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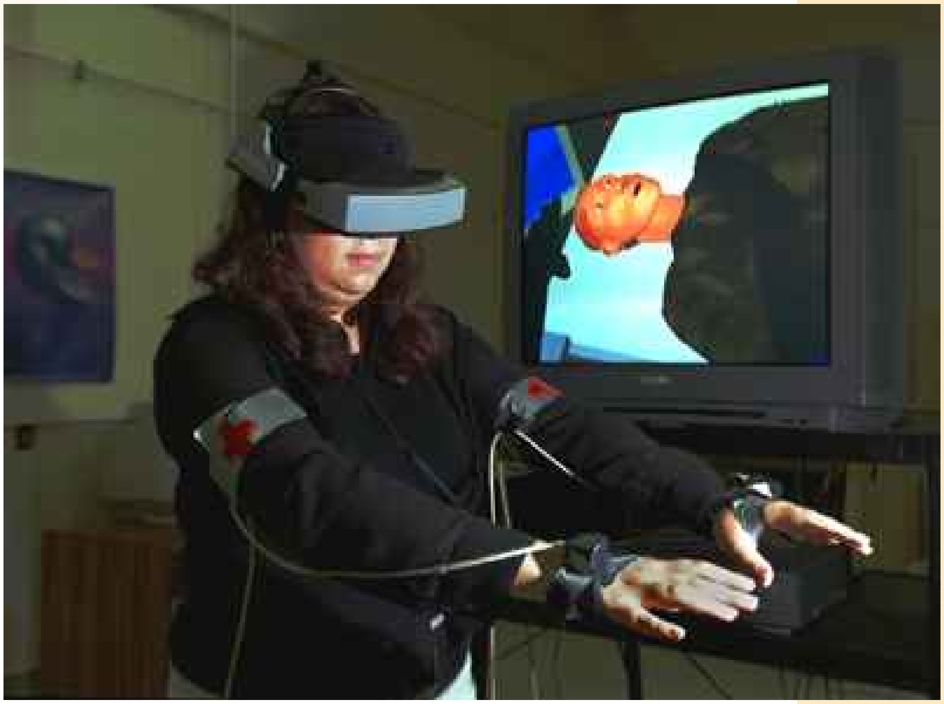
PEACE IN AN EDGY WORLD

Nonproliferation: Keeping Weapons of Mass Destruction at Bay

ALSO:
Nuclear Transparency

Minirobots Conduct Search & Rescue

Sandia National Laboratories
A Department of Energy National Laboratory



Sandian Lydia Tapia demonstrates BioSimMER, a virtual reality application developed at Sandia. This tool allows rescue personnel to practice responding to a terrorist attack that involves the release of a biological warfare agent. Through her goggles, Lydia sees the scene that is displayed on the screen behind her. The virtual patient she is treating suffers from a severe head wound and exhibits realistic symptoms, such as heavy breathing and rapid eye movement.

Nonproliferation is a U.S. priority and a key element of the Sandia Mission. Nonproliferation must address 50 years of weapon development. Weapon stockpiles of many nations still pose an escalating threat to the United States and its allies.

ON THE COVER: The Multispectral Thermal Imager (MTI) satellite, designed and built at Sandia National Laboratories, was launched March 12, 2000. The satellite is expected to have a broad range of national defense and civilian applications ranging from treaty monitoring to mapping of chemical spills, waste heat pollution in lakes and rivers, vegetation health, and volcanic activity. Its unique camera, designed and built by a government and industry team led by Sandia and calibrated at Los Alamos National Laboratory, gives the satellite the ability to photograph light and heat patterns on Earth that are not visible to the human eye.

Sandia Technology is a quarterly journal published by Sandia National Laboratories. Sandia is a multiprogram engineering and science laboratory operated by Sandia Corporation, a Lockheed Martin company, for the Department of Energy. With main facilities in Albuquerque, New Mexico, and Livermore, California, Sandia has broad-based research and development responsibilities for nuclear weapons, arms control, energy, the environment, economic competitiveness, and other areas important to the needs of the nation. The Laboratories' principal mission is to support national defense policies by ensuring that the nuclear weapon stockpile meets the highest standards of safety, reliability, security, use control, and military performance. For more information on Sandia, see our Web site at *http://www.sandia.gov.*

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FROM THE *Editor*

Dear Readers:

Remember talk of the "peace dividend" at the end of the Cold War? In 1989, as the Soviet Union split apart and the Berlin Wall crumbled, many Americans felt that a large portion of the nation's enormous defense budget should be redirected into social programs, healthcare, and rebuilding our national infrastructure.

But as we've come to learn, the very visible threats of the Cold War have been replaced with more subtle and even invisible threats. Acts of terrorism and concerns about the transgressions of rogue states keep America vigilant. And that vigilance requires new weapons—primarily technologies that provide the eyes and ears that can detect threats to our national security and counter them if necessary.

Sandia National Laboratories is playing a big part in helping to stem the proliferation of weapons of mass destruction throughout the world. Sandia's initiatives in nonproliferation and arms control include the development of technologies and programs that help restrict the supply of weapons, materials, and know-how to proliferators; and monitoring technologies for detecting detonations occurring underground, underwater, in the atmosphere, or even in space.

In addition, Sandia's Cooperative Monitoring Center assists political and technical experts throughout the world to acquire the technology-based tools they need to assess, design, analyze, and implement nonproliferation, arms control, and other cooperative security measures.

While America remains at peace, it is truly a peace in an edgy world, as shown in this issue of Sandia Technology.

Chris Miller

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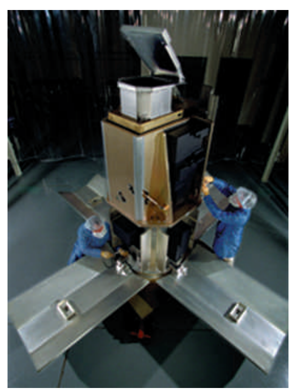

INSIGHTS

by Victor Allessi, CEO, U.S. Industry Coalition

COOPERATIVE MONITORING CENTER-

because local disputes can rattle a planet

The end of the cold war reduced the likelihood of global war but has increased regional conflict. Without the stability of two dominating superpowers, local disputes over resources, territory, immigration, and ethnic and political antagonisms can escalate into regional conflicts. If the regions involved have weapons of mass destruction (WMD), regional wars could be devastating.

U.S. Department of Energy (DOE) goals for nonproliferation of WMD and their delivery systems remain relevant into the 21st century. Achieving regional security is critical to nonproliferation for three reasons:

First, regional tension and threat perceptions may motivate nations to acquire WMD. Addressing these tensions can decrease them, and direct national efforts toward econimic growth.

Second, regional concerns affect negotiation and implementation of global arms control and nonproliferation. For example, regarding the signing of the Comprehensive Test Ban Treaty, nations like India and Pakistan, base their actions on those of their neighbors.

And third, global progress in nonproliferation may require progress in regional arms control and the establishment of regional regimes tailored to unique geographic and historic circumstances. An example is how Argentina and Brazil developed a bilateral nuclear agreement before participating in global nonproliferation.

The DOE established the Cooperative Monitoring Center (CMC) at Sandia in 1994. The CMC promotes development of technical and scientific infrastructure for arms control around the world by conducting training workshops to explore how technology can facilitate solutions and by providing assistance to ongoing international negotiations and discussions. In conjunction with several other Sandia departments, the CMC supports and displays international experiments that use technology to enhance nuclear transparency and confidence-building measures. The Visiting Scholars program offers extended assignments to perform research. *(Please see sidebar, page 15).*

Workshop participants receive hands-on experience with monitoring hardware, software, and data processing capabilities for a range of applications. For example, the CMC collects monitoring data from nuclear facilities worldwide as part of an experiment to demonstrate the role of remote monitoring in nuclear transparency.

All CMC projects support U.S. policy at the departments of State and of Defense. Officials in the departments of State and Energy actively participate in agenda setting and often attend workshops.

"Cooperative evaluation, development, and experimentation can be a very important part of the strategy to deal with nonproliferstion," said Arian

The Cooperative Monitoring Center at Sandia

Pregenzer, Center co-manager with Frederick Luetters, manager of the Advanced Concepts Department of the International Security Center.

"Confidence building, responsible partnership, and technology can be used to help resolve some conflicts and to implement solutions," she added. "It always bears asking the question, how can we cooperate with someone else?"

But disputing nations must have the will to resolve conflict before technology can help people implement peace and build confidence and security, said Kent Biringer of the CMC staff. "These are all U.S. concerns," Biringer said. "War elsewhere would impact U.S. energy supplies, military alliances, Americans working abroad, and could motivate attacks on U.S. embassies. Finding ways the labs can help solve problems is the CMC goal."

Indeed, the world could use some creative ways to begin peace processes.

The post-Cold War era has brought new kinds of regional problems: terrorism, proliferation, resource issues.

The CMC has worked with 85 countries as well as delegations from the United Nations and the United States Information Agency. The Center focuses on nonproliferation in Russia, the Middle East, and Asia. The CMC demonstrates how to use about 100 technical systems with nonproliferation applications. Nations working with the CMC may take interest in these systems because, in addition to monitoring WMD, the systems can be used to monitor conventional military activities and environmental conditions. *(Also see News Notes, page 19.)* All these technologies are "over-the-counter" items that are exportable, unclassified, and available to anyone anywhere.

Among the information, security, and data authentication systems available through the CMC are:

- Radiation sensor systems;
- Motion detectors that can trigger a video camera;
- Seals on containers;
- Monitors to detect changes in container weights;
- Access-control monitors to track physical access to areas that might store nuclear materials; and
- Ground sensors (magnetic, seismic, acoustic, and fiber optic) to detect and monitor activity in areas of concern.

The CMC operates under these tenets:

- Regional problems require regional solutions—each region is unique and needs to create its own foundation for confidence building and arms control;
- Education and training are key to constructive, regional participation;
- Agreements on WMD may be the last step in the regional security process;
- Collaborative technical experiments provide opportunities to investigate a range of monitoring options in nonthreatening environments.

Conference unites a world of science and technology to curb WMD proliferation

The Cooperative Monitoring Center at Sandia has hosted the International Arms Control Conference for three years. Attending the annual event are representatives from the United Nations, NATO, and more than 40 nations. Together these experts discuss how to limit the spread of chemical, biological, and nuclear weapons.

"This conference brings together key leaders and policy-makers in the arms control community to discuss issues that will be of concern to nations around the world in the coming century," said conference chair Dr. James Brown of the CMC. "Previous conferences have allowed for a creative exchange of ideas and have resulted in valuable relationships among some of the world's top arms-control experts."

The 2000 conference was held April 14 – 16.

CMC Visiting Scholars Program

In an informal setting, each scholar tries to understand the other's point of view in an attempt to find workable solutions.

Since 1997, in cooperation with the University of New Mexico (UNM), the Cooperative Monitoring Center has operated a multidisciplinary research and analysis program called Visiting Scholars. The program brings scholars each year to the CMC to research how technology can support cooperative security. One important area of research is nonproliferation. Other topics are cooperative monitoring for nuclear transparency, confidence building, environmental issues, and arms-control verification.

The Scholars program brings in policy experts to conduct research for three to six months, during which researchers from opposing countries may collaborate on a common problem. In an informal setting, each scholar tries to understand the other's point of view in an attempt to find workable solutions. Most participants are established scholars with professional, military, or academic qualifications.

Past visiting scholars have published papers on such topics as cooperative and environmental monitoring of the Indian and Pakistani coasts, cooperative border security for Jordan and Israel, solving territorial disputes in South Asia, confidence-building measures that could be proposed for use in the Korean Peninsula, as well as a confidence-building study of the India-China border, and an environmental monitoring study of the Indian and Pakistani coasts.

UNM's Institute for Public Policy helps manage the program. The institute assists in recruitment, administration, and project oversight. Participating scholars are hired as temporary employees of UNM and have full access to UNM libraries and research facilities. The CMC provides office space, computers, communications, and administrative support.

NEWS *Notes*

SANDIA JOINS NATIONAL CHARGE INTO 21ST CENTURY NANOTECHNOLOGY REVOLUTION

Sandia and other U.S. Department of Energy (DOE) national laboratories will venture further into the truly tiny realm of atomic and molecular maneuvering. This follows a recent announcement of a "National Nanotechnology Initiative" by President Clinton at the California Institute of Technology (Caltech) in Pasadena.

The initiative would increase overall federal funding for nanoscience and nanotechnology R&D by 84 percent to $497 million beginning in fiscal year 2001. It would increase the funding at DOE from $58 million to $96 million in fiscal year 2001 (66 percent more than in 2000).

Nanotechnology refers to the manipulation or self-assembly of individual atoms, molecules, or molecular clusters into structures with dimensions in the 1- to 100-nanometer range to create materials and devices with new or vastly different properties. For comparison, a human hair is about 10,000 nanometers thick.

Scientists believe the ability to move and combine individual atoms and molecules will revolutionize the production of virtually every man-made object and usher in a new technology revolution at least as significant as the silicon revolution of the 20th century.

"The possibilities to design materials and devices with extraordinary properties through nanotechnology are limited only by one's imagination," said Tom Picraux, Director of Sandia's Physical and Chemical Sciences Center.

Building solar cells containing nanolayers or nanorods could significantly increase the amount of electricity converted from sunlight. Computer memory devices that take advantage of the spin of electrons could hold thousands of times more data than today's memory chips. Molecular devices that mimic processes within living cells could help doctors find or treat diseases. And nanoclustered catalysts could help destroy environmental pollutants using the energy from sunlight.

Sandia already has used ion-implantation techniques to create lightweight aluminum composites that are as strong and durable as the best steel available. Nanostructured semiconductor materials created at Sandia may enable highly efficient, low-power lasers for high-speed optical communications. Biosensors that use molecular bundles similar to those found in living cells are being created that could warn people when traces of a chemical or biological warfare agent are detected.

Although nanotechnologies hold great promise, scientists need a much better understanding of the special rules that govern how nanoscale structures behave and interact, and how these rules can be harnessed to create materials and devices.

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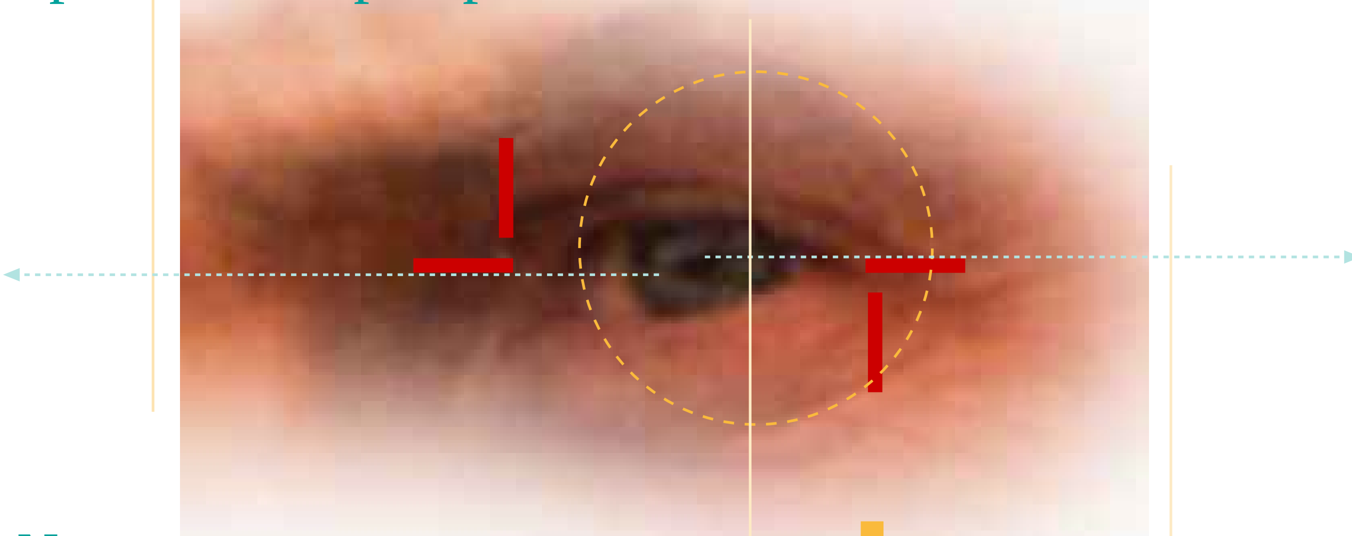
NUCLEAR TRANSPARENCY

Nuclear transparency is making what you're doing open and available to the intereste public so people can make their own decision



Nuclear transparency shows citizens of the participating nation as well as those of neighboring nations that industries are in compliance with global norms for nonproliferation and safety.

The nuclear transparency program began in 1996. Sandia researchers believed that nuclear transparency and confidence-building measures—if implemented regionally—could be useful to the Korea Energy Development Organization (KEDO), which was constructing two reactors.

"How could North Korea's neighbors get data to supplement the International Atomic Energy Agency (IAEA) safeguards and be confident about nonproliferation compliance?" asked John Olsen, Cooperative Monitoring Center staff member in charge of the nuclear transparency project. "Could we then make someof that data available to encourage safer operations too?" The answer seemed to lie in the Internet.

"We believe Internet technology is really the way to make transparency work, get data to people who need it, and do so in a cost-effective way," Olsen said. "While working on this project, quite a few nuclear industries in northeast Asia have greatly expanded the use of the Internet. We feel their cooperation in our nuclear transparency Web site is a logical extension of what they are doing themselves anyway."

If a Web site could show that fissile materials were not being diverted and that material transport was safe, then regional observers could have additional assurance that operations were safe and nonproliferating. If, on the other hand, the Web data were worrisome, public exposure would encourage the plant in question to modify its procedures.

"We believe Internet technology is really the way to make transparency work, get data to people who need it, and do so in a cost-effective way. While working on this project, quite a few nuclear industries in northeast Asia have greatly expanded the use of the Internet. We feel their cooperation in our nuclear transparency Web site is a logical extension of what they are doing themselves anyway."

"Is there radiation floating around? You can't hide bad news. If you have an accident, everyone will know, and you'll look worse if you weren't open about what you were doing in the first place."

The principle is simple: If you know everyone is noting the data on your company every day, then you reinforce safe procedures to avoid potential embarrassment.

"The Japanese call it a safety culture," Olsen said. "In the long run, it might get nations to show fissile material is safe beyond their compliance with IAEA safeguards.

"Is there radiation floating around? You can't hide bad news," Olsen said. "If you have an accident, everyone will know and you'll look worse if you weren't open about what you were doing in the first place."

Central to the nuclear transparency effort is an international, nongovernmental group called the Council for Security Cooperation in the Asia Pacific (CSCAP). CSCAP working groups convene to discuss regional issues from a policy perspective. One of those topics is how to make nuclear transparency widespread and how to get commercial, Pacific-rim nuclear powers to participate. The fledgling program does not address military use of nuclear power.

The transparency program currently focuses on building cooperation by making hyperlinks to Web postings of airborne radiation levels and by providing daily operating data on nuclear power stations.

The CMC is asking nuclear operators and regulators to send radiation data directly to the nuclear transparency Web site. This will permit the display of many sets of regional data at a centralized Web site. Currently, even the data that are available are extremely difficult to find unless one can read all the regional languages.

Eventually, the nuclear transparency project will move to more sensitive topics and touch on nonproliferation. However, regional participants have stressed the need first to build a tradition of cooperation, starting with near-term goals such as airborne-radiation levels. Japanese and Chinese Taiwanese nuclear industries have expressed strong interest in the project and have provided access to Web sites with a variety of operational and safety data. South Korea and China have shown interest in nuclear transparency, and they participate in CSCAP meetings that guide development of the project. The Web site has been in development for one year and will probably open to the public next year.

■

A constant supply of nondefense technology evolves from national security research.

The make-up of fire retardants, insecticides, and pesticides along with plastics and food-processing technology rely on chemicals developed as nerve agents for national defense. Oil exploration uses the same electronic devices that trigger nuclear bombs. And some peaceful applications of nuclear power have used the infrastructure and expertise created for nuclear weapons.

Here is a look at how sensors are improving everyday life in the nondefense sector:

Sensors developed for defense purposes are important nonproliferation tools that can detect weapons-grade nuclear materials. As terrorism becomes more prevalent at home and abroad, sensors are becoming central to safety in public facilities as well as in detecting nuclear smuggling. Airports have long used this technology to check passengers and baggage for weapons.

Similarly, law enforcement organizations are employing sensors to detect the storage or transport of drugs, and sensors in public schools are making these institutions safer for children.

Industry uses sensors for safety, quality control, and inspection. Sensors are beginning to make automobiles smart enough to protect drivers from their own misjudgment and road hazards outside the car. The clothing industry also uses sensor technology to gauge how well and consistently textiles, such as cotton, are woven.

Sensors developed for defense purposes are important non-proliferation tools that can detect weapons-grade nuclear materials.

CZT SENSOR ‘RADIATES’ BENEFITS

We can expect advances in cancer detection as a result of improved radiation sensors, such as the CZT sensor *(see page 7)*.

A radioisotope can be injected into an area of rapid cell growth to make a tumor glow. This tool could improve diagnosis and the surgeon can see the exact location and chart a map for removal. CZT technology is being commercialized already for the treatment of breast cancer. Radiation sensors offer similar advantages to the treatment of heart disease.

Similarly, a radiation sensor can advance environmental clean-up efforts by hastening detection of radiation underground.

NASA will use the Sandia-developed CZT technology for a $150 million study of gamma-ray bursts, the most powerful energy source in the universe. These bursts come from outside the galaxy and may hold clues to the origins of the cosmos.

NEWS *Notes*

MINIROBOTS CONDUCT GROUP-SEARCH MISSIONS

Sandia National Laboratories researchers have developed a computer program that provides group intelligence for a swarm of minirobots to aid rescuers in finding avalanche victims.

In Sandia computer simulations, searchers using the swarm computer algorithm, called distributed optimization, found avalanche victims four times faster than simulations of any published search scheme currently in use.

“That’s with conditions as simple as possible,” said Rush Robinett of Sandia’s Intelligent Systems and Robotics Center. In more complicated situations, where depth of snow, burial, or rocks or trees created complications, the Sandia algorithm comparatively was even faster, he said.

In its primary use for the Department of Defense, the search algorithm enables cockroach-sized robots to “talk” to each other through radio transmitters and home in on a target far more quickly than solitary searchers using more conventional means. The group-search technique, called swarming, relies on neither a central intelligence telling the searchers what to do nor the intuition of individuals. Instead, each robot continually informs others of its position and of the strength of signal received at that position from the sought-for source. The steady streams of information from multiple sources allow each member of the swarm to continually refine the direction of its search.

Skiers in avalanche country already carry radio beacons as standard equipment. But search techniques to locate the beacon are still somewhat unsophisticated. A standard approach is to exhaustively search every inch of ground—a time-consuming procedure. Another requires the searcher to turn at a right-angle when signal strength decreases. Such searches are difficult because buried obstacles mask the strength of radio signals, and the transmitter’s physical orientation is unknown.

Says Robinett, “Because finding the location of a radio-frequency sender and finding the center of a region from which some form of lethality is emanating are essentially the same activity, we can solve a whole class of similar problems with the same algorithms. By carrying lightweight radios, GPS positioning devices, and pocket computers programmed with robotic search algorithms, rescuers would be told [by computer screen], ‘South three steps for most efficient path search,’ or some such thing.”

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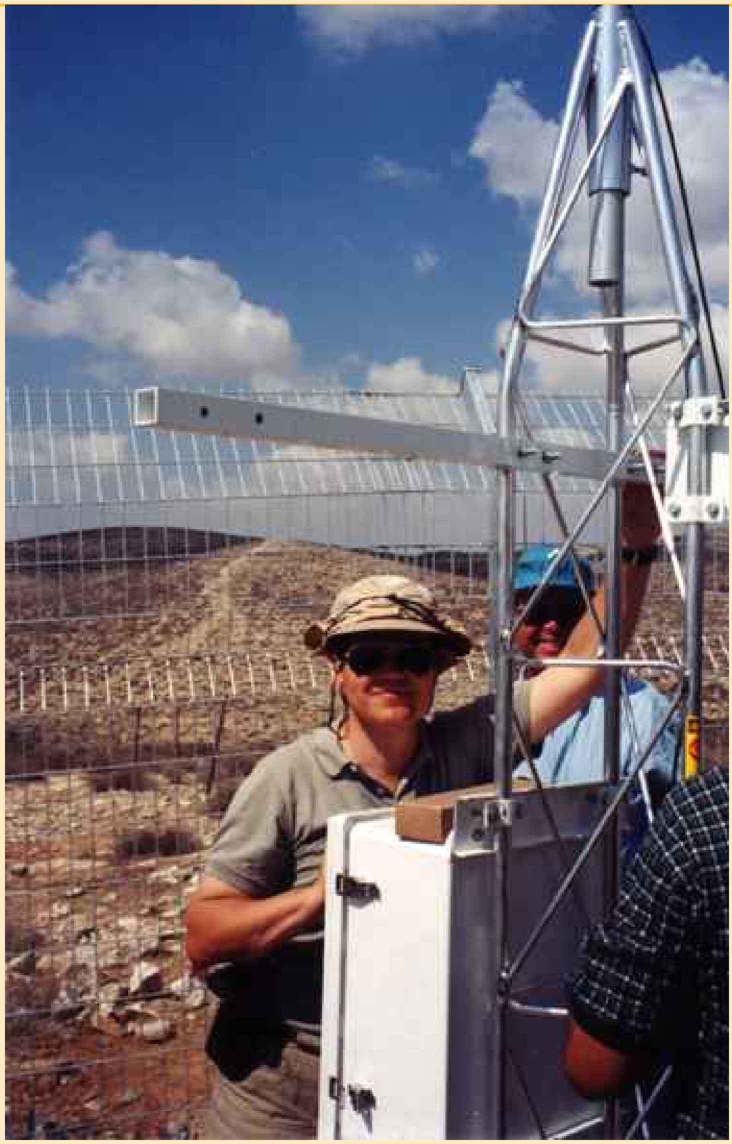
NEWS *Notes*

PALESTINIAN AND ISRAELI RESEARCHERS COLLABORATE IN SANDIA PROGRAM



Israeli and Palestinian environmental researchers are collaborating and sharing information through a year-old project initiated by the Cooperative Monitoring Center (CMC) at Sandia National Laboratories.

The collaboration brings together scientists to study ways to help maintain shared sustainable grazing and agricultural systems important to the future of both Israel and the Palestinian Authority. Meteorological data are fundamental to environmental research but had not been readily available to regional scientists.

"In the environmental sciences the ecosystem does not function according to political boundaries," said Ben-Gurion University Professor Moshe Shachak, a preeminent desert ecologist who serves as Israeli coordinator for the project. "Therefore, especially in the Middle East, we must have cooperation if we are to have a sound environmental program. The goals of the program are to understand the structure and function of water-limited systems and to preserve the services they provide for humans."

CMC Program Manager Arian Pregenzer helped initiate the project on Sustainable Land Use Monitoring in the Middle East while visiting Israel in the spring of 1998. About a year ago the U.S. Department of Energy approved a small amount of funding for a collaborative experimental project linking Palestinian, Israeli, and American researchers at the CMC and the University of New Mexico.

Selected as Palestinian project partners were the Agriculture Department of Hebron University and the Palestinian Ministry of Environmental Affairs. The Israeli partners were Ben-Gurion University Mitrani Center for Desert Ecology and the Ministry of Agriculture's Volcanic Center.

The team members decided to install meteorological stations at four ecological research sites located along a 100-kilometer-long ecological gradient in the northern Negev Desert. Precipitation levels at the sites range from about 6 to 12 inches a year. Two of the stations are in Palestinian-controlled areas of the West Bank, and two are in Israel.

Sandia-supplied monitoring and communication equipment have been installed at the research sites for data collection and sharing. The stations take hourly measurements of air temperature, rainfall, soil temperature, soil moisture, wind speed and direction, barometric pressure, and relative humidity—all variables that help define ecological conditions. The Palestinian and Israeli partners collect and share the data from all the stations weekly by cellular modems. The CMC maintains a Web site so that any researcher in the world can see and use the data.

"The researchers can use the environmental data in a variety of ways; for example, studying long-term climate changes, determining optimum irrigation amounts for specific plants, and monitoring air quality," said Michael Vannoni, CMC Middle East Program manager. "As a result of this collaboration, several joint research proposals to international funding organizations have already been submitted by the partners."

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INSIGHTS

by Victor Allessi,
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America's Nonproliferation Efforts Must Expand with a Changing World

Victor Allessi,
CEO, U.S. Industry Coalition
Excerpted from keynote address given at Sandia National Laboratories' 50th Anniversary International Colloquium, Nov. 2, 1999

The end of the Cold War and the collapse of the Soviet Union ended a period of great predictability. For the 40 years of the Cold War, it was clear what was the threat, from where it came, and what was needed to cope with it. Today, life is less predictable and we cannot fully understand the implications of the New World. In the decade since the end of the Cold War, the U.S. nuclear weapons laboratories have met the challenge of a changed world, particularly the real threat of a hemorrhage of Russian nuclear weapons or expertise into the hands of rogue or terrorist states. The future is unclear, but there are several things that must be taken into account in managing the challenges of the future as they arise.

For many Americans, the end of the Cold War meant that security policy has taken a backseat to the domestic economy. The great prosperity of the United States following the end of the Cold War has led people to think all is well, and it is contributing to a growing indifference to international involvement. The national laboratories have been farsighted enough to understand fully that U.S. prosperity and security are linked with how the United States deals with the rest of the world.

The national laboratories have been at the forefront of dealing with proliferation and terrorism, regional instabilities, and an emerging China. They were among the first to recognize that the collapse of the Soviet Union was not an unmitigated blessing for the United States as the collapse would inflict desperate straits on thousands of nuclear weapons scientists living in impoverished isolation in closed cities and other institutes previously involved in weapons of mass destruction. The Soviet collapse created a new situation, a new potential threat more likely than the threat of nuclear war during the dark days of the U.S./Russian rivalry. This new threat was the hemorrhage of Russian weapons of mass destruction, nuclear materials, and expertise to rogue nations, or worse, to terrorist organizations. Efforts of the U.S. national weapons laboratories played a significant role in keeping this hemorrhage from happening.

The end of the Cold War and collapse of the Soviet Union meant the end of a world that had lasted 40 years and had required an incredible amount of intellectual and staying power. Congress mandated an end to nuclear testing and the U.S. nuclear weapons program plummeted in size. Almost overnight the world as we knew it changed. Weapons laboratories jumped into the breach to address the new threat posed by a collapsed Soviet Union as well as changed nuclear weapons policies. The first effort consisted of a lab-to-lab interaction, with weapons scientists of the former Soviet Union to focus their science for commercialization. The labs also took the initiative of starting what has come to be called the Cooperative Threat Reduction Program to promote a safe, secure dismantlement program. The labs have supported the Initiative for Proliferation Prevention as well as the material protection and accounting program, and the verification technology that makes nuclear arms control possible.

> *Congress mandated an end to nuclear testing, and the U.S. nuclear weapons program plummeted in size. Almost overnight, the world as we knew it changed.*

Most Americans take peace for granted, as though it were a birthright of the Cold War's end. Our peace and security are the result of persistent hard work by our nations experts.

With a nuclear weapons policy calling for no new weapons and no testing, the national laboratories' scientists addressed the challenge of maintaining the safety and reliability of the nuclear weapons stockpile. The resulting science-based stockpile stewardship program will allow us to do what was considered impossible 10 years ago—that is to maintain the

Nonproliferation attempts to keep weapons of mass destruction at bay

PEACE in an EDGY WORLD

Don't get too comfy—that's a message to Americans. Worldwide development of weapons and information technology may be putting the United States on a hit list for attack at home.

"Americans are going to be less secure than they believe themselves to be"*

*Commission on National Security/21st Century report on how to restructure U.S. defense

This unnerving U.S. prognosis is just one part of an increasingly edgy military forecast. Today ever more nations are developing nuclear fire power and other weapons of mass destruction (WMD)—which include chemical, biological, and nuclear arms—along with the missiles to deliver them. Sandia National Laboratories has responded with nonproliferation initiatives.

Nuclear proliferation requires the acquisition of plutonium or highly enriched uranium. Both require significant technical resources to produce. An alternative to producing them is to smuggle them. Indeed, the smuggling of nuclear materials poses another urgent threat.

Rogue nations and terrorists may find biological and chemical weapons more within their grasp. Biological weapons use living organisms and the toxins they produce. Compared to nuclear arms, bioweapons are easy to acquire but tough to detect in the factory and on the battlefield. As genetic engineering creates advances, bio-weapons will likely mutate to many and varied forms—all unhealthy.

What is nonproliferation?

Nonproliferation programs use science and technology to address three goals:

1. Control the spread of material and technology that can be used in WMD
International agreements to limit material production and technology development or application are crucial nonproliferation tools. Export controls can limit commerce in technologies and materials. To strengthen national controls, nonproliferation efforts may help countries develop domestic export controls and internal controls of the essential WMD ingredients. A range of U.S. programs exists to ensure that stocks of fissile materials worldwide are held under the highest standards of safety, security, and international accountability. Efforts are also under way to eliminate excess stocks of these materials.

2. Detect, monitor, and verify adherence to nonproliferation agreements
Intelligence gathering, which relies heavily on advanced science and technology, is key to national and international cooperative monitoring efforts. In addition, the International Atomic Energy Agency (IAEA) performs nuclear safeguard inspections of more than 25,000 facilities in 20 countries. Together these initiatives deter violations and enhance compliance with international agreements.

3. Resolve issues that contribute to proliferation
This goal combines efforts to control technology—the supply side of proliferation—while curbing the demand for WMD. International programs provide incentives for cooperative nonproliferation policies, attempt to resolve regional conflicts and build confidence, and apply international science and technology to security problems.

Here is another way of looking at the benefits of arms control and nonproliferation. Such programs typically:

- Diminish the incentives that lead to regional conflict;
- Help predict the size and structure of armed forces;
- Lessen the fear of aggressive intent;
- Reduce the size of national defense-industry establishments;
- Encourage growth of vital, nonmilitary industries;
- Ensure—through effective monitoring and verification—confidence in compliance with agreements and treaties; and
- Contribute to a more stable and calculable balance of power.

Nonproliferation is a U.S. priority and a key element of the Sandia mission. Nonproliferation must address 50 years of weapon development. Weapon stockpiles of many nations still pose an escalating threat to the United States and its allies.

According to a congressional study, *"Missiles in North Korea, for example, now can reach U.S. territory with a high explosive chemical, biological, or possibly nuclear weapon."*

Emerging WMD powers are not only well-armed, but may exist in states of heightening tension with neighbors, who feel anxious to become equally well-armed. In the complex relationships that link countries around the world, conflict in distant lands could have unpleasant results at home. Tantamount to peace then is the need to stop the development and spread of WMD.

The end of the Cold War added to the nonproliferation challenge. Political instability and economic uncertainty in the former Soviet Union, along with the spread of advanced technology elsewhere, raised proliferation to new heights worldwide.

Nuclear weapons remain a threat to U.S. security. Russia will probably maintain an arsenal of thousands of nuclear weapons. Britain, France, and China have maintained nuclear weapons for decades, and Israel, India, and Pakistan are believed either to have WMD or the capability to assemble them. At least 20 nations have or are seeking WMD and the missiles to deliver them.

But the news on WMD isn't all bad. Years of emphasis on arms reduction and nonproliferation are paying off. Many nuclear warheads previously aimed at the United States have been reprogrammed, and many countries that might otherwise have acquired WMD, have not. Nonetheless, the United States must continue to broaden international arms reduction and to respond to historic and new threats by strengthening nonproliferation.

Science and technology are the crux of WMD development and its deterrent. Technologies supporting WMD often have *dual use*— defense and non-defense applications. To complicate matters further, a burgeoning number of nations are emerging as WMD powers. In such a hair-trigger world, international scientific and technological cooperation offers important advantages. It can:

- Apply international expertise to develop alternatives to proliferation;
- Provide incentives for complying with nonproliferation policies;
- Encourage reform and reform-minded scientific and technological communities;
- Provide new missions for weapons experts who might otherwise contribute to proliferation;
- Address legitimate security needs, thereby reducing incentives for developing WMD; and
- Increase mutual understanding, openness, and confidence.

Sharable and cooperative technical efforts that support detection monitoring, confidence-building, and openness are important to post-Cold War nonproliferation. U.S. labs, including Sandia National Laboratories, and commercial firms are pursuing a variety of technical initiatives to facilitate detection, monitor adherence to international norms, and support verification of compliance with agreements and treaties. Some of these initiatives include, for example, land-based, airborne and space-based remote sensing; near-infrared reflectance; ground-based radiation and optical detectors and imagers; electronic identification and seals; fiber optics; miniaturization and packaging; and data integration, packaging, analysis, and communication.

COMPREHENSIVE TEST BAN TREATY:
Expectations Vary

Excerpted from testimony, October 1999, to the U.S. Senate
C. Paul Robinson
President and Laboratories Director,
Sandia National Laboratories

A test ban cannot prevent states from acquiring nuclear weapons if they are determined to do so. Credible nuclear weapons can be constructed without nuclear testing, as several nations, including South Africa, have demonstrated. The underground nuclear tests by India and Pakistan in 1998 are another example. These events were not developmental tests; they were demonstrations of nuclear capability that had been developed much earlier, with little or no testing.

Proliferation decisions are most strongly influenced by factors such as how regional security environments evolve over the long term and whether the U.S. nuclear umbrella remains effective for our allies. Our non-proliferation objectives must be pursued vigorously through counter proliferation options, economic incentives, and other means.

"However, it must be acknowledged that a nuclear test ban is no barrier to the development of a few basic nuclear weapons by leaders of rogue states or even by well-financed terrorists groups."

It is doubtful, however, that a nation could develop a potent and diverse nuclear arsenal without performing developmental and proof tests of warhead systems. Thus, there may be value in achieving an international norm that eschews further nuclear explosions. Such a norm, if abided by, may retard the development of major new national nuclear forces.

However, a nuclear test ban is no barrier to the development of a few basic nuclear weapons by leaders of rogue states or even by well-financed terrorists groups. Unfortunately, I know of no means to effectively rule out such developments, although global safeguards on nuclear materials will remain the first lines of defense.

While the treaty does not prohibit the deployment of new nuclear designs, from a practical standpoint we are limited to previously tested concepts. Scientists agree the United States would be ill advised to place a new, sophisticated nuclear explosive design into the stockpile without prior testing and validating. Consequently, the designs of primaries and secondaries are effectively frozen by a prohibition on testing. Previously tested designs could be weaponized to provide new military capabilities.

The question of whether the U.S. stockpile contains the appropriate warhead for the evolving threats is always an issue. For example, nuclear weapons we currently have may well carry too high a yield and be far too disproportionate a response to be a credible deterrent. Proven designs of lower yields exist that might be adaptable for new military requirements in the future. I believe that such weapons could be deployed this way without the need for nuclear tests.

Moreover, adapting deployed nuclear designs to new delivery systems or even to other delivery modes is not constrained by the elimination of nuclear-yield testing. New delivery modes can be achieved and certified for older designs without nuclear testing.

The modernization of warhead electronics and systems packaging is not only certainly possible, it is essential over time so that older electronics can be replaced with modern components. In this process, emphasis is always placed on increasing the safety, security, and use-control features of the systems. Sandia carries this responsibility for all U.S. nuclear weapons.

A Look at Sandia's Nonproliferation Technologies

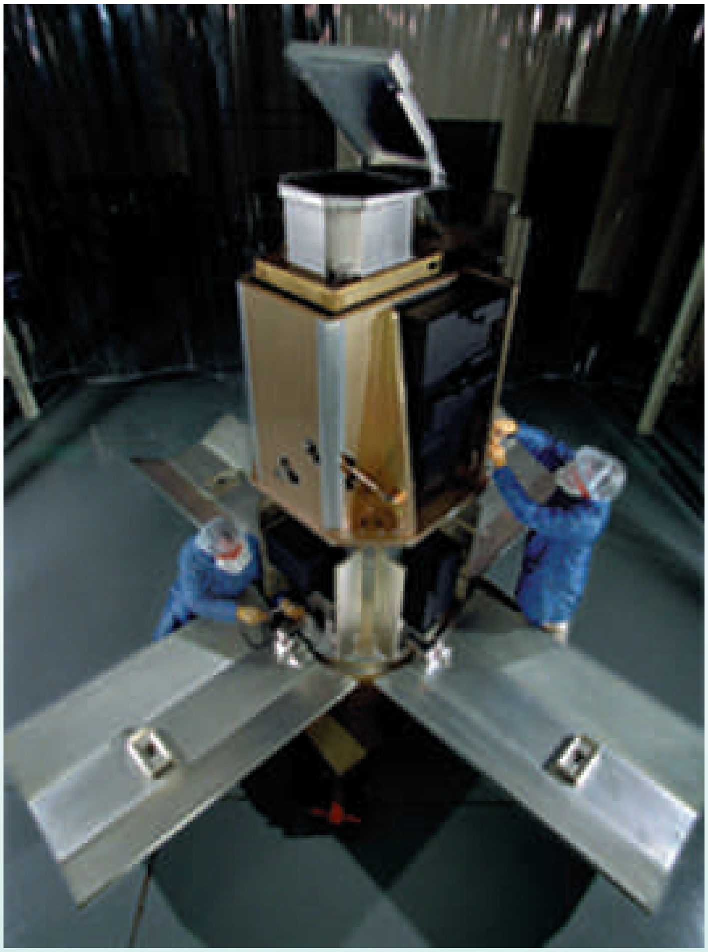
Technology is key to defense, including weapons of mass destruction (WMD). It's also at the core of nonproliferation.

SENSING TECHNOLOGY

Rapidly breaking through former constraints, sensor technology is changing how we perceive the world as this field opens many new opportunities.

Multispectral Thermal Imager

Funded by the Department of Energy (DOE) Office of Nonproliferation and National Security, the Sandia-developed multispectral thermal imager (MTI) is a 1,500-pound satellite designed to hitch a ride on a converted intercontinental ballistic missile. Once in space, the MTI assumes a polar orbit 350 miles up. From this vantage, the MTI sensor, during its three-year life, will detect and characterize WMD facilities. The sensor will—in 15 spectral bands ranging from visible to long-wave infrared—record images of government, industry, and natural sites. The sensor will collect data on surface temperatures, materials, water quality, and vegetation health. Twice a day, collected images will be transmitted to facilities, where the data will be processed and distributed to DOE analysts and other investigators throughout the United States. Ground-based instruments at 12 U.S. locations will compare findings on how well the MTI is doing.



Multispectral Thermal Imager

Applications include treaty monitoring, military operations, hazardous-waste site characterization, resource exploration, environmental and climate monitoring, crop health and yield assessment, as well as other national concerns. The intelligence-gathering capabilities of MTI also could benefit many fields of science, from geology and biology to vulcanology.

Sensor Fusion

Sensor-fusion technology combines independent information collected from multiple sensors to provide a clear understanding of one object. This can be done in three ways.

One means is to fuse raw pixel information from two sensors *(please see illustration page 7)*, resulting in an image or signal. This is called data-level fusion.

In addition to creating a depiction, sensor fusion technology can support decision making. Information can be combined from sensors to extract visible features or measurements. For example, to process the image of a face, eye and hair color along with the size and shape of nose and mouth might be extracted from information provided by more than one sensor. These data sets would be fused to determine the identity of one face. This is called feature-level fusion.

A third type of sensor fusion, called decision-level, also supports decision

Sensor fusion technology

Sensor fusion technology —which can identify obscured objects and track, for example, military vehicles to show a history of activity at a site—can support nonproliferation and treaty verification.

making. The technology collects features from more than one sensor. Information from each sensor presents a list of possible identities. These possibilities are fused, and then one decision is made based on all the sensor information. An analogy of decision-level fusion is voting for president: from the decisions that millions of voters make, one president is elected.

Smart Radiation Sensor

The radiation sensor is nothing new. But the ability to precisely identify radiation by using a device operating at room temperature is. In the past, radiation detection equipment used to identify radioactive isotopes had to be cryogenically cooled to minus 200-degrees centigrade. The need for cooling made the device heavy and bulky, and it required regular attention. It was impractical for field use and needed to precool for several hours prior to operation.

The new smart radiation sensor, in contrast, can be used anywhere, anytime for long-term applications and without an attendant. The new sensor uses a cadmium-zinc-telluride (CZT) crystal, which enables it to operate at room temperature. It measures the energy of x-rays and gamma rays to distinguish specific nuclear materials from a range of naturally occurring isotopes. It is now beginning to replace technology used since the 1970s.

When the crystal absorbs a gamma ray, a tiny current results. This current or pulse is measured and recorded to leave a precise “fingerprint” of the specific isotope.

The new smart sensor offers cost savings because it does not have to be cooled or attended, and is less complex than former radiation sensors.

The smart-sensor nonproliferation applications provide the ability to recognize weapons-grade radiation, namely enriched uranium and plutonium. CZT crystals are used to ensure safety and accountability of nuclear and fuel-cycle materials in storage and for treaty verification. *(See page 18, NASA application of CZT)*

REMOTE SURVEILLANCE

Research is taking flight to the skies. As lighter and therefore less expensive spacecraft are demonstrated, space offers more opportunities for national security efforts, including nonproliferation.

Thin-skin deployable mirrors for remote sensing systems

The size of the space shuttle determined the size of the Hubble telescope, which rode into space aboard the shuttle.

But today researchers are hoping to pack a mirror maybe 20 times larger than the Hubbell into the shuttle cargo bay. Made of thin-film, this ultra-light mirror would be rolled up like an umbrella, and unrolled once it's out the shuttle door.

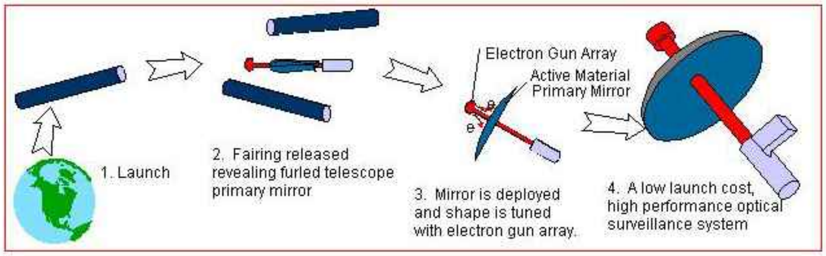
But then a problem occurs: When first unrolled, the film mirror will be misshapen like the mirror in a fun house. Sandia, working in partnership with the University of Kentucky, will resolve this problem with an electron gun to correct the shape of the film mirror.

Electronic guns are used in televisions to draw the pictures you watch. To reshape the film-mirror, instead of drawing a picture, the gun draws a surface change, but at a much higher resolution than the picture on a TV screen. The electron gun for this project will be on board a satellite. Sensors on the satellite will identify trouble spots in the film surface, and the electron gun will readjust those spots to focus the mirror while it is in space.

Besides being lightweight and relatively inexpensive to launch, the thin-skin deployable mirror could have launch-on-demand applications. It could be cut out of a sheet of film and deployed in a matter of weeks to months, as compared to years with the Hubbell telescope.

Such a technology can support nonproliferation with its ability to watch a specific target. For example, a film mirror of this sort will be able to detect missiles being unloaded from ships.

Thin Skin Deployable Mirrors



- Electron gun control of piezoelectric bimorphs has been demonstrated to provide ultra-high resolution by closing the loop on a point by point basis.
- Resolution is limited by beam spot size and beam steering ability.
- Large aperture thin-film mirror would be bolded for launch, deployed on orbit, and shape-adjusted with the electron gun.

SEISMIC SENSORS

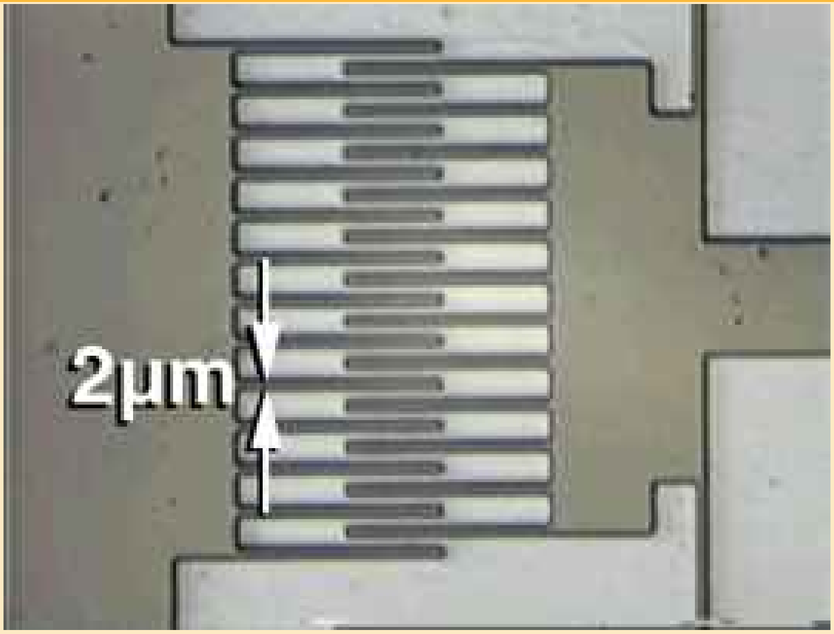
Detecting underground nuclear tests is essential to monitoring the clandestine development of nuclear weapons around the world. But are sensors "smart" enough to distinguish between a natural event, such as an earthquake, and the rumblings of a nation going nuclear on the sly? And can we really tell what's going on deep inside buried WMD facilities? Maybe we can.

Sparse geophysical networks for monitoring deep targets

Facilities that manufacture and store weapons of mass destruction are often contained inside structures or tunnels buried deeply in the ground. Detecting, characterizing, and monitoring these underground production and storage sites are central to defeating WMD proliferation.

The sparse seismic network represents a practical, field-deployable configuration. However, the application of sparse networks for accurately determining the 3-D location of underground activities has never been addressed before. Sandia's sparse geophysical networks project has been funded to design, develop, and test an advanced algorithm for sparse seismic networks to determine the 3-D location of underground activity.

NEWS *Notes*



Diamond micromachine—a tiny comb drive propels a microscopic diamond piston.

SANDIA CREATES WORLD'S FIRST DIAMOND MICROMACHINES

Sandia National Laboratories has created what are believed to be the world's first diamond micromachines.

The machines are etched from a surface of amorphous diamond, the hardest material in the world after crystalline diamond, in a manner compatible with current silicon chip and surface micromachine manufacturing techniques.

Diamonds interest researchers because of their superior wear-resistant qualities, resistance to stiction—a combination of stickiness and friction—and potential as a biocompatible material that could be used medically inside the human body without generating allergic reactions.

Researchers have constructed a diamond comb drive whose tiny interspaced teeth move forward and backward as an electrical current reverses constantly between positive and negative. It is the first demonstration of a micromotion drive using amorphous diamond.

The point, said researchers John Sullivan and Tom Friedmann, is to create a layering technology that can increase the life span and performance of micromachines.

"Micromachines, for their marvelously tiny size, are still machines. They're subject to wear, even if it's only at the micro level," said Friedmann. "One estimate in the literature claims that diamond should last 10,000 times longer than polysilicon in wear applications."

Silicon MEMs (MicroElectro-Mechanical Systems) are already used in a variety of applications ranging from airbags in cars to optical micromirrors slated for possible deployment on satellites.

There are two kinds of diamond: crystalline and amorphous. Sandia researchers use amorphous diamond, which until recently had been impractical because of its tremendous internal stresses. Those stresses prevented the material from being able to stand alone or to thickly coat any but the strongest substrates. However, Friedmann and Sullivan developed a process which overcame that obstacle.

Crystalline is currently impractical because of the far higher temperatures needed to synthesize it and the surface roughness that precludes its use in a multilayer surface micromachine technology.

Sandia's millimeter-square drive consists of two diamond combs on a flat surface, with the teeth facing each other. One comb is bolted down; the other moves freely within the confines of a spring.

The laboratory devices, funded by Sandia's Laboratory-Directed Research and Development Office, are estimated by researchers to be marketable in about five years.

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Material Protection, Control & Accounting

Since the early 1970s, Sandia has been responsible for developing technology, s
and standards to protect nuclear weapons and materials at DOE facilities and
transport. In addition, Sandia has worked to protect nuclear material and
weapons at facilities in many nations around the world.

Since the breakup of the Soviet Union in 1991, the United States has been working cooperatively with scientists and engineers at various Former Soviet Union (FSU) institutes, laboratories, and organizations to reduce nuclear weapon proliferation, as well as reducing theft, diversion, and unauthorized possession of nuclear materials.

Cooperative interactions are encouraging the dismantlement of all types of weapons of mass destruction (WMD), advancing nonproliferation, and helping FSU states convert defense-oriented capabilities to civilian, market-driven enterprises. This cooperative program is expanding Western access to the world-class science and technology that exist within the FSU.

Barcoding has been put on nuclear reactor plutonium disks to track them and to protect against theft.

Sandia's International Security Program helps achieve worldwide protection and control of nuclear materials and weapons by working with the FSU on Material Protection, Control, and Accounting (MPC&A).

As the name suggests, the MPC&A program is based on principles of physical protection of nuclear materials, materials accountability, and materials control. MPC&A systems provide a cost-effective and reliable way to manage special nuclear material. These benefits are critical at sites where nuclear material is produced, stored, or routinely handled. Training workshops, improvement of existing MPC&A systems, and design and installation information for new MPC&A systems are all available through this program.

MPC&A systems ensure that security and environmental concerns are properly addressed at multiple levels. First, the systems provide institutional assurance that nuclear material is properly accounted for, in the control of appropriate personnel, and under proper measures to prevent inadvertent damage to the environment. Second, the systems create a basis for accurate national inventories of nuclear material and provide real-time information about the status and control of those materials. Finally, MPC&A systems are consistent with the International Atomic Energy Agency philosophy for international safeguards to assure nuclear materials are used in accordance with treaty obligations. Thus, MPC&A provides technical means for participating in confidence building and nuclear transparency.

The MPC&A program has two objectives:

- Reduce the threat of nuclear proliferation by cooperating with Russia, the newly independent states (NIS), and the Baltic States to improve MPC&A for all weapon-useable nuclear material in other than nuclear weapons.

- Encourage development of a technology-based nuclear safeguards culture and the infrastructure to sustain such a culture in Russia, the NIS, and the Baltic States.

The MPC&A program started after the breakup of the Soviet Union. By 1997, Sandia had installed physical-protection upgrades at facilities in the republics of Kazakhstan, Ukraine, Belarus, Georgia, Uzbekistan, Latvia, and Lithuania. All have fresh reactor fuel or are nuclear research facilities that possess proliferation-sensitive nuclear material. Upgrade activities at these nuclear research facilities included installation of intrusion detection sensors, video assessment cameras, central alarm stations, and hardening of nuclear material storage areas.

By 1998, J.D. Williams, manager of International Projects I Department, reported that the MPC&A team had upgraded security at 53 sites across 11 time zones. Currently, activities have been completed or are in progress on more than 80 MPC&A projects. Many have been expanded to multiple activities at given locations as more nuclear material has been identified.

> ***"In the beginning, relationships weren't very open. Eventually (the Russians) let us visit their smaller, less important sites. They eventually became more open when they saw we were sincere and able to providewhat we promised. That's how we built trust."***
>
> *J.D. Williams*

"The Soviet Union was a totalitarian government, and guards were everywhere," Williams said. "People would not even think of stealing materials. They knew they couldn't get away with it."

Following the breakup of the Soviet Union, materials control became haphazard, and conditions were ripe for theft. Fewer guards were on duty, little money was available to maintain facilities, and many workers were paid only sporadically. "The fear was that a terrorist group or third-world country would obtain the materials and use them to make nuclear weapons," Williams said.

Lithuania is the site of the Ignalina Nuclear Power Plant, which has two 1,500-megawatt power reactors similar to those at Chernobyl. Work at Ignalina has included improvements to a central alarm station and vehicle access portal. Personnel have received training on physical protection concepts, system operation, and maintenance. The MPC&A work there has included collaboration with other national labs and experts from other nations, although Sandia performs the lead role in physical protection.

Los Alamos National Laboratory has taken the lead in helping the nations develop computerized accounting systems. Several other labs have worked on materials-control procedures.

Originally, the MPC&A was slated to be completed by 2002; however, Russian economic and political conditions may warrant an MPC&A extension.

(For more detail on confidence building and nuclear transparency, please refer to the Cooperative Monitoring Center section of this document, page 13)

NEWS Notes

THREE EXPERIMENTAL WIND TURBINES SPIN IN TEXAS PANHANDLE

Three wind turbines spinning in the Texas Panhandle promise to answer some big questions about harnessing wind power to generate electricity.

Members of Sandia's wind energy technology department installed the turbines—each 16 meters in diameter on 22-meter-tall towers—last fall at the U.S. Department of Agriculture's research station in Bushland, Texas. Researchers will assess turbine operation during heavy wind gusts and study ways of building better blades.

"This will be the first time Sandia will test propeller-blade turbines on a long-term basis," said Herb Sutherland, an engineer working on the project. "We hope to gather load and wind inflow information continuously for about one year."

Before this project, data were typically taken in segments that covered only a few hours of operation. The long-term data will permit the researchers to develop design tools and components that will increase the efficiency of the turbine and its ability to produce reliable electrical power.

Sandia has been field-testing turbines at the Bushland site since the late 1970s. The multiyear test programs focused on eggbeater-shaped vertical-axis turbines. The vertical axis projects were concluded after the technology lost favor with the U.S. wind industry. Sandia has now shifted its research to horizontal-axis turbines—the turbines with propeller-type blades.

The three turbines at Bushland were originally used to generate electricity for a commercial "wind farm" in Palm Springs, Calif. They are smaller than the newer utility-grade wind turbines, but are more suitable for conducting experiments.

The Bushland turbines will be used for two experimental projects, including the Long-Term Inflow Structural Testing (LIST) project headed by Sutherland, and the Blade Manufacturing Initiative (BMI) led by Tom Ashwill.

The LIST project will include measurements of wind speed, wind direction, and blade loads at regular intervals over a year, with the goal of creating a better blade design.

"We are particularly interested in wind loads created by large wind gusts passing through the rotor," Sutherland said. "A gust induces extraordinary loads into the blades that can significantly reduce their ability to function reliably. A single large event can reduce the life of a turbine blade by half."

The BMI project will spend the next several years determining how to build a blade that is more durable, yet lighter and less expensive, Ashwill said.

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viability of the U.S. nuclear-deterrence capability without testing.

Although the future is unclear, there are several challenges that must be taken into account.

First, for the foreseeable future, Russia will be unsettled and its economy will remain in the doldrums. A new generation of leadership is needed to transform Russia. This means Russia will not be able to take care of many of the tasks that Sandia can help with to protect against brain, equipment, material, and weapons drain. This role will continue to be important well into the future.

There will be other challenges. The world is not standing by while Russia sorts itself out. India and Pakistan boldly surfaced as nuclear powers. It is unclear what direction Iran, Iraq, and North Korea will take. Sandia's work and its Cooperative Monitoring Center are more important than ever.

Through the Cooperative Monitoring Center, Sandia offers a way to improve transparency in troubled world regions by providing some degree of confidence that other nations are not violating arms-control agreements, especially regarding chemical, biological, or nuclear weapons.

In addition to the arms control and nonproliferation challenges as we move into the 21st century, Sandia's more traditional role maintaining a safe, secure deterrent for as long as the United States needs such a deterrent will grow harder. We will continue to live in a complex political environment. We will continue depending on nuclear weapons for some time to come. We have committed ourselves to providing a nuclear umbrella to protect our friends, who have foregone nuclear weapons, and our pledge must remain credible.

This role has become harder with the defeat of the Comprehensive Test Ban Treaty in the Congress. The same responsibilities for stewardship that existed before will continue, but a tough congressional and political atmosphere will make it harder to obtain the required support to maintain the stockpile without testing. The task of maintaining our nuclear weapons over time is already very challenging.

This could lead to a growing doubt about the reliability of the nuclear stockpile. I worry about the need to deter a Russia more dependent on nuclear weapons as its conventional weapons continue to deteriorate. I worry about countries that have forgone nuclear weapons under the Non-Proliferation Trust and who depend on the U.S. nuclear umbrella. As I speak, the United States and Russia are struggling with what to do about START II and trying to begin serious talks about START III. I worry that START III will become a victim to decreased confidence in the viability of the strategic nuclear stockpile.

Nuclear weapons stewardship will be the greatest challenge for the 21st century to the nuclear weapons labs. This stewardship will be partner to the challenges of arms control, nonproliferation, and help to the Former Soviet Union.

The end of the Cold War and the collapse of the Soviet Union ended a period of great predictability. For the 40 years of the Cold War, it was clear what was the threat, from where it came, and what was needed to cope with it. Today, life is less predictable and we cannot fully understand the implications of the New World. In the decade since the end of the Cold War, the U.S. nuclear weapons laboratories have met the challenge of a changed world, particularly the real threat of a hemorrhage of Russian nuclear weapons or expertise into the hands of rogue or terrorist states.

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