical plant. The chemical sensors attach directly to a battery-powered, unattended ground sensor system.



◀ **Figure 5.** A MIMS-compatible interface module measures and converts chemical sensor, pH, temperature, and conductivity signals, analyzing and sending these data to the MIMS network.



▲ **Figure 6.** The laboratory prototype of the acoustic spectrometer, when completed, will be used as a standard for tine-array development and testing.

the substances (Fig. 5). The interface's intelligence is supplied by a programmable microcomputer capable of neural network processing and by Echelon's LonWorks™ on-board neuron chip for easy integration into MIMS networks.

Acoustic Spectrometer

The Acoustic Spectrometer project is aimed at developing a low-power sensor that can detect and spectrally analyze and identify the source of acoustic signals. The sensor uses a silicon tine array which has significant advantages over a microphone and digital signal processing (DSP) circuitry. A resonant tine array automatically "computes" the acoustic spectrum. No power is consumed by the resonant tines; power is only consumed when the tine vibrations are measured. A tine array is not overloaded or jammed by a single or a few strong acoustic signals, contrary to a single microphone with DSP circuitry.

The tine array developed is a micromachined silicon wafer, using state-of-the-art etching technology to produce highly accurate and sensitive resonant tines. LLNL's laboratory acoustic spectrometer, which proved the technology, uses optical interferometry to measure tine vibration amplitude with high sensitivity (Fig. 6). A field acoustic spectrometer will use capacitive techniques to measure the amplitude of the tine vibrations. The capacitive technique will not be as sensitive as optical interferometry but will permit a smaller, more rugged spectrometer to be built.

Micropower Radar Sensor

The micropower radar sensor is based on a novel form of radar known as ultra-wideband impulse radar. A very short electromagnetic impulse is propagated from the sensor, and only the echoes that reflect

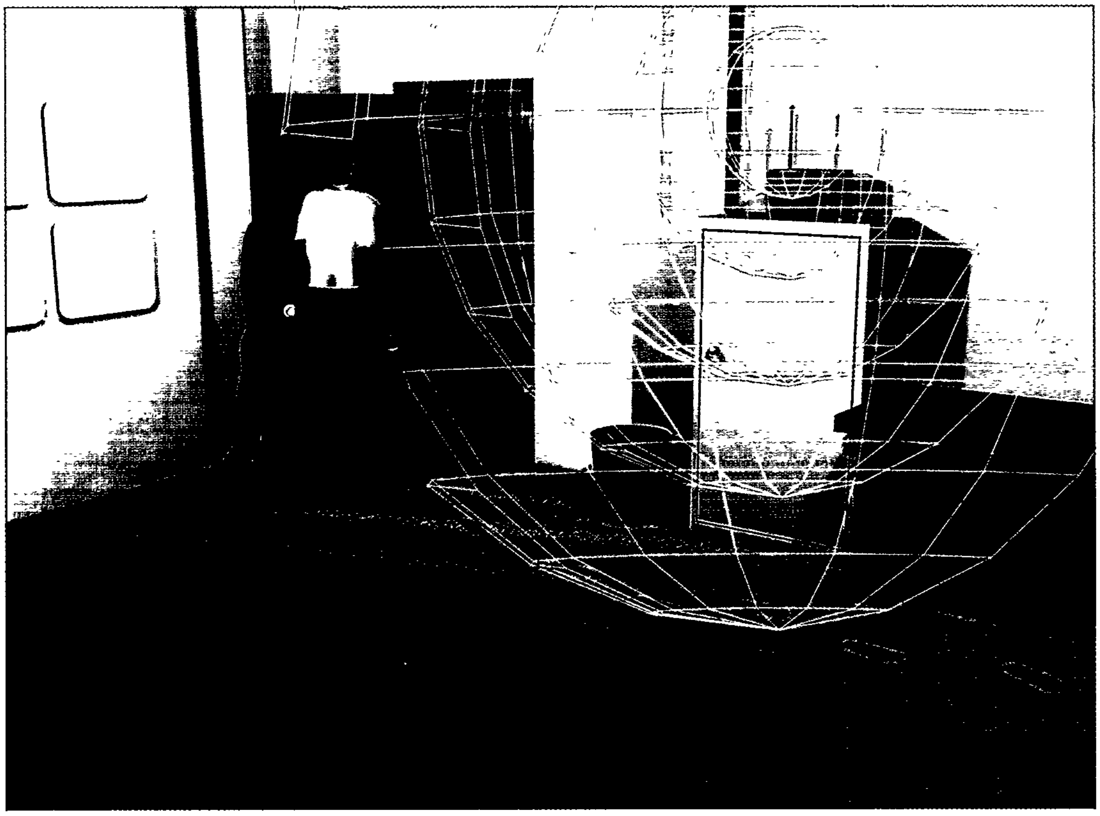


Figure 7. The micropower radar sensor, seen here on top of the cabinet, can detect moving objects that enter its 6-meter spherical detection range. The sensor not only detects what is moving but how it is moving (toward it, away from it, etc.).

from a defined range are detected. The echo acceptance range, or range gate, forms thin, invisible detection shells projected around the sensor. When an intruder penetrates the shell, the reflected signal within a range-gate is modulated. Only motion-modulated signals are detected, eliminating triggering on stationary "clutter." The radar does not respond to objects outside its range gate, and it does not falsely trigger on nearby moving objects such as insects or animals.

LLNL's improved prototype is compatible with the MIMS architecture. This improved version has 16 independent, adjustable range-gates and can detect movement and determine how the detected object is moving within an annulus centered on the radar antenna. The final MIMS-based system is expected to have an adjustable detection range from a meter to 30 meters with annulus depths of half a meter to the full radius of the detection range (Fig. 7).

Intelligent Nuclear Sensor

LLNL's Intelligent Nuclear Sensor prototype is a low-power, field gamma-ray spectrometer module (Fig. 8). The module uses an external, thallium-activated NaI detector assembly in conjunction with a

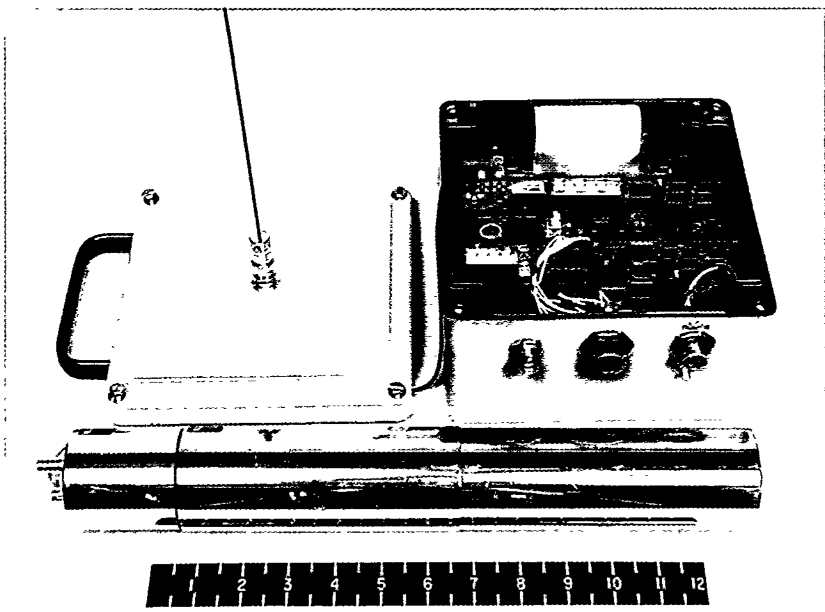
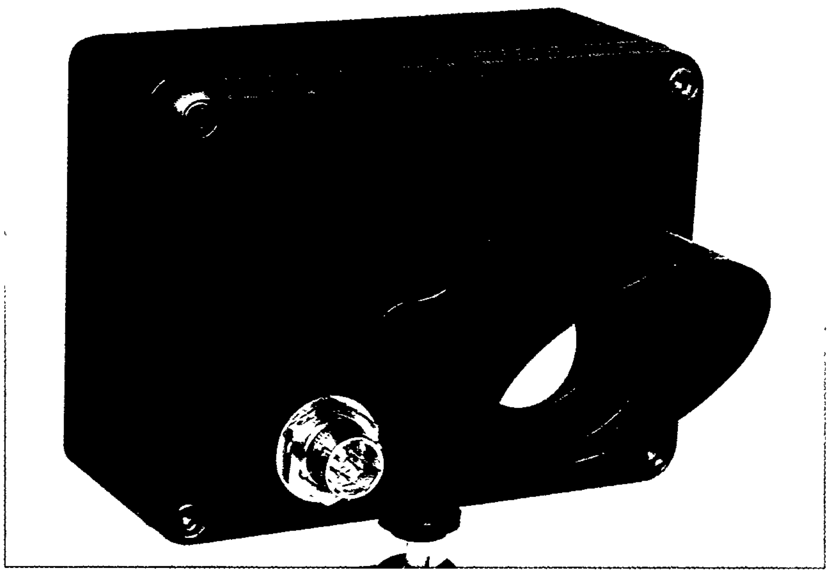


Figure 8. The latest version of this low-cost Intelligent Nuclear Sensor includes the capability to count the output of a separate neutron tube or other device that generates pulses (ruler in inches).



▲ **Figure 9.** The solid-state infrared camera weighs 1 kilogram and is watertight, encased in an anodized aluminum housing.

4,095-channel pulse-height analyzer. Analysis software on the module itself classifies radiation signatures from special nuclear material (SNM). A detection range of 6 meters for kilogram quantities of SNM in slow-moving vehicles is possible. The module features a self-adjusting power supply to compensate for temperature and environmental changes, and a specialized, high-speed, template-matching algorithm for SNM detection.

Solid-State Infrared Camera

The Solid-State Infrared Camera, developed by LLNL to provide infrared imaging for the MIMS project, is a self-contained, infrared image-acquisition and image-processing system for field installations (Fig. 9). It can detect a moving object, acquire image data, and process these data to produce a highly compressed, infrared image of the object. A 50-millimeter germanium lens focuses an infrared image of the moving object onto a 32-element, pyroelectric linear array sensor. Image data are acquired by an analog-to-digital converter at a rate of 400 scans per second from the sensor array. Converted data stored in the camera's memory bank are processed by an on-board microcomputer. Up to 4.5 seconds of image data can be acquired for each image sequence. The camera's microcomputer processes the image data, looking for edges or major features. Next, the edge data are converted into a black-and-white, two-level image. Finally, a compressed data file of the image is sent to a receiving station. Consequently, the camera achieves a data compression of approximately 20:1 to potentially 200:1, depending on the speed and size of the object (Fig. 10).

Testing and Evaluation

The MIMS program actively pursues opportunities to demonstrate to and work with the customers of these technologies. The Item Transparency & Tracking (IT&T) Demonstration, held at LLNL in December 1994, exhibited unattended, remote monitoring for arms control applications. Lessons from the IT&T Demonstration and other activities (see the Kurchatov–Argonne-West Demonstration, page 32) are continuously being incorporated. The MIMS program also integrates and tests many different kinds of sensors and unattended monitoring systems at Idaho National Engineering Laboratory's (INEL) Sensor System Evaluation Center.

Item Transparency and Tracking Demonstration at LLNL

DOE sponsored a major field test of the MIMS system in 1994 at LLNL in the Hardened Engineering Test Building (HETB) located within the high-security plutonium facility known as the "Super Block." All DOE national laboratories and private industries were invited to participate. The HETB simulated a nuclear-weapon storage facility. Six basic MIMS capabilities were demonstrated: (1) remote monitoring and tracking of declared items;

Figure 10. The solid-state infrared camera is seen deployed in a typical monitoring situation. When a vehicle passes by the camera, an image of the vehicle is acquired, and the other, stationary background elements are ignored.

(2) sensors; (3) multi-sensor compatibility; (4) non-intrusiveness of the host's regular activities; (5) data display; and (6) analysis by multi-sensor data and data-fusion work. (A video presentation of the field test is available through LLNL.)

The IT&T scenario showcased commercial and DOE-developed sensors integrated into a remote monitoring system. It demonstrated the concept of monitoring declared nuclear-weapons items within a high-security weapons facility and transmitting data to a remote display and analysis monitoring station. Two nuclear-explosive-like assemblies (NELAs) were instrumented and simulated the monitored nuclear weapons (Fig. 11).

Visitors to the IT&T Demonstration were given an opportunity to see current

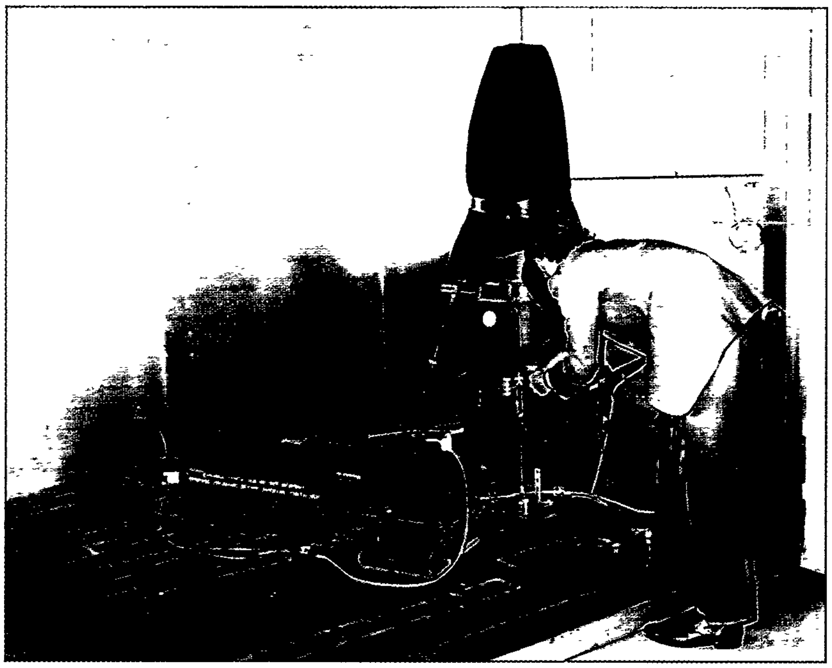
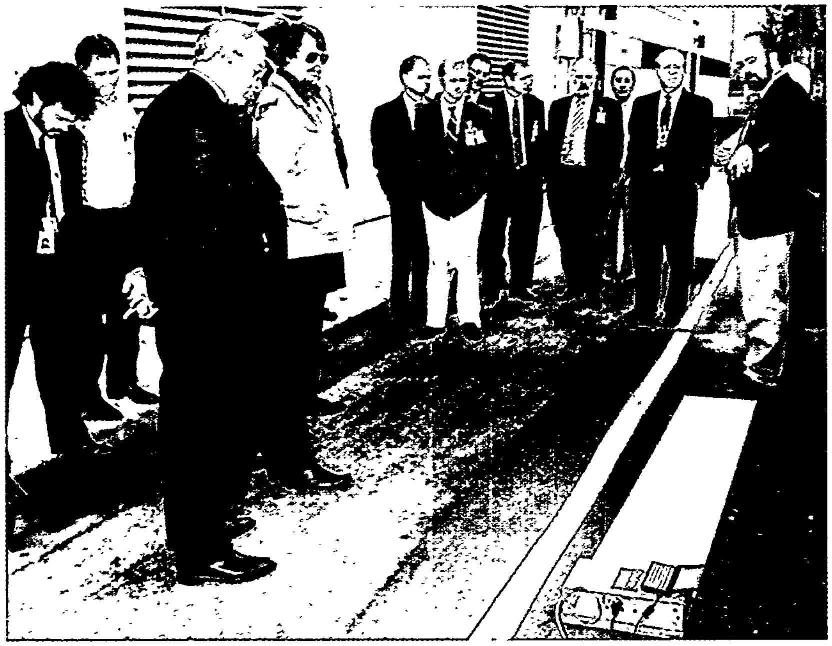
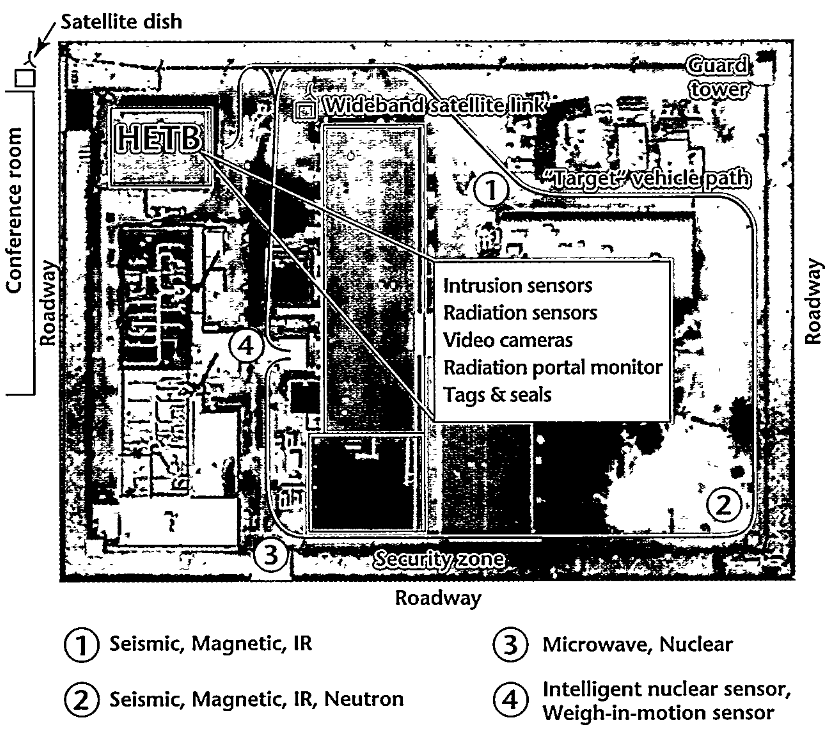


Figure 11. The MIMS sensors were attached to nuclear-explosive-like assemblies (NELAs) located inside a simulated nuclear-weapons storage facility at Lawrence Livermore National Laboratory's "Super Block" compound.



▲ **Figure 12.** Visitors to the Item Tracking & Transparency (IT&T) Demonstration were shown sensor technologies throughout the Super Block as they would be placed in a storage facility; seen here is Pacific Northwest National Laboratory's neutron detector.

▼ **Figure 13.** An overlay of the demonstration site shows the placement of the sensors throughout the Super Block. The HETB is the simulated storage facility.



technology supporting the new transparency and confidence-building regime (Fig. 12). The concept of non-intrusively verifying the presence of declared nuclear materials and differentiating them from undeclared items is integral to nonproliferation agreements. Conceptually, this new regime requires a monitoring system independent of the facilities' permanent security system that does not disrupt regular operations. While not foolproof, item transparency and tracking is intended to build trust between governments.

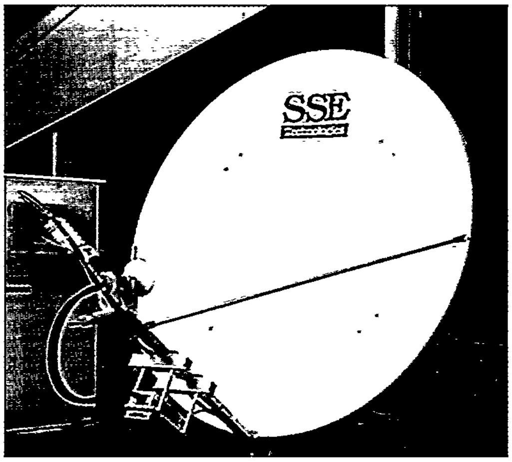
IT&T Scenario Tested the MIMS Network

Sensors were installed to detect components leaving, entering, and moving within the HETB and the Super Block (Fig. 13). Components passed by four monitoring points outside a simulated nuclear-weapons storage facility. Sensors inferred but did not necessarily detect what occurred to the components—only that something did occur. Video cameras supplied near-real-time coverage of activities; the video was also recorded on-site for later retrieval and analysis. Real-time video images and data were transmitted via satellite link to a conference room located outside the Super Block (Fig. 14). At the end of the exercise, observers confirmed that only one of the weapon-like items had been returned to the simulated storage area. It demonstrated how a monitoring party can have immediate and remote access to relevant information regarding the disposition of declared nuclear-weapons components.

IT&T Sensor Suite Performed Successfully

Both commercial sensors and DOE developed sensors were integrated into the common MIMS architecture based on the LON technology. A single LON network developed by Echelon Corp. was deployed. The individual nodes of the network were hardwired together. Remote, battery-operated sensors communicated via radio-frequency with a LON node. All sensor data were saved onto an optical disk.

Figure 14. Sensor information was transmitted in real time to a receiving station in a conference room located across the street from the Super Block, including live television transmission.



Acquiring and Displaying IT&T Data

During the IT&T, sensor information was transmitted through the network to the on-site digital acquisition system (DAS). Sensor events were then processed, stored, and displayed locally by the DAS (Fig. 15). As events were processed and stored, the DAS displayed three types of information on a computer monitor: the sensor's real-time status, the last data values reported, and a log of the last message reported from each sensor. The sensor's real-time-status window displayed current activity within the system; the auxiliary or process data window displayed analog or process data information last reported by system sensors, and the last message log displayed the time and date and event message transmitted by each of the system sensors. Output from the DAS was transmitted via a satellite link to the visitors located in a nearby conference room.

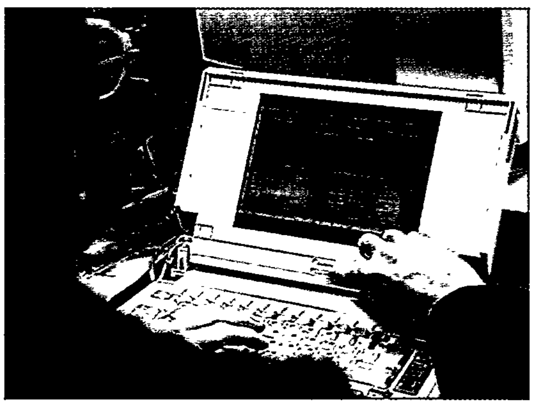


Figure 15. The laptop computer is the onsite data image and review station, looking at sensor data from the NELAs in the simulated storage bay.

IT&T Conclusions

The IT&T test demonstrated modular sensor segments; secure unattended operation; the integration of commercial systems, multi-sensors, and data fusion; and user-friendly data-handling and display methods. A realistic scenario evaluated the integrated MIMS architecture and hardware for cooperative, unattended monitoring, showing the flexibility and capabilities of the MIMS system. These sensors and the item-tracking scenario provided evidence that items could be monitored in a transparent fashion using sensor and network technology, and that a monitoring party can have immediate and remote access to relevant information regarding the disposition of declared nuclear-weapons components.

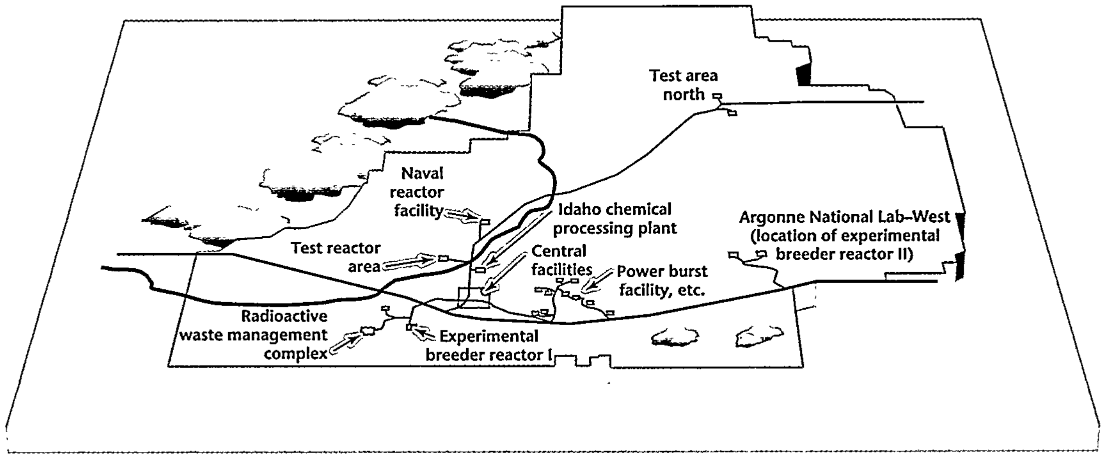


Figure 16. The Sensor Systems Evaluation Center (SSEC), located at Idaho National Engineering Laboratory (INEL), is the test bed for many of the sensor systems being developed for cooperative remote monitoring scenarios.

The Sensor Systems Evaluation Center at INEL

The ultimate purpose of the Sensor Systems Evaluation Center (SSEC) is to ensure that a proposed technology will truly solve a particular cooperative remote monitoring problem. Such confidence building and transparency technologies are part of the new, more cooperative climate in international relations.

The SSEC, located at the Idaho National Engineering Laboratory (INEL), exists to test many kinds of devices, but it focuses primarily on technologies for cooperative remote monitoring and treaty verification (Fig. 16). Thus, while INEL tests projects for several U.S. government agencies, most of its activity supports the MIMS program.

The SSEC strives for maximum realism by using the actual working facilities. Whenever possible, test plans involve real nuclear fuel or other components, real radioactive waste, and on-going nuclear processes. When there are no on-going operations to meet a specific need, SSEC personnel devise a field test to realistically address the desired goal. While major new construction or facility modifications have not been totally ruled out, these options are usually avoided to minimize costs.

The SSEC serves three functions: (1) it provides a framework to field test individual sensors for transparency and cooperative remote monitoring; (2) it field-tests the specific approach for multi-sensor system integration; and (3) it helps identify technology "gaps" where specific improvements are needed.

Evaluating Technology for Cooperative Remote Monitoring

Many facilities useful to cooperative remote monitoring tests are spread over the 572,000 acres of the INEL reservation. Extensive operational histories for these facilities can guide the design of new tests and help put test results in perspective. For example, the first breeder reactor, Experimental Breeder Reactor I (EBR-I), operational in 1951, produced electricity for the town of Arco. Its successor, EBR-II, is currently being de-fueled in preparation for decommissioning. The high-neutron-flux Material Test Reactor (MTR) produced the first significant quantities of many of the transuranic elements (americium, curium, etc.). The technological descendant of the MTR, the Advanced Test Reactor (ATR), is still in operation (Fig. 17). Several other reactors, in various standby or shutdown modes, are available within the reservation.

Other INEL facilities that can simulate nuclear-handling operations include fuel dissolution and reprocessing systems; large- and small-scale hot cells (several operational, others in standby mode); high- and

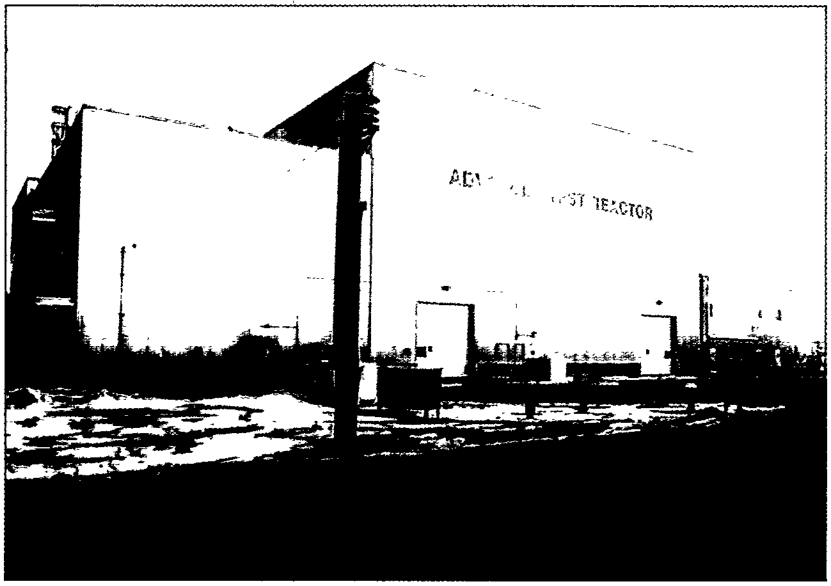


Figure 17. The Advanced Test Reactor, the successor to the first high-neutron-flux reactor at INEL, produces many of the transuranic elements.

low-level waste storage areas; and various underground structures.

Field Tests Driven by Application and Device Needs

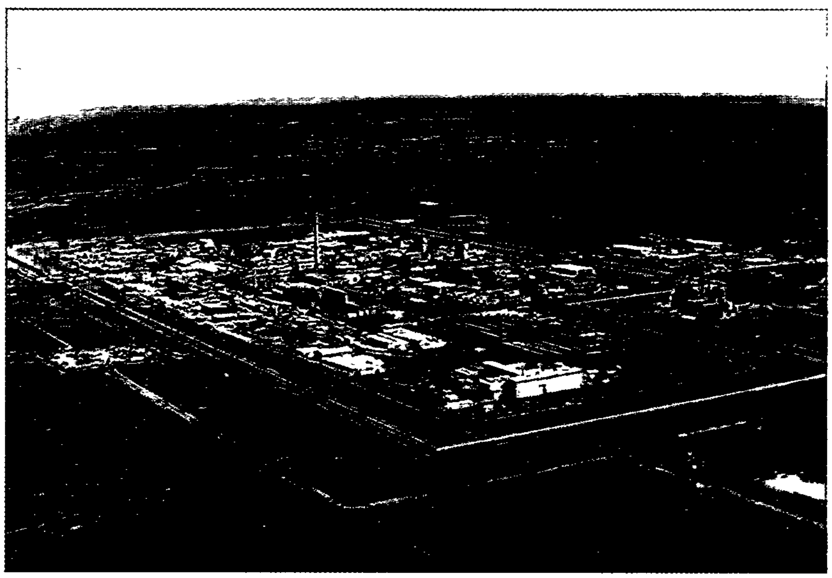
For broad-spectrum field tests, devices are solicited from developers, procured commercially, or adapted from previous development programs. A particular sensor or another device may be appropriate for several cooperative remote monitoring situations, or scenarios. The SSEC typically runs two or three such large-scale scenarios a year.

For a small group of sensors, or for one sensor at a time, field tests typically start with a request from the sensor developers. SSEC personnel work with the developers to devise ways to rigorously test the technology and then help install the equipment needed for the test.

In either case, once the equipment is installed and a test begins, the day-to-day system operation is supported by INEL personnel. As data accumulate, they are remotely sent back to the developers at their home laboratories. For longer tests, some sensors may be swapped in and out or applied to another part of the scenario. If problems occur or changes are desired, the developers return and make modifications (either here or back at their laboratories) and then the test continues. The end product of this cycle is a fully tested prototype with performance data to highlight its features. A follow-up operational phase may be initiated to demonstrate one or more sensors for potential users.

Currently, the SSEC is working with other DOE national laboratories to implement a fuel-tracking scenario, following the transfer of spent fuel from an old storage basin to a newer one at the Idaho Chemical Processing Plant. The older basin, located in Building CPP-603, was completed about 45 years ago and has been in continuous use since then. Fuel is now being moved from there to the CPP-666 storage basin (Fig. 18).

Figure 18. A fuel-tracking scenario at the Idaho Chemical Processing plant follows the transfer of spent fuel from an old storage basin to a newer one.



◄ **Figure 19.** A shielded cask is lifted by a straddle carrier and taken to a fuel-receiving pool, where fuel is transferred from the cask into new storage containers.

Fuel pieces are first loaded into a shielded cask underwater, and the cask is moved to where it can be lifted by a straddle carrier (Fig. 19). The carrier takes the cask to CPP-666, where the cask is lowered into a fuel-receiving pool, and the fuel is transferred into the new storage containers. An array of motion sensors, door alarms, radiation monitors, video cameras, and other equipment follow this operation from start to finish. Components from INEL, LLNL, PNNL, SNL, and several commercial vendors are already on site.

Multi-sensor Synergism

Except in the most limited and static cases, a credible cooperative remote monitoring system requires an array of sensors and other devices. The DOE cooperative remote monitoring program tries to capitalize on available commercial technologies to complement developments from the DOE national laboratory system.

A common accepted platform links such diverse devices into a synergistic, multi-sensor structure. The preferred approach is a network standard defined by the LonMark™ Association, an industry group whose members collectively hold 90%+ of the world market for all kinds of monitoring and control systems. The major players in this market (e. g., Honeywell, Johnson Controls, Carrier) are actively supported by over 120 other companies involved in manufacturing, system integration, and engineering management. The aim of the LonMark Association is to achieve a basic level of "plug-and-play" compatibility among products from many different companies, but still allow enough leeway so new features can be added. ❖

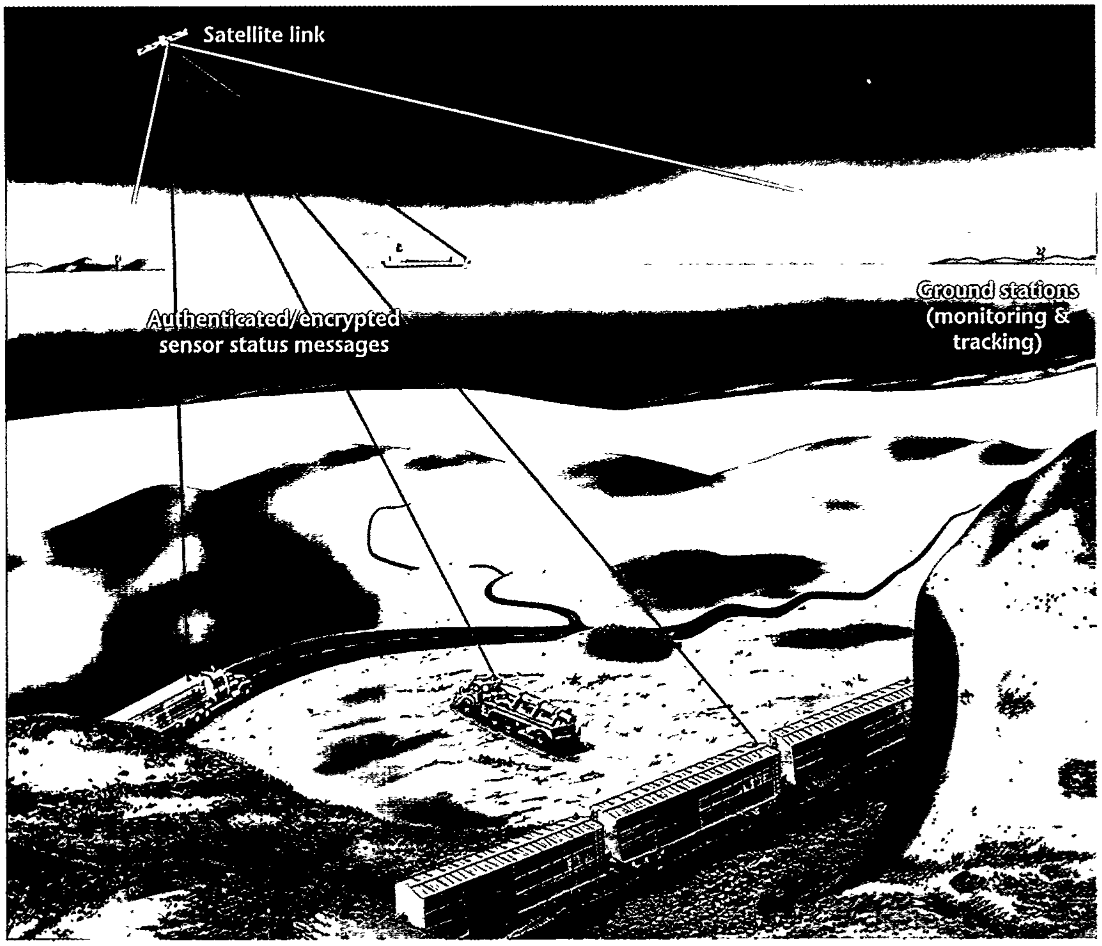
Contacts for MIMS

DOE/MIMS Program
Contact: **Carl Friesen**
Phone: 202-586-6486
Fax: 202-586-2612
Email: carl.friesen@hq.doe.gov

Sandia National Laboratories
Contact: **Nicole S. Andrews**
Phone: 505-844-2969
Fax: 505-844-6067
Email: nsandre@sandia.gov

Lawrence Livermore National Laboratory
Contact: **David W. Myers**
Phone: 510-422-1639
Fax: 510-422-9343
Email: myers7@llnl.gov

Idaho National Engineering Laboratory
Contact: **Evan E. Filby**
Phone: 208-526-3748
Fax: 208-526-1390

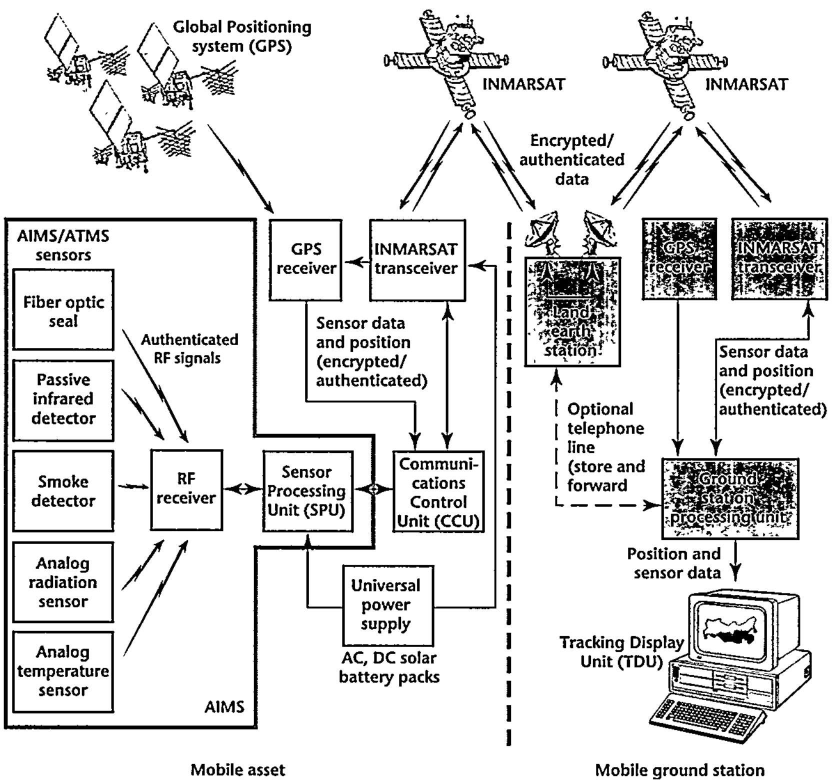


Authenticated Tracking and Monitoring System (ATMS)

The Authenticated Tracking and Monitoring System (ATMS) addresses the status and location of proliferation-sensitive items during shipment. The ATMS tracks and monitors items in transit (or stationary) from a mobile or fixed ground monitoring station (above picture). Wireless sensor packs provide near-real-time event and state-of-health data, which are collected by a processing unit and transmitted to ground stations through a satellite communications link (the International Maritime Satellite, INMARSAT). Position information is provided by Global Positioning System (GPS) satellites. The ATMS can monitor any shipment regardless of the transportation mode (rail, truck, ship, or air) anywhere in the world.

Applications for the ATMS include arms control, verification of nonproliferation treaties, military asset control (location and status), or any type of bilateral or multinational nuclear-weapons dismantlement agreement. The Department of Energy (DOE) and the Defense Nuclear Agency (DNA) jointly sponsored the development of ATMS at Sandia National Laboratories (SNL). Commercial applications for ATMS include inventory control and tracking of any high-value items.

Pictured above: The Authenticated Tracking and Monitoring System (ATMS) allows proliferation-sensitive items to be tracked globally.



▲ **Figure 1.** The block diagram illustrates the operation of the Authenticated Tracking and Monitoring System (ATMS).

ATMS Operation

The ATMS sensor packs include a variety of wireless, battery-powered, radiofrequency (RF) sensors: containment sensors (such as fiber-optic seals), environmental and safety sensors (smoke and fire detectors and temperature sensors), and intrusion detection sensors (microwave and passive infrared intrusion detectors and door-entry switches). We chose the Authenticated Item Monitoring System (AIMS) as the initial core for the sensor suite because of its level of maturity and its acceptance by international safeguards agencies; however, other item monitoring systems can be used.

The ATMS sensors report significant sensor activations, or "events," to a nearby Sensor Processing Unit (SPU). Besides event reporting, each sensor sends periodic messages that indicate its state of health, ensuring that all sensors are on line and have not been tampered with. All wireless sensor data are authenticated to ensure data integrity.

The SPU packages all incoming sensor messages and sends this information to the Communications Control Unit (CCU) for subsequent satellite transmission by the INMARSAT transceiver (Fig. 1). Sensor status information combined with GPS location data are transmitted in an encrypted and authenticated mode to a ground station, either fixed or mobile. Encryption prevents unauthorized persons from monitoring the status and location of the shipped material. Authentication prevents anyone from concealing a diversion by recording and altering the data for retransmission at a later time. The ATMS user-customized authentication and encryption are based on a widely accepted, commercial, exportable software. The processing unit at the ground station decrypts and authenticates the data and displays position and sensor data for the operator on a Tracking Display Unit (TDU) in near real time.

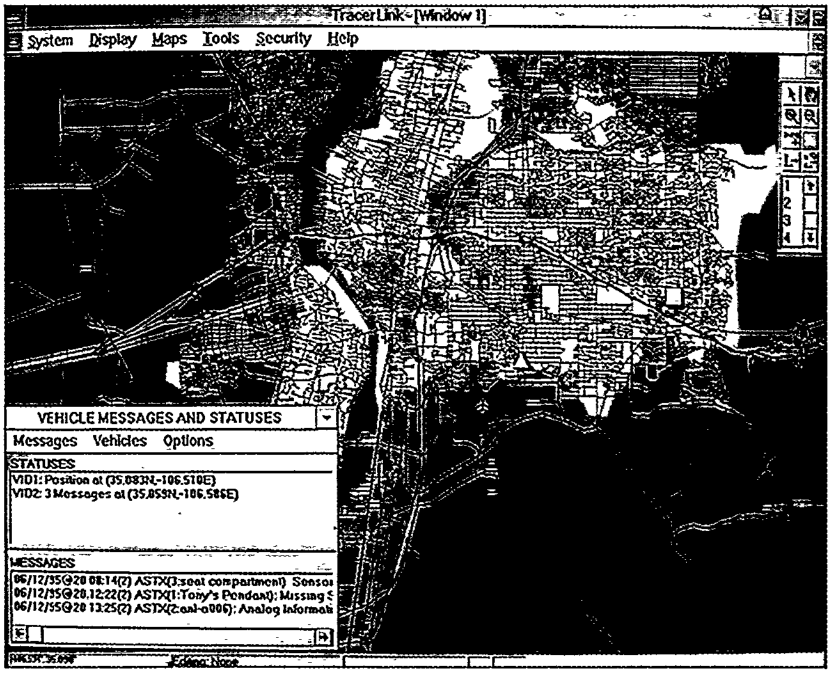
Customized commercial software loaded in the TDU allow users to monitor shipments against different background maps. Through menus, users can display information on item and sensor status. Zoom controls show shipments at various resolutions, from a suite of vehicles moving on a world map to a specific vehicle moving through a city with street-level resolution. Shipment-tracking resolution depends, in part, on the periodic report level (typically between 5 minutes and 1 hour). A 5-minute report-in interval for a shipment traveling 50 kilometers per hour allows the shipment to be tracked between report-in intervals with an accuracy of 4.2 kilometers. During the actual report-in period, when absolute position is recalculated and updated by the GPS, accuracy increases to 50 meters (Fig. 2).

Figure 3 shows a typical scenario in which the ATMS monitors a rail-car shipment of proliferation-sensitive items. Wireless sensor packs continually monitor the presence and integrity of the shipped material within the rail car. Door-entry switches and temperature sensors monitor access and environmental conditions, respectively. Sensor data and state-of-health information are reported to the SPU by authenticated RF links. The CCU acquires geographic information from the GPS satellites and combines that information with the sensor data, which is then authenticated and encrypted for transmission by INMARSAT to the remote-monitoring ground station.

Status

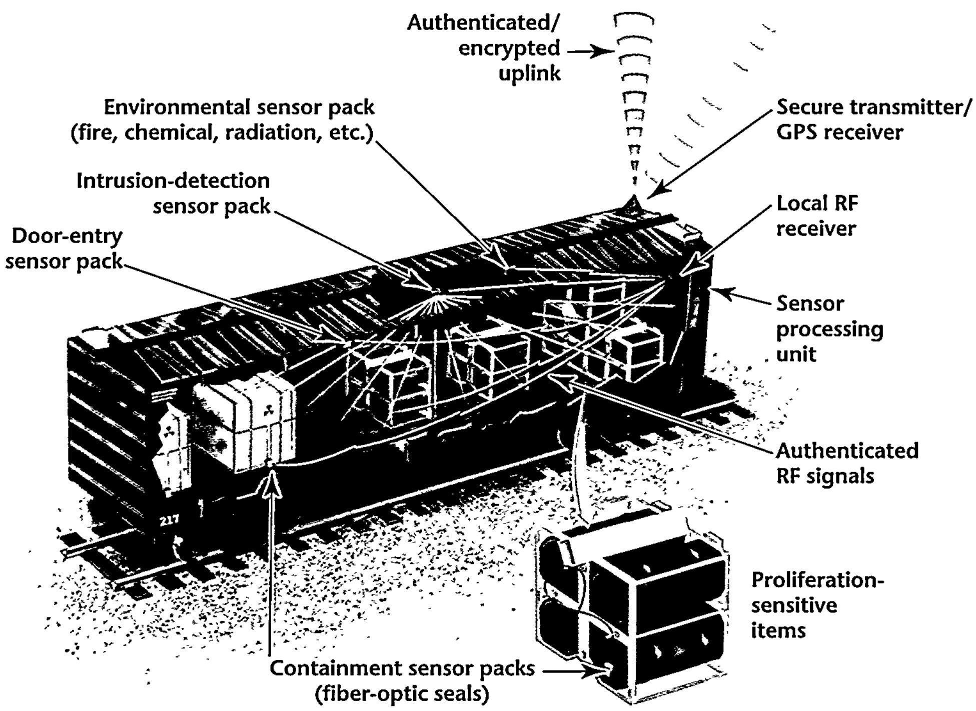
ATMS was born with a proof-of-concept demonstration for Ambassador Goodby in August 1993. Using equipment borrowed from other projects, a road shipment of mock weapon containers was successfully tracked and monitored during three days across five Western states. Sufficient interest was generated to fund, beginning in mid-FY94, the development of a field prototype. Part of this development has been jointly funded by DOE and DNA. The initial tasks for this project were to develop system requirements, obtain INMARSAT licensing, design the communications control and ground station processing units, procure prototype hardware, and code rudimentary software. A laboratory prototype system was assembled and demonstrated in FY95. The first field prototype will be completed by the end of FY96. It will include two-way communication between the monitoring station (either fixed or mobile) and the cargo vehicle, authentication and encryption of the INMARSAT data channel, and a software user interface with tracking and cargo monitoring information displays and an interactive control screen. ❖

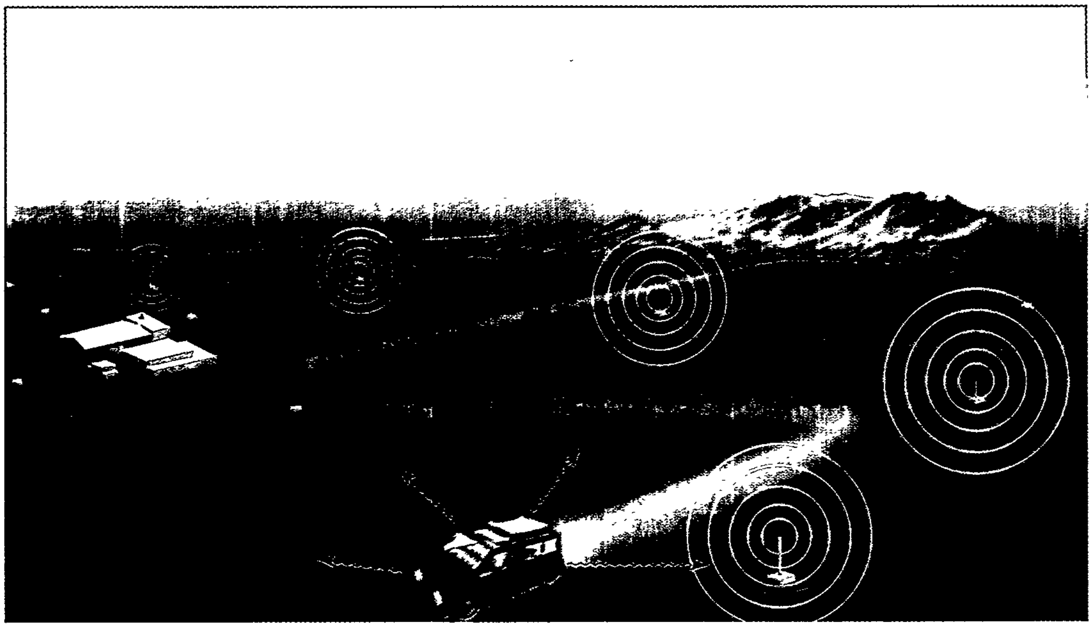
CONTACT: **Lee Schoeneman**
Sandia National Laboratories
PHONE: 505-844-2049
FAX: 505-844-5321
EMAIL: jlschoe@sandia.gov



▲ **Figure 2.** The resolution of the display for a shipment being tracked in Albuquerque, New Mexico, is set by the user's requirements through the software.

▼ **Figure 3.** Closeup of a rail-car shipment shows how the ATMS components are linked together at the item.





Tracking Nuclear Materials by Wide-Area Nuclear Detection (WAND)

Pictured above: Wide-Area Nuclear Detection (WAND) is defined as the ability to track nuclear materials located inside a moving target, for instance a vehicle driving along rural roads. The unique radiation signature is registered by the nearest detector, and the information is sent back to a central location.

With the collapse of the Soviet Union and the impending emergence of rogue nuclear states, concern about nuclear proliferation has never been higher. Considerable effort is under way to employ advanced technical means to monitor all phases of the nuclear fuel cycle.

The Wide-Area Nuclear Detection, or WAND, concept incorporates inexpensive, multiple radiation detectors and collateral sensors into networks to monitor and track nuclear materials. Such networks can be installed in places where continuously staffed perimeter monitoring is not practical; e.g., in very large zones with numerous chokepoints or in situations with a high probability of insiders circumventing the chokepoints. These networks can be monitored in real time to allow emergency response personnel to converge on a trouble spot, or they can be used for long-term monitoring. WAND can be employed outside a facility without interference or intrusion. The networks can be scaled down for small areas (such as airports and seaports), and scaled up for urban centers and regional rural areas (above picture).

Because nuclear radiation is the only unique signature emitted during all phases of the nuclear fuel cycle, it would ordinarily be the signature of choice for fuel-cycle and nuclear-weapon-materials monitoring. Unfortunately, the laws of physics limit the range of even the most expensive radiation detectors—with costs exceeding $1,000,000—to short distances. Consequently, using radiation detectors for monitoring has been largely limited to close-in applications—portal or other chokepoint situations. Such monitors are quite effective, but their requirements for continuous staffing add to their initial cost, making them quite expensive to operate.

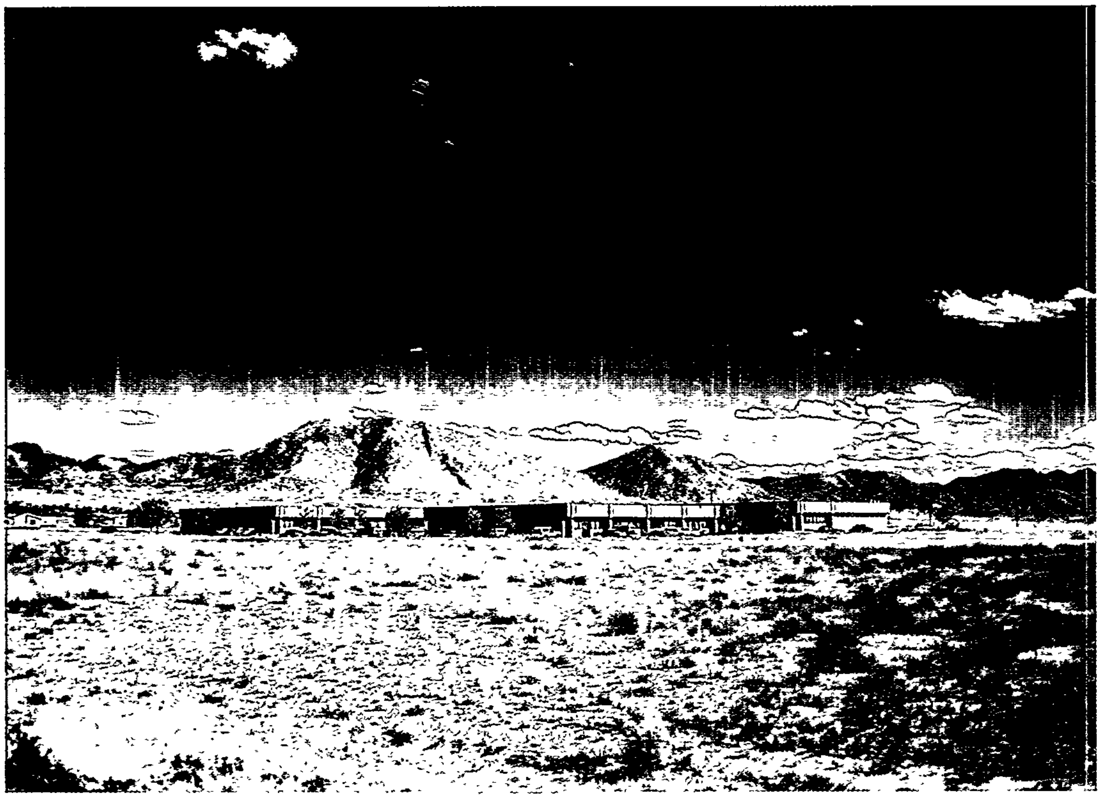
Other signatures—infrared, chemical, seismic, and electromagnetic—have been studied in recent years. These indicators can be detected at greater ranges than nuclear radiation, providing broader coverage. They are, however, indirect, non-unique, or limited to certain phases of the nuclear fuel cycle. The compelling uniqueness of the nuclear radiation signature motivated us to re-examine this indicator in an effort to overcome its coverage and cost limitations.

The WAND System

WAND uses network algorithms to process the output of multiple, small detectors, achieving a lower number of false alarms and broader coverage than a single, large detector. Using dispersed, unattended, networked nuclear detectors operating as a single entity was unexplored until 1994 when we examined this concept with simple systems studies that modeled the performance of a network of detectors operating as a single entity. These studies indicated a 10- to 100-fold increase in effectiveness over arrays of like detectors acting individually. In contrast to chokepoint monitors, WAND covers broad areas and can track as well. In addition, choke-point monitors are highly visible, whereas a WAND system may be low-profile—incorporating concealed sensors to avoid theft and vandalism. WAND is not envisioned to replace existing technology but rather to complement chokepoint detectors and other elements in a total protection regime.

The Department of Energy's Office of Research and Development (NN20) funded Lawrence Livermore National Laboratory to develop a small-scale network of simple detectors, the foundation for an experimental testbed to develop a WAND system. We exploited, to the extent possible, existing hardware and technology. In FY95, we concentrated on detecting plutonium using neutron detectors and demonstrated a WAND system. We are also using the system as a testbed for detector and network algorithm development and optimization. In FY96, we will track a californium source around the Lawrence Livermore site to demonstrate a proof of this principle. ❖

CONTACT: **Zachary Koenig**
Lawrence Livermore National Laboratory
PHONE: 510-423-7524
FAX: 510-422-2485
EMAIL: koenig1@llnl.gov



International Remote Monitoring

The next 20 years will bring new opportunities for international and regional cooperation on issues ranging from halting weapons proliferation to managing the environment and natural resources. A growing number of countries will be party to multi-lateral or regional cooperative agreements. Effective implementation of cooperative agreements will require the acquisition, processing, analysis, and sharing of large quantities of information. "Cooperative monitoring" will become a vital security component for individual countries, regions, and international institutions.

Three on-going Department of Energy (DOE) efforts address these new opportunities: (1) the Cooperative Monitoring Center (CMC) at Sandia National Laboratories (SNL) in Albuquerque, New Mexico; (2) the International Remote Monitoring Project (IRMP); and (3) field trials with the International Atomic Energy Agency (IAEA).

Pictured above: The Cooperative Monitoring Center (CMC) is located at Sandia National Laboratories (SNL) in Albuquerque, New Mexico.

Cooperative Monitoring Center

Many of the entities who need to be involved in cooperative monitoring—countries, regions, and international institutions—lack experience and the technical infrastructure necessary to fully participate in cooperative regimes. Even technically sophisticated countries will require improved information acquisition and management capabilities. A successful transition into a more cooperative world presents a complex technical and political challenge. The CMC at SNL has been established to help meet this challenge (above photo).

SNL, like other DOE national laboratories, has long been involved with U.S. treaty verification, monitoring, and nuclear stewardship. The CMC's mission is to assist political and technical experts worldwide in acquiring the technology-based tools needed to assess, design, analyze, and implement nonproliferation, arms control, and other security measures. Visitors to the CMC receive hands-on training with monitoring hardware, software, and data processing. The CMC assists in the collaborative development of prototype monitoring systems and experiments. Representatives from the Middle East, South Asia, Northeast Asia, and states of the Former Soviet Union have participated in CMC-sponsored workshops, seminars, and the visiting scholars' program.

▲ **Figure 1.** CMC visitors participate in hands-on training and workshops.

Issues

Monitoring technologies can facilitate a wide variety of cooperative agreements. Arms control issues addressed at the CMC include nuclear weapons and materials, conventional military forces, weapons delivery systems, and chemical and biological weapons. Other areas, unrelated to arms control, that can benefit from cooperative monitoring technologies include natural resources management, pollution identification, trade and commerce monitoring, and the monitoring of natural disasters.

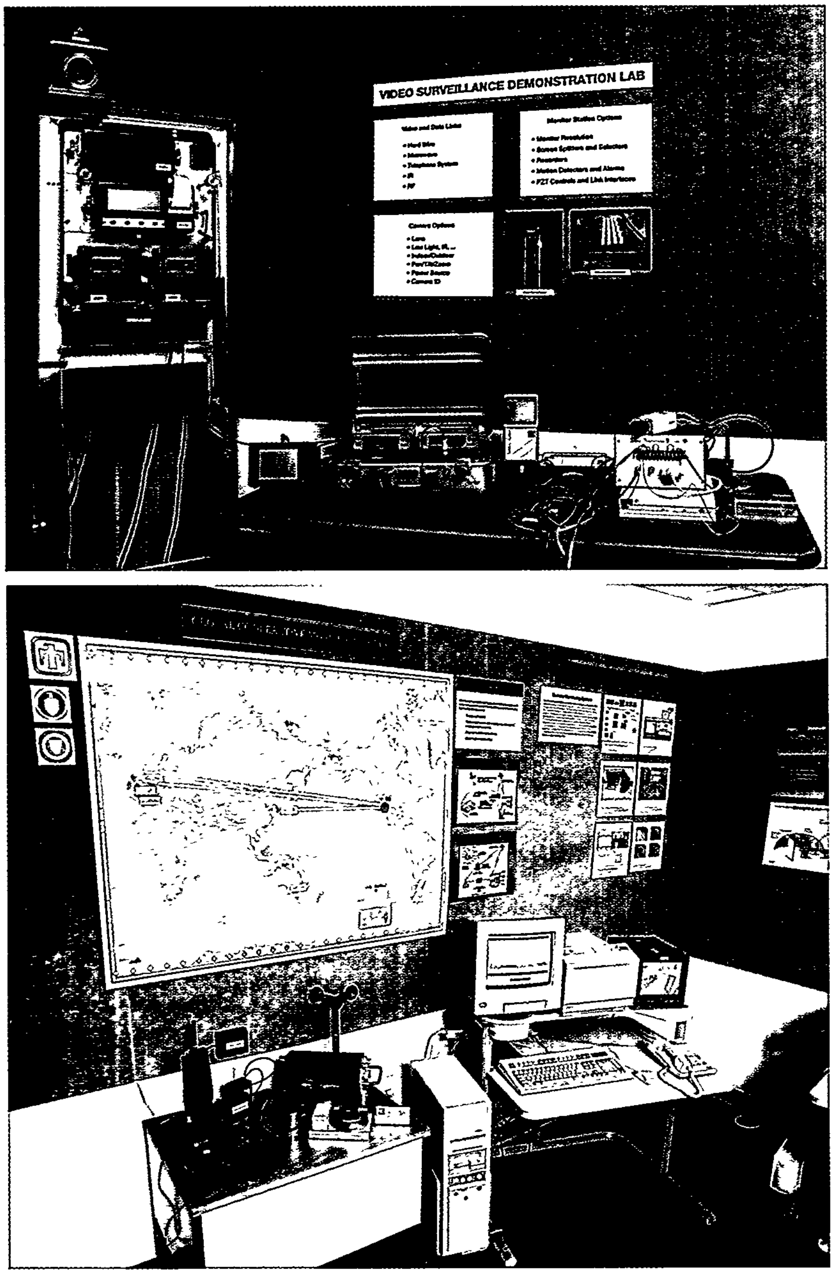
The CMC performs a wide variety of technical analyses, drawing heavily on collaborations established with other research institutes, universities, and laboratories. Such analyses include analyzing cooperative monitoring options, establishing precedents for regional arms control and nonproliferation, and evaluating monitoring system designs.

The CMC supports a range of research, training, and communication needs and houses laboratories in which experimental monitoring systems are developed for deployment worldwide (Fig. 1). Numerous unclassified, exportable monitoring technologies and data-display capabilities have been assembled at the CMC and are demonstrated for domestic and foreign visitors (Fig. 2). Conference facilities at the CMC support meetings and workshops, and offices are provided for visiting scholars and students interested in conducting research and developing concepts for regional cooperative monitoring.

Technical Capabilities

The technical capabilities demonstrated at the CMC leverage long-standing, national security-related technology programs into new cooperative applications. Some of the capabilities include remote monitoring, item and vehicle tracking, and environmental monitoring and assessment.

By facilitating cooperative security agreements and encouraging the development of regional arms control infrastructures, the CMC is contributing to the nation's nonproliferation objectives. The CMC also serves as a forum for making the capabilities of the DOE national laboratories accessible to a broad range of U.S. government agencies.



▲ **Figure 2.** CMC visitors are shown monitoring technology in operational display rooms.

The International Remote Monitoring Project

The spread of nuclear knowledge and technology—along with escalating regional tensions and conflicts—has led to an increased risk of nuclear-weapons proliferation. This increased risk is just one of several factors that have resulted in an increase in the responsibilities, obligations, and importance of the International Atomic Energy Agency (IAEA). The IAEA's monitoring techniques have demonstrated their merit; however, new approaches will improve the IAEA's efficiency and cost-effectiveness of its safeguards.

One approach is to rely more heavily on a comprehensive, transparent, and open regime. Key to an open regime is timely data collection. The remote transmission of safeguards-relevant data directly to the IAEA from integrated systems of unattended sensors located in nuclear facilities world-wide would facilitate timely data collection. Such remote monitoring systems would allow the IAEA to obtain data quickly and reduce the number and duration of inspections.

DOE, with its international partners, has established the International Remote Monitoring Project (IRMP), which evaluates the reliability and effectiveness of remote monitoring systems through field trials. In these field trials, a variety of sensors are integrated into a network to form flexible and modular remote monitoring systems for installation at participating nuclear facilities.

The IRMP system and the Modular Integrated Monitoring System (MIMS) [see page 4, this issue] share the same system design. Like MIMS, the IRMP employs a Local Operating Network (LON) to interconnect sensor nodes. The network accommodates a variety of sensors, data storage units, and data display units. An external communications interface provides remote access to the data. While MIMS emphasizes technology development, the IRMP concentrates on field evaluations.

IRMP Objectives

During the initial phase of the IRMP, data acquired by the remote monitoring systems are transmitted on demand to monitoring stations located at Sandia National Laboratories' (SNL) Cooperative Monitoring Center (CMC) in Albuquerque, New Mexico, and at various National Authority headquarters. This first phase allows DOE and its international partners to gain experience with the remote collec tion and transmission of safeguards-relevant data. In the next phase, with the permission of the National Authority, data from a majority of the participating facilities will be transmitted to the IAEA.

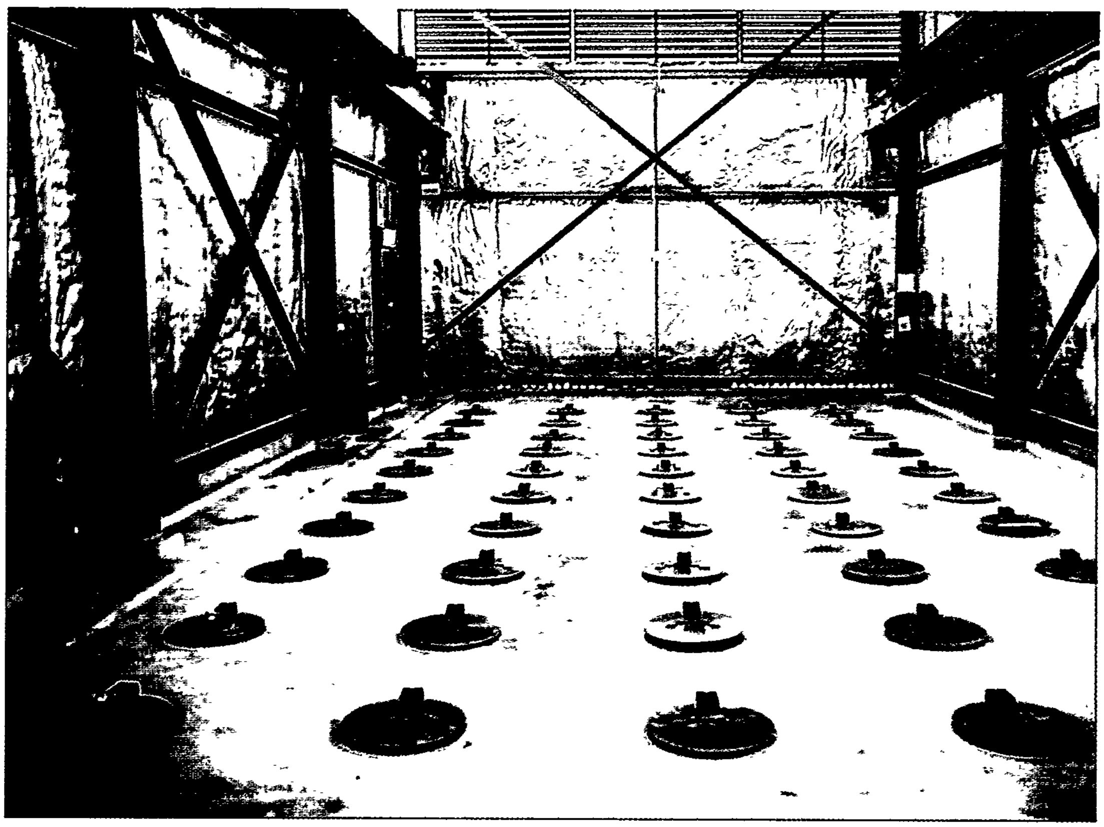
The IRMP has three specific objectives: (1) examining and defining technical parameters for communications protocols, digital standards, sensor and subsystem interfaces, data integration and display, overall reliability, and other areas as necessary; (2) demonstrating cost-savings for inspections while maintaining or strengthening safeguard effectiveness; and (3) gaining international acceptance of remote monitoring for international safeguards applications.

Participants in this project currently include the U.S., Australia, Sweden, Japan, Argentina, Germany, JRC Ispra, and Finland.

Field Trials

Australia—Spent-Fuel Storage Facility, Lucas Heights

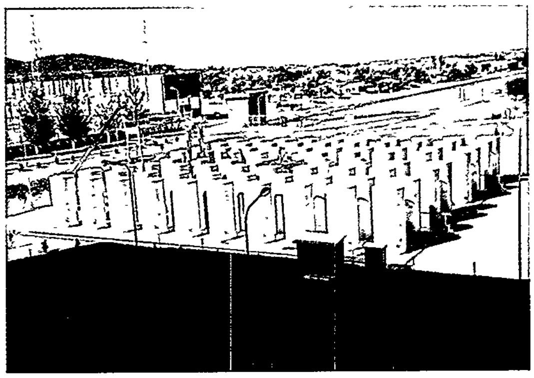
The remote monitoring system in Lucas Heights, Australia (a dry spent-fuel storage facility) monitors 49 spent-fuel storage tubes under IAEA seals (Fig. 3). Using a commercial telephone link, researchers at remote monitoring stations in Canberra, Australia, and Albuquerque, New Mexico, retrieve data and images on demand. Since its installation in February 1994, the system has been upgraded and has functioned well. Additional upgrades and the involvement of the IAEA will start in 1996.



▶ **Figure 3.** The remote monitoring system installed at the Lucas Heights Dry Spent-Fuel Storage Facility in Australia monitors 49 spent-fuel storage tubes under IAEA seals.

Argentina—Embalse Nuclear Power Station, Cordoba

The remote monitoring system at the Embalse Nuclear Power Station, Cordoba Province, Argentina, monitors four typical Candu spent-fuel silos located in a storage area at the reactor site (Fig. 4). The silos are under the safeguards control of the IAEA, the Brazilian-Argentine Agency for Accounting and Control of Nuclear Materials (ABACC), and the Argentine Ente Nacional Regulador Nuclear (ENREN). At present, the data are accessed through a commercial telephone link by the ENREN offices in Buenos Aires, the ABACC offices in Rio de Janeiro, and a station at the Cooperative Monitoring Center in the U.S. In addition, the IAEA has access to the data stored independently on site.



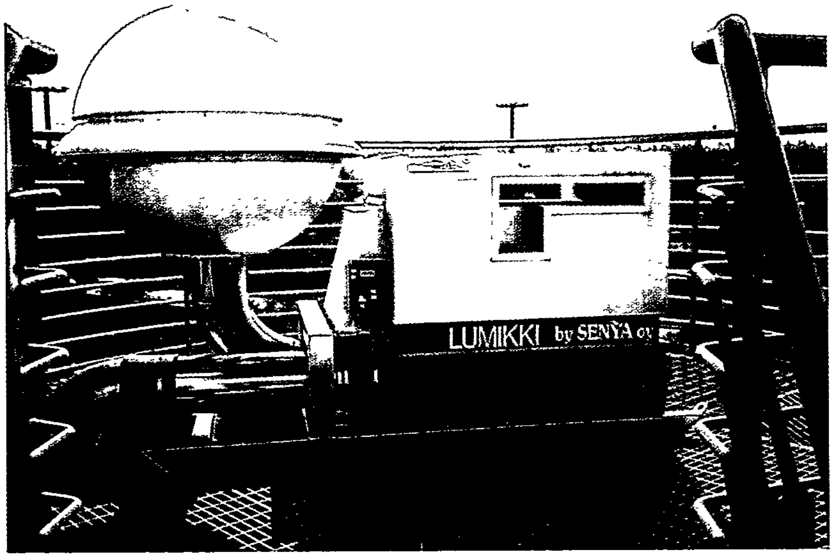
▲ **Figure 4.** The remote monitoring system at the Embalse Nuclear Power Station in Argentina monitors the safeguards conditions of four Candu spent-fuel silos located in a storage area at the reactor site.

Finland—STUK Atmospheric Monitoring System, Helsinki

Under an agreement with the Finnish Centre for Radiation and Nuclear Safety, the DOE is supporting the installation of a remote monitoring system in Helsinki, Finland. This installation will demonstrate using remote monitoring for environmental applications and the Internet to retrieve data. An environmental monitoring unit will monitor radioactive particulates (Fig. 5). The remote monitoring system will observe the environmental unit and use the Internet for remote access to the radiation measurements and to state-of-health information about the unit. Internet access will require installation of a special link between the remote monitoring system's control computer and an Internet server.

U.S.—Idaho National Engineering Laboratory, Pocatello, Idaho

The remote monitoring system at the Idaho National Engineering Laboratory (INEL) monitors operations at the Idaho Chemical Processing Plant (Fig. 6), which handles spent fuel, high- and low-level radioactive waste, and recovered highly enriched uranium. The remote monitoring system uses MIMS (see page 4, this issue) and includes sensors from DOE national laboratories and commercial firms. At present, the data are accessed over a commercial telephone link by monitoring stations at INEL and the CMC at SNL.



◀ **Figure 5.** An environmental monitoring unit of the STUK Atmospheric Monitoring System in Helsinki will demonstrate the use of remote monitoring for environmental applications and the use of the Internet for the retrieval of data.

Figure 6. Two video images, personnel and vehicle access, are seen here from the remote monitoring system installed at the Idaho National Engineering Laboratory.

Future Plans

The remote monitoring field trials have already met the IRMP's objectives by better defining the technical requirements, demonstrating cost-savings, and introducing remote monitoring to a variety of countries as a viable technology for international safeguards applications. Future installations and the participation of additional countries will expand the scope of the application and promote international acceptance of the technology. In the long term, we hope that the IAEA will adopt remote monitoring systems as an important technology for supporting IAEA safeguards.

International U.S. and IAEA Remote Monitoring Field Trials

The IAEA and the U.S. Support Program are conducting field trials to evaluate the application of remote monitoring to routine IAEA safeguards. The first phase was a remote monitoring demonstration given by U.S. Energy Secretary Hazel R. O'Leary to IAEA Director-General Hans Blix and the IAEA General Conference on September 18, 1995, in Vienna, Austria. The demonstration included satellite transmission of data from a prototype remote-monitoring system installed in a Y-12 Plant vault at Oak Ridge National Laboratory (Fig. 7). The Y-12 vault stores fissile

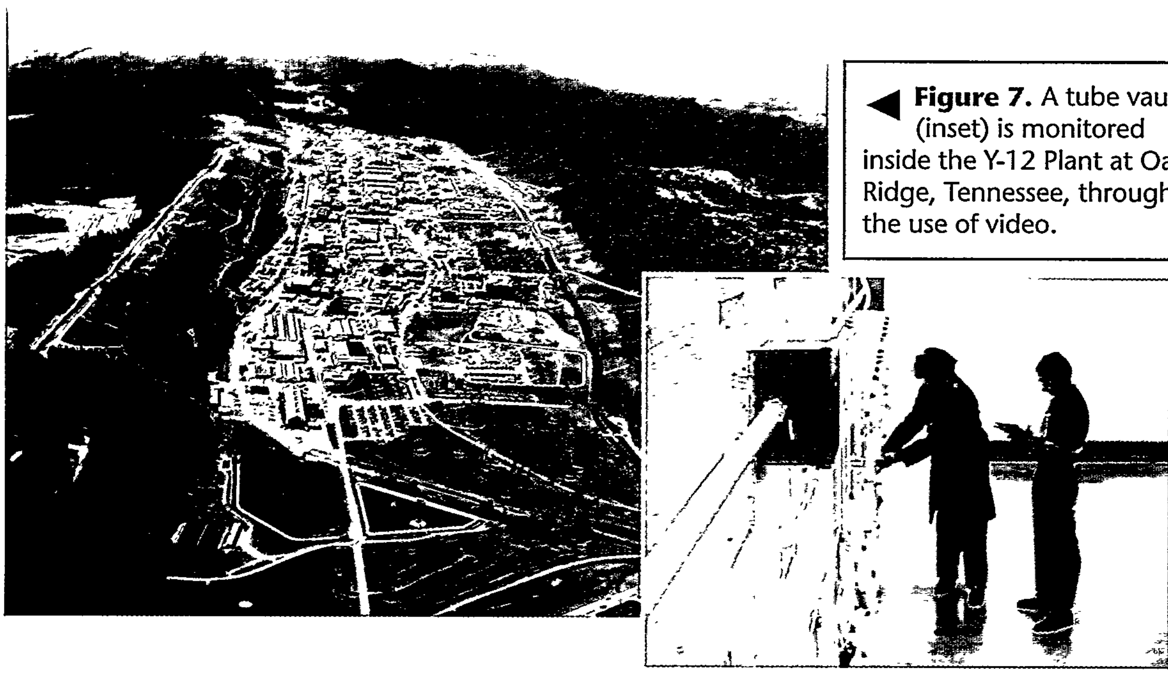


Figure 7. A tube vault (inset) is monitored inside the Y-12 Plant at Oak Ridge, Tennessee, through the use of video.

▲ **Figure 8.** IAEA Deputy Director-General for Safeguards Bruno Pellaud is monitored by the remote monitoring system prototype at the IAEA General Conference.

material no longer used for defense purposes. A mock nuclear-handling facility complete with a remote monitoring system constructed for the conference gave attendees in Vienna an interactive demonstration of the system and sensors (Fig. 8).

Phase 2 will be a field trial conducted jointly by DOE and the IAEA. Phase 2 field trials will begin in April 1996 and will last six months. At the conclusion of these field trials, a workshop will be held to discuss findings and results, which will be documented in a joint U.S.–IAEA report. Key objectives of the joint field trial are to:

- Identify reliable, durable, and cost-effective sensors and sensor combinations that can operate unattended, achieving IAEA verification goals at a storage facility.
- Examine satellite and telephone links for transmission efficiencies, and compare the economic advantages of using these links to support long-term IAEA communications planning.
- Evaluate front-end triggering of video-frame recording to confirm, in comparison to the current method of interval recording, that this new method can significantly reduce data without losing any significant event images.
- Identify authentication and encryption solutions that satisfy IAEA and DOE protection requirements.
- Exercise the system at regular intervals to verify that the sensors are functioning properly.
- Work with the IAEA to assess the acceptability of a remote monitoring system as a routine IAEA inspection mechanism.

The field trials are expected to demonstrate the following benefits for both the IAEA and facility operators:

- Reduction of inspection effort, cost, and intrusiveness through reducing the number of on-site inspections.
- Improvement of inspection efficiency and effectiveness by enhancing the quality, quantity, and frequency of data collection and analysis.
- Continuous verification of the presence of every individual item in an inventory instead of verification, during interim inspections, of the integrity of the containment and surveillance system and the actual presence of only a small subset of the inventory items.
- A dramatic reduction in time to detect potential anomalies in the inventory (in the case of Y-12, from 30 days to 1 day or less).
- Reduced radiation exposure to inspectors and operator personnel.
- The opportunity to perform no-notice inspections, achieving a fully independent interrogation process.
- Enhancement of the system to allow the IAEA to remotely inventory items for attribute measurements (e.g., radiation and temperature); currently, only an item's presence is monitored. This would greatly reduce or possibly eliminate the annual, physical-inventory verification process.

If the Phase 2 field trial is successful in meeting its objectives and proving the benefits provided by remote monitoring systems over traditional inspection methods, it is hoped that the IAEA will use this experience to define a clear set of requirements and policy guidelines for applying remote monitoring systems to improve the efficiency and effectiveness of routine IAEA inspections. ❖

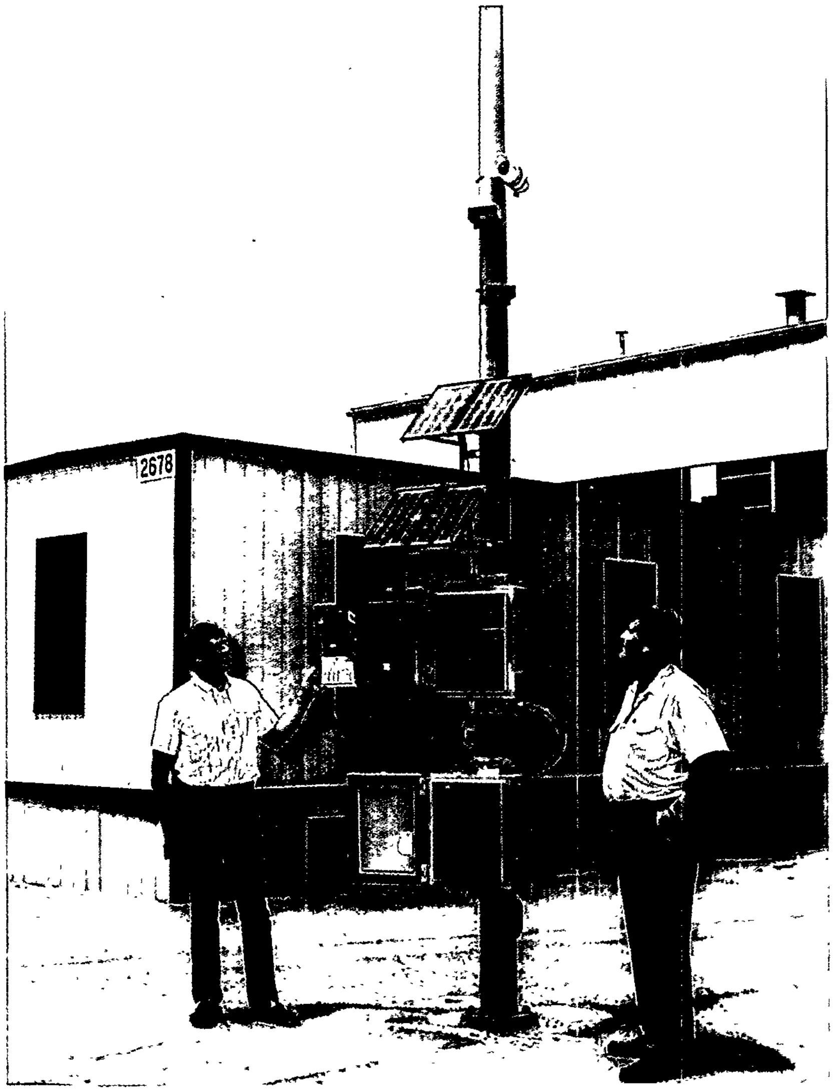
Contacts for International Remote Monitoring

Cooperative Monitoring Center at SNL
CONTACT: Arian Pregenzer
Sandia National Laboratories
ADDRESS: Mail Stop 1373
Albuquerque, NM 87185-1373
PHONE: 505-271-4185
FAX: 505-271-4187
CMC Homepage URL:
http://www.cmc.sandia.gov

International Remote Monitoring Project
CONTACT: Stephen A. Dupree
Sandia National Laboratories
PHONE: 505-844-9930
FAX: 505-844-6067
EMAIL: sadupre@sandia.gov

International U.S. and IAEA Remote Monitoring Field Trials
CONTACT: Bobby H. Corbell
Sandia National Laboratories
PHONE: 505-844-8468
FAX: 505-844-5321
EMAIL: bhcorbe@sandia.gov

Project Dustcloud: Monitoring Test Stands in Iraq



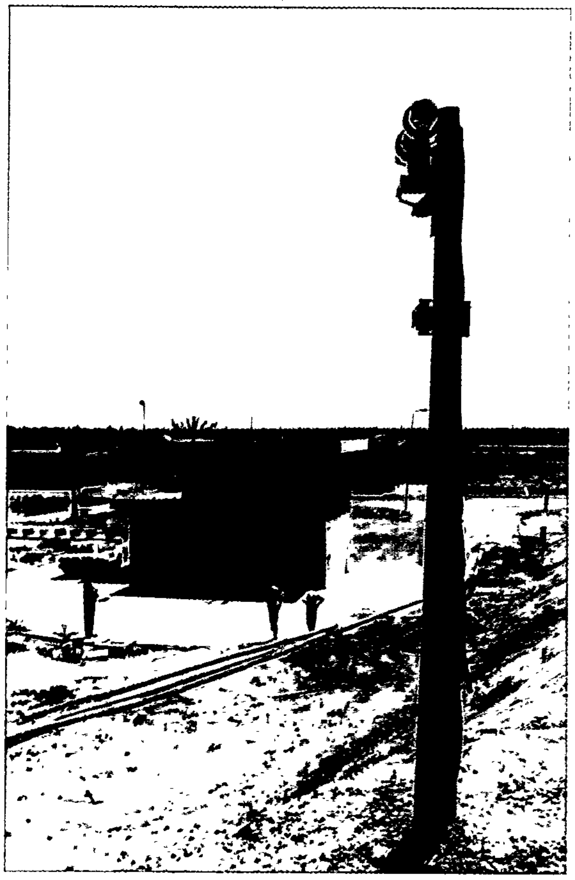
Pictured above: The unattended video-surveillance system has solar chargers to power the infrared trigger, video camera, transmitter, and local recorder.

In April 1993, the United Nations Special Commission (UNSCOM) contacted the Department of State to request hardware for monitoring rocket-motor test stands in Iraq. The Department of Energy's Lawrence Livermore National Laboratory (LLNL) responded with Project Dustcloud. Two video-monitoring systems were integrated and deployed in Iraq within two weeks of the request, one at the Al Azim solid motor test site and one at the Al Rafah liquid engine test site.

The original system consisted of a time-lapse VHS video recorder, black-and-white charge-coupled device (CCD) cameras, passive infrared sensors, a power supply, and a slow-scan video unit that sent still-video images over a standard analog telephone line (above photo). The system was enclosed in two fiber-glass cabinets. In December 1993, LLNL responded to a request to upgrade the hardware for a more robust communication link and installed two point-to-point radio telephones.

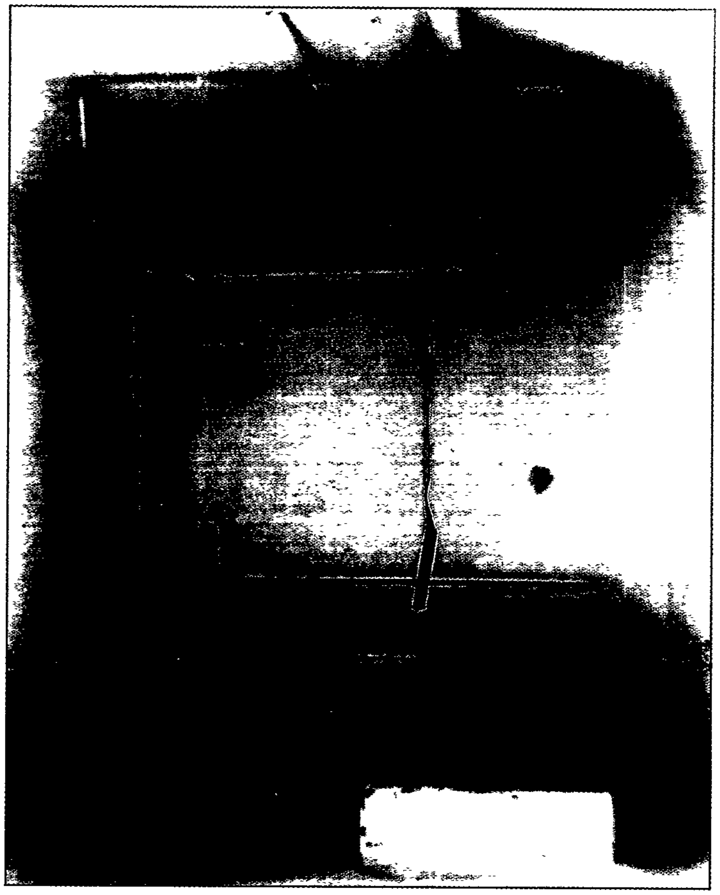
Although this system satisfied the original specifications, it was technically cumbersome and did not lend itself to expansion of the cameras and sensors or to mass production. When it became evident that more systems would be needed, we designed a new modular, expandable monitoring system design that could be easily replicated.

During this latter phase of Dustcloud, 20 modular and rack-based monitoring stations were manufactured and delivered



◀ **Figure 1.** The solid-fuel horizontal test facility at Al Azim has an infrared trigger and the video camera mounted outside the engine test facility. The control room is to the left (next to the car).

▼ **Figure 2.** A video camera is also mounted inside the engine test facility.



in a six-week period (Figs. 1 and 2). Additionally, LLNL provided the in-field technical support necessary to complete the installation, certification, and testing. The system became operational during the summer of 1994 and is the template for future monitoring systems of this type. The current monitoring system consists of individual nodes that may be part of a network communicating to a central control location or that may stand alone. Each unit accommodates up to four CCD cameras, two infrared retroreflective motion sensors, a motion sensor recorder, a VHS time-lapse video recorder, a digital video-sending unit, a radio telephone link, and a battery-backed-up power supply. Cameras can be positioned up to 300 meters from a node, and a simple field modification can further extend the distance. The system supports two-way communication via radio telephone links up to a distance of 90 kilometers. Simultaneous communication with up to six nodes is possible. Video is sent via a high-speed modem to a central control location, or, in the event of a problem at the node location, the node itself may initiate communication with the central control location. Each monitoring node is capable of continuous autonomous operation with suitable installation using solar power and batteries. ❖

CONTACT: **Bob Guyton**
Lawrence Livermore National Laboratory
PHONE: 510-422-8889
FAX: 510-422-9343
EMAIL: guyton1@llnl.gov

Bilateral Remote Monitoring: Kurchatov–Argonne-West Demonstration

Pictured above: Energy Secretary Hazel R. O'Leary meets with Russian representative Dr. Nikolai Ponomarev-Stepnoi during the March 1995 demonstration of U.S.–Russian bilateral monitoring.

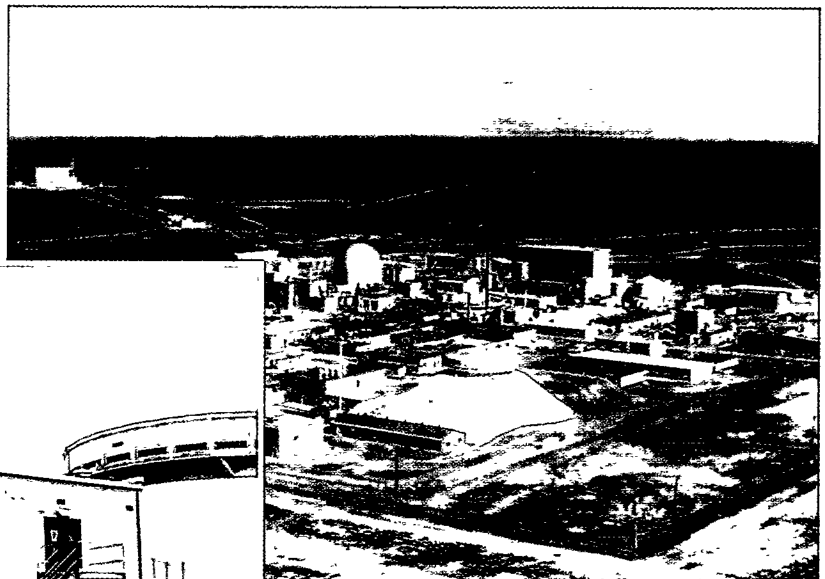
Since the end of the Cold War, organizations in the U.S. and Russia have worked together on a number of initiatives related to nuclear-material safeguards. These cooperative activities are conducted as both "government-to-government" and "laboratory-to-laboratory" projects. Methods and equipment for domestic safeguards and security have been widely shared in support of these activities. In March 1995, DOE, SNL, and the Kurchatov Institute Russian Research Center demonstrated cooperative remote monitoring of weapons-usable nuclear material between the Kurchatov Institute in Moscow and Argonne National Laboratory-West in Idaho (above picture). SNL worked with both sites to demonstrate and evaluate technology developed as part of the Cooperative Monitoring Program's Modular Integrated Monitoring System task and DOE's International Remote Monitoring Project (see pages 4 and 24, respectively, this issue).

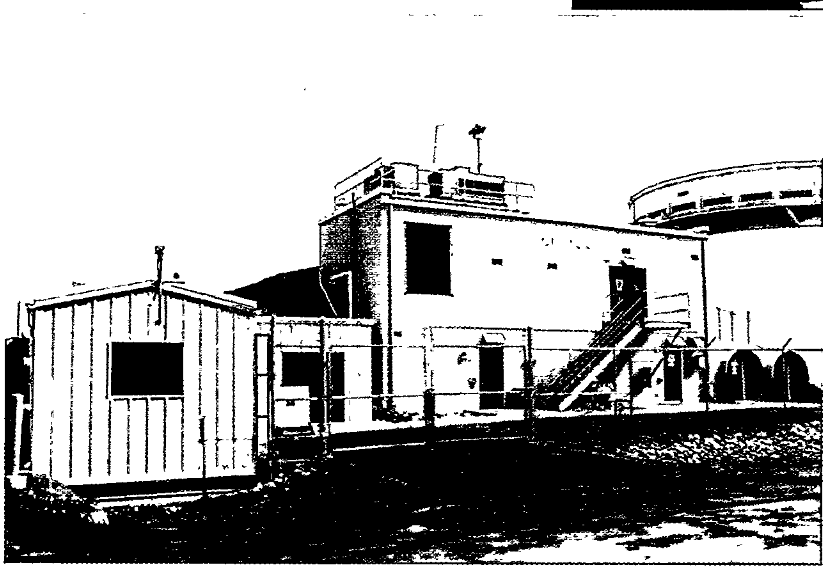
Facilities

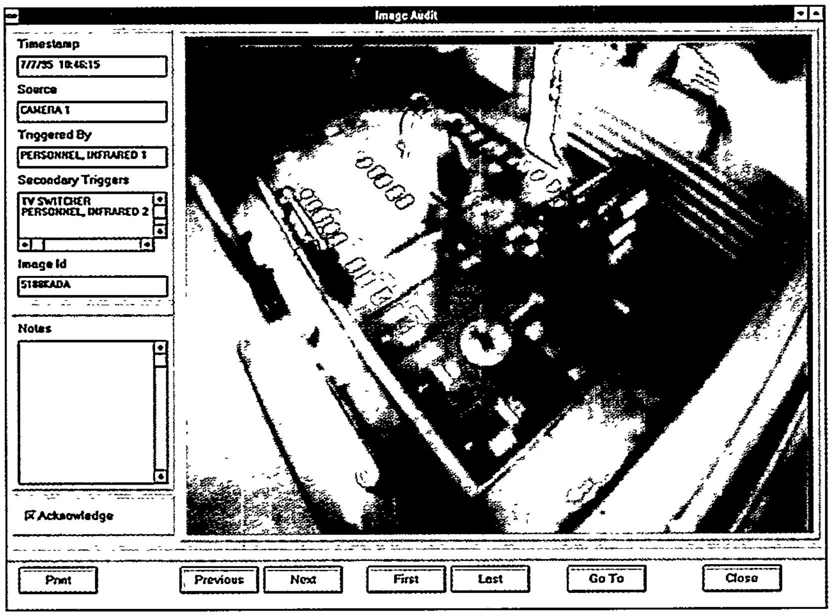
The Kurchatov Institute selected its Gas Plant (Building 209) as the participating storage facility (Fig. 1). The Gas Plant contains an underground vault filled with water for storing spent nuclear fuel. Additionally, six storage containers and a storage cabinet provide aboveground storage for fresh nuclear material. Seventy kilograms of highly enriched uranium (HEU) are stored in the Gas Plant. Argonne National Laboratory-West selected its Fuel Manufacturing Facility (FMF); 130 kilograms of stored HEU are monitored at the FMF (Fig. 2). On-going, that bilateral remote monitoring evaluates and

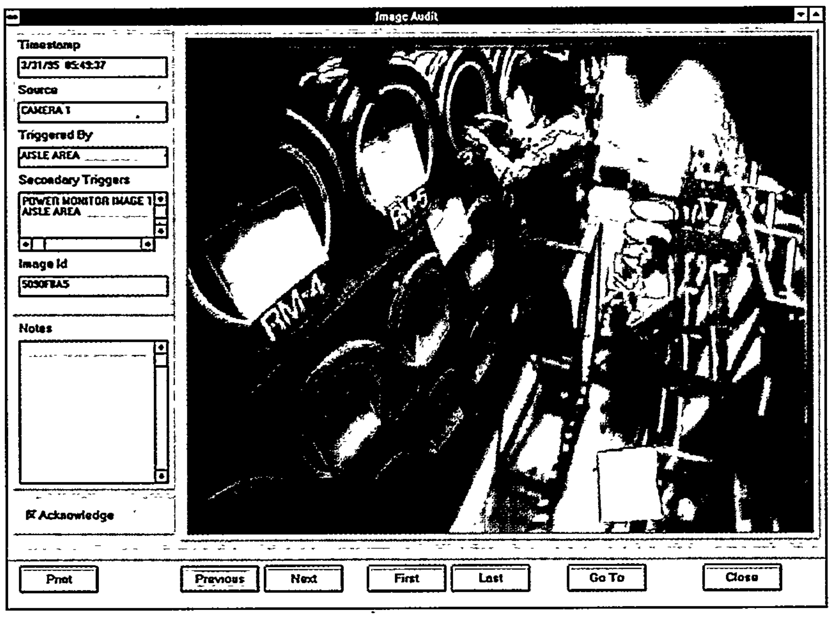
Figure 1. The Gas Plant (upper picture) at the Kurchatov Institute was chosen as the participating Russian storage facility.

Figure 2. The Fuel Manufacturing Facility (lower picture) at Argonne National Laboratory-West was chosen as the U.S. participating site.









◀ **Figure 3.** Video displays of the Kurchatov Gas Plant storage vault and the Argonne National Laboratory-West Fuel Manufacturing Facility.

analyzes the monitoring systems at both sites, with minimal impact on regular facility operations to date.

At each site, a Data Acquisition System (DAS) collects sensor and video information from the site's monitored storage area, storing it locally. Sensor data and images collected by the DAS can be reviewed at a Data Image and Review Station (DIRS) at each site. A DIRS operator at Kurchatov can request, by telephone, transfer of data and images from the DAS at the Kurchatov Gas Plant and from the DAS at the Argonne FMF. Similarly, a DIRS operator at Argonne-West can request transfer of data and images from the DAS at the Argonne FMF and from the DAS at the Kurchatov Gas Plant. In addition, for testing purposes, data from the DAS at each site can be remotely transferred, by request, to a DIRS at SNL's Cooperative Monitoring Center in New Mexico. Figure 3 shows video displays of the monitored storage areas at Kurchatov and Argonne-West.

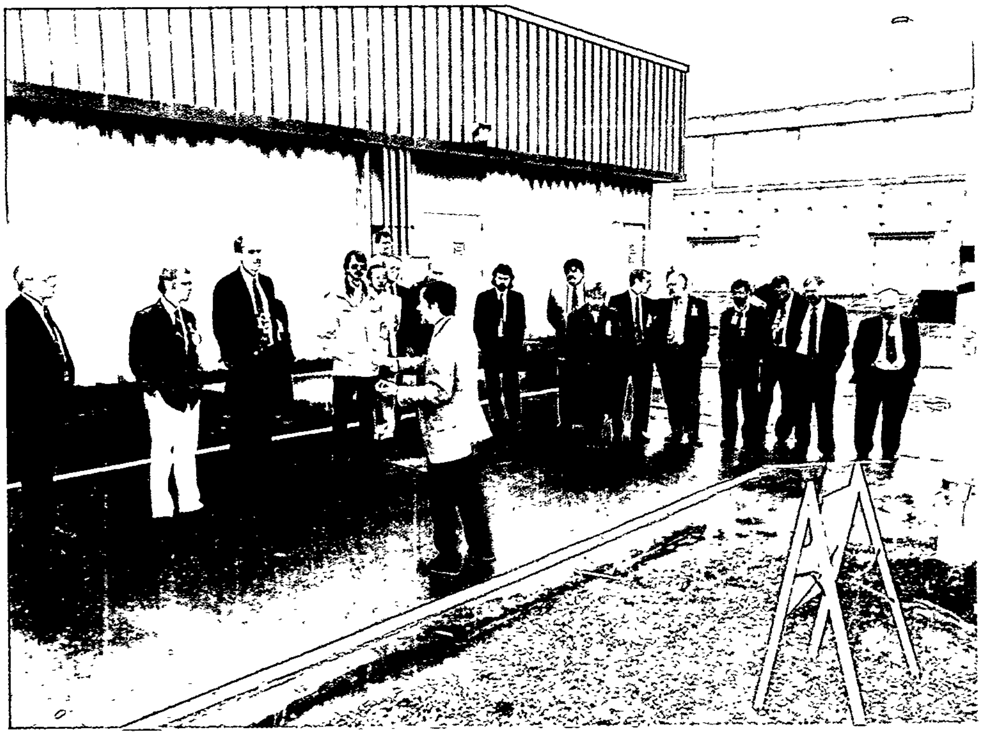
Future Plans

Plans are being discussed for future bilateral, remote monitoring nonprolifera-tion efforts include:

- Establishing a Russian–U.S. Nuclear Monitoring Center;
- Expanding the demonstration system at Kurchatov to its Central Storage Facility;
- Cooperatively enhancing both U.S. and Russian technology and components; and
- Expanding the use of the remote monitoring system to other Russian facilities and agencies.

Domestic and international safeguards that provide long-term control of and global assurance about the security of nuclear materials are the front line of defense against the threat of losing control of fissile materials. It is hoped that the bilateral U.S. and Russian remote monitor-ing task exemplifies how countries can work together within the framework of a mutually beneficial cooperative remote monitoring regime to support nonproli-feration efforts. ❖

CONTACT: **Rebecca Horton**
Sandia National Laboratories
PHONE: 505-844-3138
FAX: 505-844-6067
EMAIL: rdhorta@sandia.gov

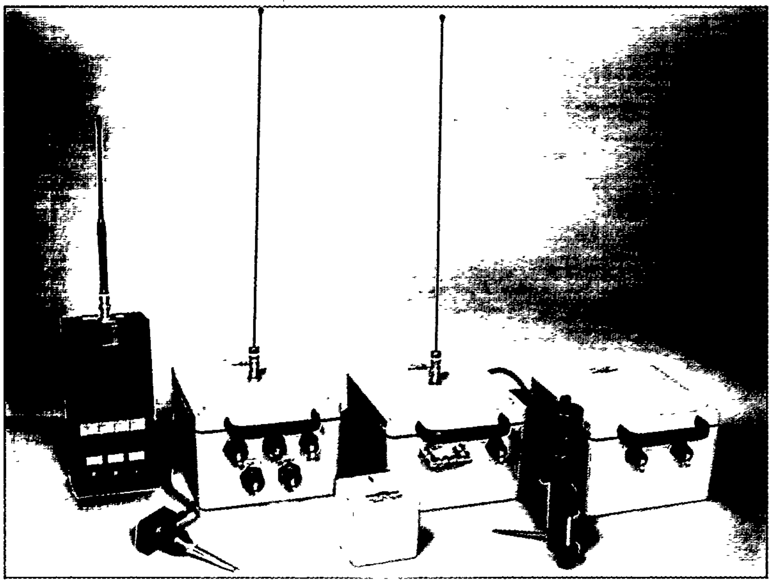


INSENS Sensor System Project

The Immigration and Naturalization Service (INS) has incorporated a modular architecture in its new generation of unattended ground sensors. Lawrence Livermore National Laboratory (LLNL) designed, developed, and produced the prototypes of this multi-probe, unattended ground sensor system that incorporated sensing elements, repeaters, and receivers linked into existing Border Patrol systems (Fig. 1). The project was funded by the INS and the President's Office of National Drug Control Policy. The Border Patrol monitors trails near the border and around its checkpoints to detect illegal entry of people and contraband into the U.S. These trails are major conduits for drugs entering the U.S., and these sensors are the first alert to illegal activities. The new sensors are an application of an LLNL-developed, open, unattended ground sensor system architecture called Modular Intelligent Sensor System (MISS), which allows revisions and improvements to algorithms without remanufacturing.

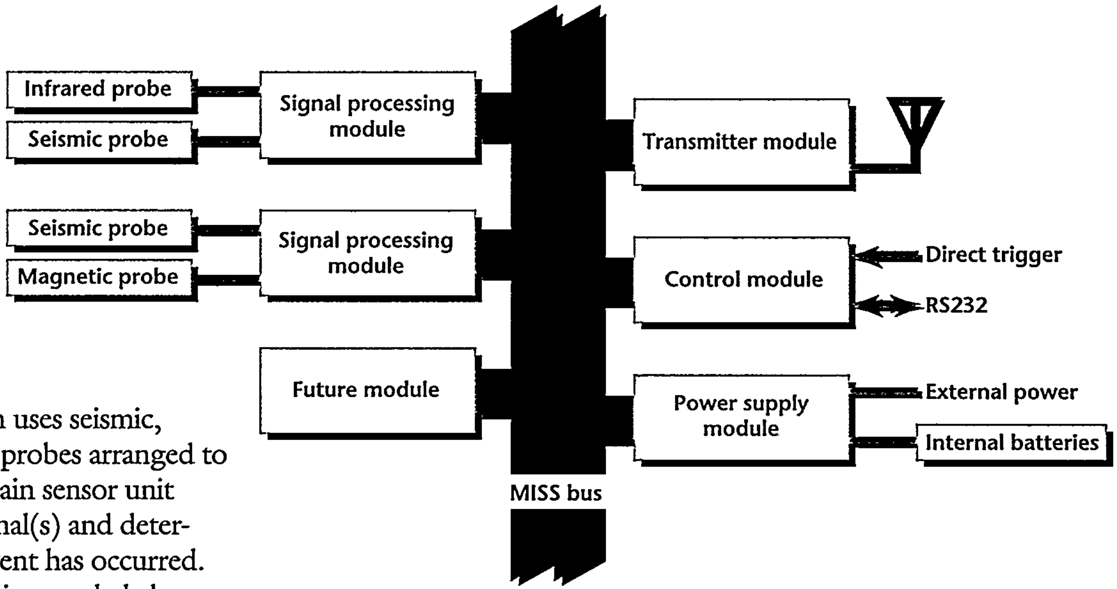
The key aspect of the MISS architecture is that intelligence is included in all modules. This design philosophy allows the system's control module to perform a broader set of operational activities and relieves it from addressing the operational details of each probe in the sensor system. A byproduct of this architecture is a simpler, more generic system control software that allows easier inclusion of new modules (Fig. 2). The MISS architecture uses a standard intermodule communication format so that modules can be added or removed as operational requirements change. The backbone of the architecture is based upon the I^2C bus developed by Philips/Signetics. This bus is designed as a low- to medium-speed, multi-drop communication system for use among compatible chips or subsystems located within a single enclosure.

Pictured above: Two INSENS-like unattended ground sensors were emplaced at the Item Tracking and Transparency Demonstration in December 1994.



◀ **Figure 1.** The entire INSENS system includes a portable monitor, a general sensor, a repeater, an external power source, (back row, left to right), a seismic probe, a directional magnetic probe, and a passive infrared probe (front row, left to right).

▼ **Figure 2.** The Modular Intelligent Sensor System (MISS) architecture is the backbone for the network of unattended ground sensors.



The INSENS system uses seismic, magnetic, and infrared probes arranged to detect movement. A main sensor unit evaluates the probe signal(s) and determines if a significant event has occurred. If so, the sensor transmits a coded alarm signal. A repeater receives coded alarm messages from the sensor and transmits them to the portable monitor. A portable monitor decodes the alarm message. The monitor can be used both by field personnel and, when located at Border Patrol headquarters, can be interfaced with a computer to alert dispatchers.

The open architecture developed for INSENS is currently being adapted by the Department of Energy to support its nonproliferation program. New transducers are being interfaced into the architecture including nuclear, radar, imaging, chemical, and acoustic detectors. LLNL has continued with developing software and detection algorithms embedded in the sensor elements. The INSENS sensor system was installed at two monitoring sites for the Item Tracking and Transparency Demonstration in December 1994 (see page 10). ❖

CONTACT: **David W. Myers**
Lawrence Livermore National Laboratory
PHONE: 510-422-1639
FAX: 510-422-9343
EMAIL: myers7@llnl.gov

Air Force Technical Applications Center

Charles McBrearty (4 copies)

Arms Control and Disarmament Agency

Thomas Graham
Janey Hatcher
John Holum
Arthur Kuehne
Stephen Ledogar
Sally Mullen
Steven Steiner

Bureau of Multilateral Affairs

Richard D'Andrea
David Clinard
Pierce Corden
Katherine Crittenberger
Donald Mahley
Bob Mikulak

Bureau of Nonproliferation Policy

Susan Burk
Michael Rosenthal
Larry Scheinman
Joseph P. Smaldone

Bureau of Strategic and Eurasian Affairs

R. Lucas Fischer
Rodney Jones
Karin Look
Stanley Riveles
Davis Wollan

Bureau of Intelligence, Verification, and Information Management

Robert Cockerham
R. Stephen Day
Richard Morrow
Jerry A. Taylor
Thomas Yehl

Central Intelligence Agency

Craig Chellis
Wilson Cook
Ruth David
Rena Epstein
John Fish
Torrey Froescher
Lawrence Gershwin
Robert Herd
Douglas J. MacEachin (2 copies)
James Meditz
David Newsom
Gordon Oehler
James Pavitt
Don Pittman
Daniel Tisler
Patricia Wartell
Ruth Worthen

Community Management Staff

Bill Richardson

Congressional Offices

Senator Bingaman Staff

Ed McGaffigan

Senator Domenici Staff

Peter Folger

Senate Armed Services Committee

L. Monica Chavez
Gregory J. D'Alessio
Donald A. Deline
Bill Hoehn

House National Security Committee

Andrew K. Ellis
Lee Halterman
Chris Williams

Senate Select Committee on Intelligence

Don Mitchell

House Permanent Select Committee on Intelligence

Diane S. Roark
Mark M. Lowenthal

Senate Foreign Relations Committee

Bill Ashworth

House Appropriations Committee

Jeanne Wilson

Senate Appropriations Committee

W. David Gwaltney
Alex Flint

Governmental Affairs Committee

Randy Rydell

House International Relations Committee

Chris Kojin

Defense Nuclear Agency

Chuck Gallaway (2 copies)
Don Linger (2 copies)

Defense Technology Security Administration

Edward B. Levy

Department of Energy

DOE/S

Hazel O'Leary, Secretary

DOE/DP

Liza Gordon-Hagerty
Gen. Eldon Joersz
Victor Reis
Tom Seitz
Robin Staffin

DOE/EH

Tara O'Toole

DOE/EM

Clyde Frank

DOE/EML

Phil Krey

DOE/NN

Kenneth Baker
Kenneth Luongo
George McFadden
John Nettles
Joan Rohlfing
Tom Ryder
Notra Trulock
Robert Waldron

Department of Energy National Laboratories

Argonne National Laboratory

Armando Travelli (2 copies)

Brookhaven National Laboratory

Joseph Indusi (2 copies)

Idaho National Engineering Laboratory

William Blume (6 copies)

Lawrence Livermore National Laboratory

C. Bruce Tarter, Director
Wayne Shotts
TID Library (10 copies)

Los Alamos National Laboratory

Siegfried Hecker, Director
Donald Cobb (20 copies)

Oak Ridge National Laboratory

Robert Upchurch (4 copies)

Pacific Northwest National Laboratory

Thomas Fox
James Fuller (5 copies)

Remote Sensing Laboratory

Richard Pollina

Sandia National Laboratories

Rebecca Horton (25 copies)
James Kelsey (6 copies)
Tom Sellers (3 copies)

Savannah River Technology Center

Al Boni (3 copies)

Department of Energy Operations Offices

Office of Scientific and Technical Information

Axel Ringe
OSTI Archives

Albuquerque Operations

Bruce Twining

Idaho Operations

John Wilcynski

Nevada Operations

Terry Vaeth

Oakland Operations

James Turner

Oak Ridge Operations

Joe LaGrone
Robert Spence

Richland Operations

John Wagoner

Department of Defense

OUSD/Office of the Asst. to the Sec'y of Defense (Atomic Energy)

Ralph Alewine, III
Ted Procir
Harold Smith (2 copies)

OUSD/Counterproliferation

Col. Ellen Pawlikowski

OUSD/International Security Policy

Ashton Carter
John Harvey
Franklin Miller

OUSD/Acquisition

George Bader
Arthur Johnson
Darel S. Johnson
Frank Kendall
George Schneiter
Thomas Troyano

OUSD/Research and Engineering

K. Anita Jones

Defense Intelligence Agency

John Berbrich
Joe Kerr

Personnel Programs, Education, and Training

David W. McIlvoy

Defense Technical Information Center

Kurt Molholm

Advanced Research Projects Agency

Raymond S. Colladay
Terese Esterheld

On-Site Inspection Agency

Jeorg Menzel

Institute for Defense Analysis

Jeff Grotte

Strategic Defense Initiative Organization

Henry Cooper

U.S. Army Foreign Science and Technology Center

Keywood Cheves

U.S. Army Dugway Proving Grounds

Reed Carlson

U.S. Army, ERDEC

Joe Baranoski
Steve Godshaw

U.S. Army, SSDC (CSSD-TA)

Matthew Nichols

Department of State

James Goodby
James P. Timbie

Bureau of European and Canadian Affairs

Alex Burkart
Alexander R. Vershbow

Bureau of Intelligence and Research

L. Elizabeth Frisa
Randolph Bell
Charles J. Jefferson

Bureau of Politico-Military Affairs

Richard Davis
Anne Harrington
Carol E. Kessler
Theodore McNamara

General Accounting Office

Raymond A. Plunkett

Federal Bureau of Investigations Laboratory

Drew Richardson

National Institute of Justice

David G. Boyd

National Security Agency

John McConnell
Michael Smith

National Security Council

Steve Andreasen
Bob Bell
Michael Fry
Elisa Harris
Daniel Poneman
Philip Zelikow

Naval Research Laboratory

Richard Cassidy
Timothy Coffey

Office of Management and Budget

Bob Civack

University of California National Security Panel

John F. Ahearne
Sidney D. Drell, Chair
Robert C. Dynes
William R. Frazer
Andrew J. Goodpaster
W. John Landis
Kaye Lathrop
JoAnn Milam
Robert Peurifoy
Daniel Simmons
Elaine Stammon, Coordinator
Rochus E. Vogt
Robert H. Wertheim
Herbert F. York

U.S. Customs

Lawrence O'Donnell