

National Labs Focus on Tools against Terrorism in Wake of Airliner and Anthrax Attacks

When the World Trade Center towers collapsed into a nightmarish pile of burning rubble after being struck by two airliners on 11 September, one of the many emergency units that rushed to the site was a radiation monitoring team based at Brookhaven National Laboratory. As firefighters, police, and medical personnel frantically searched for survivors, concerns arose about possible radiation dangers from industrial x-ray machines and other radiological sources believed to have been in the buildings.

The rescue workers at Ground Zero “wanted to know if they were walking into something that was dangerous in terms of radiological hazards,” said Ralph James, Brookhaven’s associate director for energy, environment, and national security. The RAP Team, as the Department of Energy’s Radiological Assistance Program group is known, didn’t find any significant radiation sources in the vast debris field, he said, although there still may be radiological hazards “in there somewhere. If they were there, they didn’t just go away.”

The RAP team’s immediate response to the terrorist attacks was more than a reaction to a crisis of the moment, however: It marked the beginning of a new chapter for Brookhaven and the other national laboratories. Finding ways to stop terrorists before they strike and limiting damage in the wake of an attack are becoming critical missions for the labs. This new emphasis for the labs was highlighted by Secretary of Energy Spencer Abraham in mid-November, when he asked the labs to bring their best antiterrorism technology to the DOE’s Forrestal Building in Washington, DC, so he could show the equipment to Office of Homeland Security Director Tom Ridge. After leading Ridge through more than two dozen displays of sophisticated sensors, detectors, and other gear, Abraham made reference to the 007 movies, saying, “I felt like ‘Q’ with Governor Ridge being James Bond.”

With the directors of several of the

▶ A sophisticated array of devices to detect the potential weapons of terrorism—chemical and biological agents, radioactive material, and explosives—are being developed by scientists working long hours to try to prevent future attacks.

labs looking on, Abraham said, “Our national labs are one of our best-kept secrets, and they will help us win the war against terrorism.” Lab researchers “will spare no effort to develop the tools” to fight terrorism, he said. Ridge added that “at the heart of the strategy to fight terrorism is technology.”

C. Paul Robinson, director of Sandia National Laboratories in New Mexico, told journalists at the event that “what we’re trying to do is reorient a lot of other work to get people directly into counterterrorism—the explosive detectors, the nuclear detection work—all of those threats that now seem to be our highest priority. We are shifting people more to homeland defense.”

Robinson, in a later interview, noted that, while the three primary national security labs—Sandia, Los Alamos, and Lawrence Livermore—face a “grand challenge” in responding to some potential threats from terrorists, in other areas work begun years ago in

anticipation of terrorist attacks has “put us in a good position. We’re pretty good in electronics and instrumentation, but not in biology,” he said. That is not a trivial weakness. “Bioterrorism, in my view, is still the long pole in the tent,” Robinson said. “Detection [of biological substances] has got to be taken down from two days to several hours, and our goal is to make it within 20 to 30 seconds. We have some ideas that are being explored that use electronic means to sort out and identify biological threat species.”

Devices on display

While Robinson’s focus is on the three national security labs, Brookhaven and many of the other laboratories are also shifting their efforts toward counterterrorism. At DOE’s antiterrorism event, scientists from Pacific Northwest National Laboratory (PNNL) in Washington displayed a flare gun-sized device that uses ultrasonic waves to see inside of sealed containers, a holographic imaging system that can see objects hidden under clothing, and a polymer that detects nerve agents. Researchers from Argonne National Laboratory in Illinois displayed a cyanide microsensor, as well as a warning-and-response system for chemical or biological attacks in subways or other confined spaces. Idaho National Engineering and Environmental Laboratory scientists showed their briefcase-sized portable isotopic neutron spectroscopy chemical assay system that can identify nerve agents, compressed gases, or explosives inside artillery shells or bombs.

Much of the equipment being rushed into service for the war on terrorism is essentially adapted technology, devices that have their roots in other programs. Some of the chemical and biological detectors were originally developed as part of the weapons monitoring program in the Gulf War era a decade ago. Some of the radioactivity detectors have been in use in Russia for the past few years to help prevent the theft of weapons-grade nuclear material.



SANDIA NATIONAL LABORATORIES researcher Mark Tucker examines two petri dishes: one (left) containing a growing anthrax simulant, the other showing the lack of spore growth after treatment with a new decontaminating foam.

"One approach is to take the detectors that are available today and put them into systems that can be used to enhance our security and safety," said Brookhaven's James. "Another approach is developing improved sensors that enable us to make measurements that have not been possible in the past." James, who holds a PhD in applied physics from Caltech, has spent several years developing an array of compact radiation detection devices and is focused on improving that technology. Current detectors are good, but bulky because they have to be cryogenically cooled, he said. "The technology of the future is focused on giving you this ability in a compact, room-temperature device."

James was recently selected to head a new 30-member antiterrorism working group established at Brookhaven to come up with innovative approaches to enhancing the long-term security of the US. "The vicious attacks created an enormous challenge to build an improved security framework for our nation," James said. The strong national response to the attacks means "we can expect significant growth in federal funding, and I believe a forged alliance between government and scientists to address terrorism will result."

Attacks were personal

For the people at Brookhaven, just 65 miles from the World Trade Center, the attacks were "very personal," James said. "Practically everyone at Brookhaven knew someone who either died in the World Trade Center or lost a family member. This has altered very much the way scientists and engineers conduct business here. There is a personal component that is very unusual to see. Otherwise it would not be possible to see people working until midnight, some almost overnight, in order to make progress. It's clear that they are determined to apply their technical skills to reduce the likelihood that the pain that we experienced on September 11 will be felt again."

Sandia director Robinson, who worked for several years on the 93rd floor of one of the World Trade Center towers, said there is similar intensity among scientists at Sandia and the other weapons labs. "We tend to attract flag wavers at these laboratories," he said, "and flag waving is truly in at the moment. Everybody is working 80-plus hours per week now, and most of it is voluntary."

Sandia scientists, collaborating with the other national security labs, have already developed a "laboratory

on a chip" that can identify nerve gas, mustard gas, and "all of the other known chemical warfare agents in under 30 seconds," Robinson said. "We need the same concept for biological species." The issue of counterterrorism was raised in a planning session at Sandia six years ago, he said, and "we looked at what the threats might be and tried to organize them into areas of detection, prevention, response, and recovery; then we put out a call for research proposals." Two of the early proposals Sandia funded resulted in the laboratory on a chip, and in the development of a nontoxic, noncorrosive foam that neutralizes both chemical agents and biologic species such as anthrax. The foam, shown on this month's cover, was used extensively to clean up anthrax-contaminated areas on Capitol Hill.

Following the terrorist attacks, Robinson asked an existing team at Sandia known as the advanced concepts group, under the leadership of physicist Gerry Yonas, to "put together the first line response [to the attacks]." Yonas, Sandia's chief scientist, "waved a wand and basically reorganized this group to try and think through the problems and look at what you can do to identify the threats, to protect and respond to the threats, and then look at the root causes of terrorism."

While many of the current efforts at the labs are focusing on hardware, he said, trying to understand the reasons for terrorism is important. "With root causes, we look at it from the standpoint that the people [recruited by terrorists] don't have jobs and are dirt poor. I gave a talk years ago in which I said there is only one antidote for overpopulation, and that is prosperity. Similarly, prosperity is the antidote for terrorism. We have people worrying about that and making some proposals that are actually getting good resonance with the folks in the State Department."

Combating terrorism

But Robinson acknowledges that the main mission of the labs is developing the technology for combating terrorism, and a wide assortment of devices is ready for use, under development, or on the drawing boards. James views technology development in three basic time frames: near-term (now to 2 years), midterm (2–4 years), and long-term (beyond 4 years). Defining exactly where a technology stands in the time frames isn't always easy because of the lag-time between developing a prototype at a lab and getting a usable

device into production in the private sector. Speeding up the technology transfer process for new technology is an important part of the response to terrorism, Robinson said.

Some of the new technology being showcased by the labs includes:

▷The chemical and biological mass spectrometer (Oak Ridge National Laboratory, Tennessee), billed as the first integrated instrument capable of detecting and identifying both chemical and biological warfare agents, uses an ion-trap mass spectrometer. Vapors from chemical warfare agents are converted to ions by a chemical-ionization reagent gas. The specific agents are identified from the unique ions they produce. Biological agents such as anthrax spores or bacterial toxins are heated and mixed with a reagent that produces biomarker molecules characteristic of a hazardous organism or toxin. Algorithms are being developed to differentiate between dangerous material and harmless, naturally occurring microorganisms.

▷The Raman tunable integrated sensor (Oak Ridge) is a chemical agent detector for use by emergency personnel arriving at the scene of an incident. The portable device uses a helium–neon laser, acousto-optic tunable filters, and a photosensor to detect a wide array of explosives, chemicals, and drugs in either liquid or powder form. The laser is used to illuminate suspect material, and the resulting vibration energies from the material reveal what it is.

▷The acoustic inspection device (PNNL) is a handheld ultrasonic instrument that was originally developed for weapons inspections in Iraq. The device can "see" inside of sealed containers, said Aaron Diaz, a senior researcher at the lab. "If you have a fuel truck going through a tunnel and you want to verify it is carrying fuel, this device can do it. If the truck's manifest says it is full of fuel, and it is only half full and it's got the other half filled with explosives, this instrument can tell you that too, in a non-invasive, rapid fashion." Earlier versions of the device have been used overseas for years, but the new incarnation is being commercialized by the US Customs Agency for use domestically, Diaz said.

▷The cylindrical holographic imaging system (PNNL) emits nonionizing millimeter waves from a wide-band array that penetrate clothing but bounce off the body and other objects. The reflected waves are picked up by a transceiver, digitized, and sent to a

computer, resulting in a three-dimensional image of a person, sans clothes. The system can see concealed weapons made of plastic, ceramics, and metal and can show a 360° degree view of a person. Because the imaging system is so good at stripping away clothing in near real-time, “privacy” algorithms are being developed to remove human features from the images and display concealed objects on a “gender-neutral wire frame.”

▷The compact neutron source (Lawrence Berkeley National Laboratory) is designed to use neutrons to scan baggage, air cargo, mail, and other “closed containers” for fissionable materials and explosives. The neutron generator is the size of a breadbox, with a desk-sized power supply, and has an output a 1000 times greater than devices currently being used. The device’s low-energy neutron beams strike a substance inside a cargo container, for instance, and, based on the gamma rays and neutrons that are emitted from the nuclear interactions, analysts can quickly determine the composition of the contents of the container. “It will take a couple of months to do the proof-of-principle system,” said Ka-Ngo Leung, from the lab’s accelerator and fusion research division. “Within a year it can be transferred to the private sector for mass production.”

▷The handheld advanced nucleic acid analyzer (Lawrence Livermore) can do four complete polymerase chain reaction DNA analyses of two different DNA sequences simultaneously in 15 minutes. The battery-operated machine, slightly larger than a scientific calculator, is intended to enable emergency workers to identify biological warfare agents in the field. The device is in the prototype stage.

▷The nuclear portal monitor and Palm Pilot neutron and gamma detector (Los Alamos) are designed to detect and identify the illicit movement of nuclear materials. The portal, which looks identical to airport metal detectors, contains scintillating crystals that monitor background radiation until an object moves into it. The crystals then focus on the object and react to either neutron or gamma signals. Once a radioactive source has been detected, a handheld device containing a cadmium-zinc-telluride crystal, a helium-3 detector, and a standard Palm Pilot, can pinpoint the source of the radiation. “We started



RESEARCHER DOUG ADKINS inspects a group of tiny robots he and colleague Ed Heller are developing at Sandia. The robots are intelligent and communicate with each other.

developing these detectors in 1975 to protect the labs,” said researcher Thomas Prettyman. “They’ve been installed in all of the labs, and almost all of the Russian nuclear facilities have them. They are also along the borders of the old Soviet Union to measure and monitor vehicles.”

The list of devices goes on. There is the biological aerosol sentry information system, a joint Los Alamos/Lawrence Livermore project that strings together a network of sensors to detect the release of biological agents at large public events. There is the jackhammer designed by Brookhaven engineers for rescue teams working in collapsed, unstable buildings. The jackhammer breaks up concrete, but creates fewer shocks and vibrations than a conventional device, reducing the risk of further collapse. There is the chemical agent early warning and crisis management system, developed jointly by Argonne, Sandia, and Lawrence Livermore labs. The system, already deployed for testing in a major metropolitan subway station, detects releases of hazardous chemicals, alerts the subway control center and the emergency response teams as to the nature and spread of the chemical, then recommends the best way to limit the exposure of people.

The robot family

Then, from Sandia, there is the robot family, a group of intelligent, mobile machines that can swarm over a site looking for terrorists, biological and chemical hazards, or victims trapped in a building. The robots, some a quarter-of-an-inch in size, others a couple feet long, work in groups (the sizes of

both the robots and the groups deployed depend on the circumstance), and have demonstrated independent “swarm intelligence” in carrying out their tasks, said Paul Klarer, a robotics expert at Sandia.

Beyond the development of James Bond-like devices to counter terrorism, Sandia and Los Alamos have created the National Infrastructure Simulation and Analysis Center (NISAC). The center was started in 1999, after systems analysts at the labs realized that the software they were

developing to simulate much of the US infrastructure—such things as the national power grid and transportation systems—had national security implications, said J. Darrell Morgeson, director for the decision applications division at Los Alamos.

“About 90% of the US infrastructure is in the private sector,” Morgeson said, “but what we recognized was that the federal government has the responsibility to protect that infrastructure.” NISAC is essentially using real-world data to develop virtual models of all major infrastructure systems in the country. The virtual models have already simulated the transportation patterns in several cities, and the accuracy of the simulations is high, Morgeson said.

“We are looking at large urban transportation systems, the electrical grid, and the communications grid,” he said. “We are looking at how they behave under normal conditions, under duress, and under attack. We simulate the systems down to the individual level. We can view control feedback loops, so we know when things are congested in a transportation system, and how to contend with the congestion.”

Picturing an epidemic

While such simulations have enormous implications for better urban planning and design, in the war against terrorism they can be invaluable tools for preventing or responding to attacks, Morgeson said. For example, he envisions biosurveillance sensors providing real-time data about over-the-counter drug sales to a simulation program that could paint a picture of an emerging epidemic before it was evident even to the medical community.

When Morgeson’s group tested one of their most advanced simulation programs, a transportation program called Transims, “what we really cap-

tured was the activity of individual people on a five-meter basis. If we apply that to the water, energy, food, fuel, and school systems, if we know where people are and what they are doing at any particular time, then we have a heck of a tool to know what the demands on the systems are.”

The simulations, especially if linked together into one massive model, also reveal where various systems are most vulnerable to attack, he said. “We can better protect the systems if we know where we are most vulnerable,” he said. “But if you take a different viewpoint, then you worry that if terrorists had that information, they could exploit it and use it as a planning tool.”

Morgeson said it has been difficult

to get a single government entity interested in pulling together the many simulation programs into one, overarching program. “If you believe you can simulate the entire US, you need coupled and interdependent programs,” he said. “Until Ridge’s appointment, there was no homeland secretary to pull it together. The appropriate place for this activity is at that level.”

The labs are in the midst of shifting to counterterrorist missions, but how far that shift goes and how permanent it becomes is ultimately up to Congress, James said. “Whatever they decide, we’re determined to apply our capabilities. This is a matter of global security, and the idea should be to share this [technology] around the world.” **JIM DAWSON**

Accident Cripples Super-Kamiokande Neutrino Observatory

While the tank was being refilled with 50 000 tons of water, a photomultiplier tube imploded and the shock wave set off a chain reaction that left more than 7000 PMTs shattered. That, at least, is what scientists surmise happened on the morning of 12 November in Super-Kamiokande, the world’s largest neutrino detector.

Super-K, which is buried 1000 meters deep in a defunct zinc mine in the mountains west of Tokyo, made headlines worldwide in 1998 with strong evidence that atmospheric neutrinos oscillate—or morph from one of three possible flavors into another—and therefore have mass.

The accident crippled Super-K and stunned particle physicists everywhere. “The accident was severe, but we will rebuild,” says Super-K director Yoji Totsuka. The aim, he says, is to start up with about half the original density of PMTs within a year, and fully fix Super-K by 2007.

Super-K’s water tank, some 41 meters high and 39 meters in diameter, is lined with more than 11 000 PMTs; they see the occasional flashes of bluish Čerenkov light emitted from interactions of incident neutrinos with the water. At the time of the accident, the Super-K team was refilling the tank after replacing burned-out PMTs and making other upgrades. Nearly all of the PMTs below the water line popped. The tank also sprang a minor leak.

For the first resuscitation phase, the surviving PMTs, plus some spares, will be spread evenly around Super-K. At half the usual density, the lowest-energy signals will be lost, so some solar neutrinos won’t be detectable, and proton decay, if it actually happens, will be harder to observe, but atmospheric and other studies could resume. “This is good enough for the time being,” says Totsuka.

Scientists are especially eager to restart the K2K experiment. In K2K, which is intended to verify Super-K’s spec-

tacular 1998 atmospheric neutrino results, manmade muon neutrinos are shot to Super-K from the KEK proton accelerator in Tsukuba, 250 kilometers away. Early data support oscillation, in that only 44 muon neutrinos were seen in Super-K, down from 64 predicted from measurements near the beam source. “It’s a teaser,” says Fermilab theorist Boris Kayser. “It’s consistent with the atmospheric results, but it’s not definite. You need to run longer.”

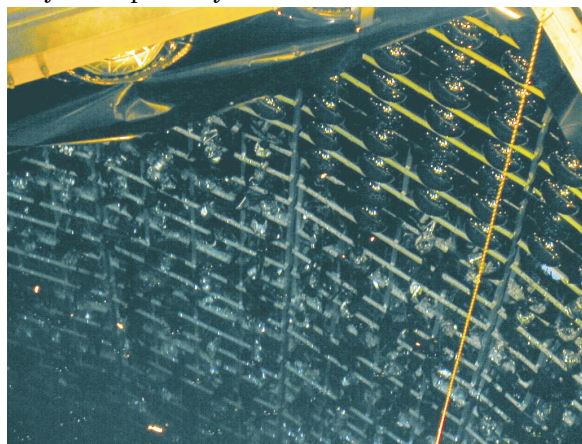
Another reason to get K2K back on track quickly is so a follow-on known as JHF-Kamioka, a high-intensity neutrino beam that will shoot neutrinos to Super-K from 295 kilometers away, can go ahead as planned in 2007. Says Totsuka, “I am afraid this [accident] might cause delays because of some kind of distrust of the technique.”

And, as long as Super-K is down, there’s one less detector keeping watch for supernova explosions. That’s a serious concern, says Hank Sobel of the University of California, Irvine, one of Super-K’s US spokesmen.

Two committees are looking into the accident. By the end of January, they are supposed to report on its cause, advise on how to avoid a repeat, and outline a plan and the costs for repairing Super-K, whose original price tag topped \$100 million.

Replacements for the 7000 burst 50-cm PMTs will cost about \$3000 apiece and will take a few years to make. The experiment also lost about half, or 1000, of its 20-cm veto PMTs, which face away from the tank’s center and monitor a concentric water sheath. The smaller PMTs cost about \$1000 each, bringing the tab for fixing Super-K to at least \$22 million. Officials of Japan’s Ministry of Education, Culture, Sports, Science and Technology say they will try to squeeze the repair costs out of the ministry’s 2002 budget. “We are hoping that the DOE [US Department of Energy] will also help support the repair of the detector,” says Sobel.

“The accident is a big setback. It causes everybody to be nervous about future experiments, perhaps more than is justified,” says John Bahcall, a neutrino expert at the Institute for Advanced Study in Princeton, New Jersey. “We will have to examine the possibility of such accidents more closely. But in point of fact, Super-K will be repaired and back on the air, doing nearly everything it was doing, and almost as well.” And, he adds, “repairing the lab is so important that, if I had the requisite skills, I would go and help.” **TONI FEDER**



SHARDS: Most of the photomultiplier tubes that were below water popped in a chain reaction that has incapacitated the Super-Kamiokande neutrino observatory in Japan. (Courtesy of the Institute for Cosmic Ray Research, The University of Tokyo.)