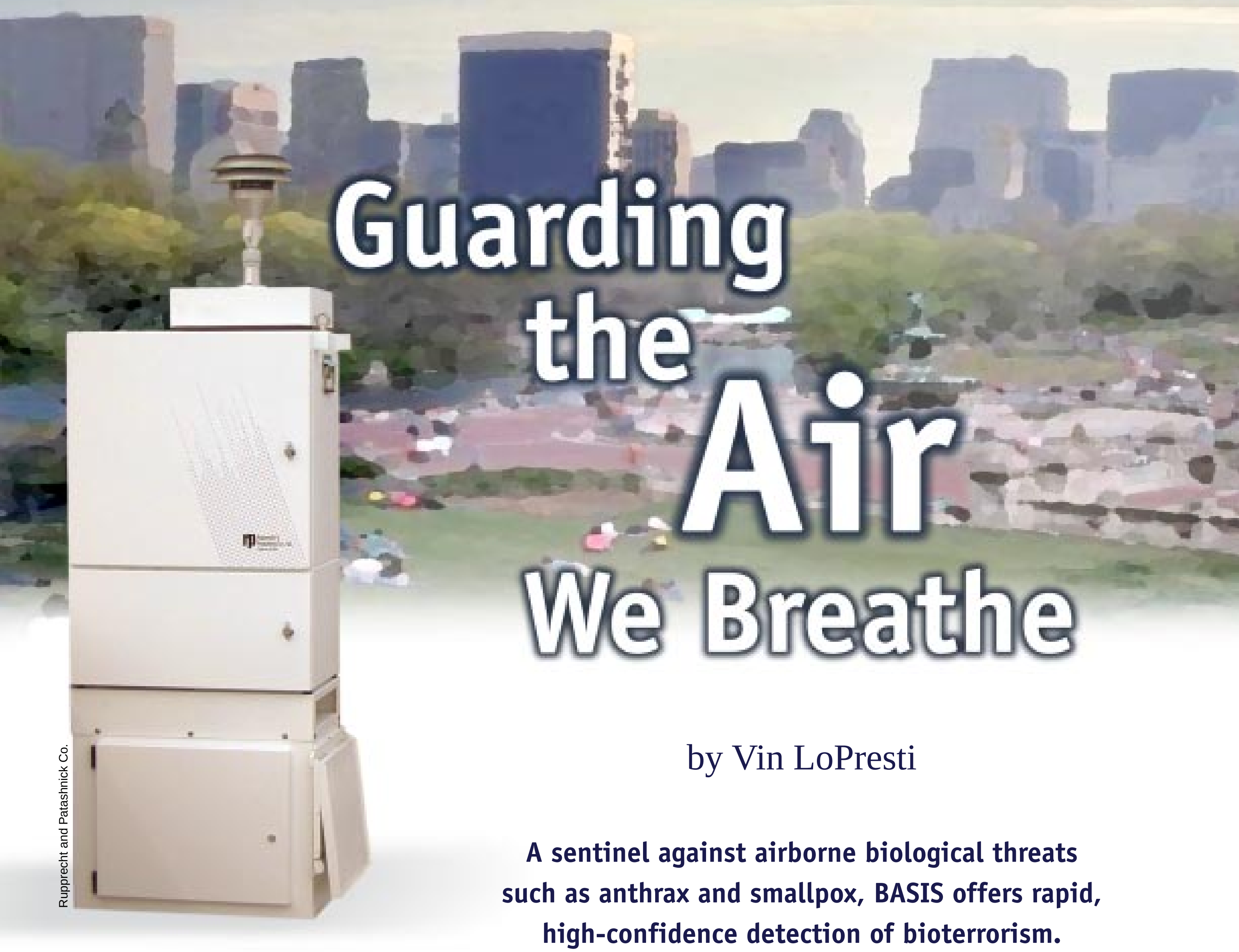


Rupprecht and Patashnick Co.

Guarding the Air We Breathe

by Vin LoPresti

A sentinel against airborne biological threats such as anthrax and smallpox, BASIS offers rapid, high-confidence detection of bioterrorism.

It's a sunny morning in late June. Tourists and locals throng midtown Manhattan, near Central Park South. The air carries a mix of aromas—sweet scents from blossoming trees in Central Park, a potpourri of ethnic foods from nearby restaurants, the pungent blend of sauerkraut and roasting hot dogs from a street vendor. But unscented and unnoted by the crowds, the air is also laced with anthrax spores from a bioterrorist attack.

Near the park's entrance, a solitary sentinel—an air sampler—stands between citygoers and a lethal infection. Drawing in the surrounding air, it collects anthrax spores on filters that are analyzed a few hours later with sophisticated DNA techniques. That night, emergency broadcasts from the city's Office of Emergency Management instruct all persons who were near Central Park South that morning where to go for antibiotic treatment.

That lifesaving sentinel is part of BASIS, the Biological Aerosol Sentry and Information System. The air-monitoring system illustrates the best in national laboratory–private enterprise collaboration in the interest of public safety. Now being deployed in cities across the country, it was developed through a partnership between

BASIS team

BASIS air samplers have been recently deployed in New York City (above and below).

Los Alamos and Lawrence Livermore National Laboratories and a New York manufacturer of air samplers, Rupprecht and Patashnick Co.

Los Alamos research into air-monitoring systems for detecting dangerous microorganisms dates back to the Gulf War, when the nation as a whole became much more aware of the threat of bioterrorism. Led by J. Wiley Davidson, a talented team of scientists and engineers from D-3 (Strategic Systems Engineering), D-4 (Technology Modeling and Analysis), and NIS-4 (Space Engineering) began designing an aerosol-biothreat detection system in the mid-1990s.

Teaming with Livermore brought the system a giant step closer to becoming a functional technology. The final steps occurred in 1999–2000, with the recruitment of Rupprecht and Patashnick, an Albany company that manufactures air samplers for the Environmental Protection Agency. By 2001, BASIS was being readied for testing, when the tragic events of September 11 drove its developers into emergency mode. Five months later, they deployed BASIS during the Winter Olympics in Salt Lake City.

A Sinister Threat

With technologies developed in part at Los Alamos, it is possible to non-invasively detect some terrorist weapons before their use. For example, acoustic detectors can identify chemical weapons in closed containers (see "Sound Solutions" in the Fall 2002 issue of *Research Quarterly*), and muon detectors show promise for detecting the transport of nuclear-weapons components (see article on page 12).

Biological weapons, however, are more sinister in that they are self-enlarging,

BASIS team

using their infected hosts to multiply them. Therefore, terrorists could initiate an attack using miniscule quantities of infectious spores, cells, or viruses. Detecting these small quantities before their release is very difficult.

Thus, at this time, the goal of biological antiterrorism—and the concept behind BASIS—is early and unambiguous release detection, or "detect to treat." Early detection can save lives—for example, early treatment of anthrax-infected individuals with antibiotics is highly successful in preventing mortality. The time course of anthrax is variable—symptoms may begin to appear at anytime from one to seven days after infection. But the overall recommendation from the Centers for Disease Control and Prevention is emphatic: "Early antibiotic treatment is essential—delay lessens chances for survival."

An Integrated System

The visible, "front-end" component of BASIS is a network of strategically deployed air samplers. Sports arenas, airline terminals, bridges and tunnels, government offices, shopping plazas, and busy street corners are all possible locations for samplers. Like the sampler that might protect passersby near Central Park, the goal is to pinpoint the time and place of a biothreat release while characterizing the threat organism's biology as expeditiously and thoroughly as possible.

A suction pump in the samplers draws outside air through filters with microscopic pores, which capture tiny particles including bacteria and viruses. Two parallel particle-capture systems operate simultaneously. One, called the holder, typically collects particles for four hours. The other, called a magazine, contains several filters, each of which collects for one hour.

So, for example, the air in a city center during the morning rush hour (6–10 A.M.) would be sampled by five filters per air sampler, a holder filter that had collected for the entire four-hour period and four magazine filters, each having collected for one hour. Only if a holder filter later tests positive for a biothreat organism are its associated magazine filters also tested. This enables hourly biothreat detection while minimizing the number of biochemical assays performed.

Software

For a deployment of the multiple air samplers needed to strategically blanket a small city or the business center of a larger city, keeping tabs on an air-sampling operation requires more than just pencil and paper. To ensure uninterrupted site monitoring, BASIS operators must sometimes adjust air-sampler operational parameters. For this purpose, samplers communicate with laptop computers running BASIS control software via either shielded coaxial cable, radio frequency, or cellular modems.

The software allows operators to remotely monitor and adjust all critical parameters for either a single sampler or an entire deployed group. For the sake of rapid recognition, these parameters are displayed both numerically and graphically. Using both visual and auditory alarms, the control computers notify BASIS operators of any changes in sampler function that would seriously impair sample collection.

There is also the issue of security. Although each sampler is locked and

BASIS team

BASIS air sampler deployed during the Winter Olympic Games in Salt Lake City.

John Flower

Parallel-path air-filtering system in the current generation of BASIS air samplers. A support team member scans a holder with a laser barcode reader when reloading filters. On either side of the holder are fresh (left) and exposed (right) magazines.

password-protected, it is clearly imperative that no tampering occur. To ensure tamper-free operation, each sampler sends a "state-of-health" message to the control computers at 10-second intervals.

Another daunting task handled faultlessly by BASIS software is tracking the fate of filters. Just before the end of a holder filter's collection period, the BASIS operator deploys a replenishment team, which delivers a fresh holder and magazine to the sampler and collects exposed filters. All filters are barcoded so that they can be tracked from deployment through analysis. Fresh and retrieved filters are contained within sealed chain-of-custody bags to ensure that filters are accounted for at all times during transit. The software's database stores the history of every filter deployed over the course of a given surveillance campaign (and from previous campaigns as well).

Mobile Biochemistry

The final component in the complex web of BASIS operations is the mobile field laboratory. All holder filters from air samplers undergo testing with the polymerase chain reaction (PCR). This assay uses highly specific bits of DNA known as "primers" that identify an organism's DNA. Thus, on a filter that contains DNA from staph bacteria (commonly found on everyone's skin), rhinovirus (a widespread initiator of common cold symptoms), and smallpox virus, primers for smallpox DNA would ignore the DNA of the other organisms and bind to the smallpox DNA with very high specificity. The subsequent addition of an enzyme (thermosensitive DNA polymerase) that duplicates DNA would produce multiple copies of only the smallpox DNA, and the other irrelevant genomes would be discarded.

A "hit" (positive test) on a holder filter mandates testing of its associated magazine filters, both to confirm the hit and to narrow the time of exposure. Should this confirmation ensue, followup testing is conducted on the target DNA. These more sophisticated assays can sometimes identify the strain of the organism present and also identify—through DNA sequencing—whether the organism has been altered by genetic engineering to make it more virulent or resistant to drugs.

A primary hit requires only eight hours from sample collection through PCR analysis. The followup testing can be done in a few additional hours, making it possible to diagnose and determine the time and place of a bio-terrorist attack within twelve hours of the release. In turn, this expeditious assessment makes it much more probable that exposed individuals can be alerted and treated before the onset of symptoms—*in time to save lives*.

Thwarting, Not Inciting, Terror

Designing an antiterrorist technology entails more than simply fitting together the pieces of a complexly interlocking system like BASIS. For the stakes are high should the system malfunction. That the system must have high sensitivity is obvious, because aerosol releases of bacteria or viruses will quickly become diluted at increasing distances from the release site. And, theoretically, it only takes one bacterial cell or virus to infect an individual, and only one infected individual to start an epidemic. BASIS' high detection sensitivity was verified

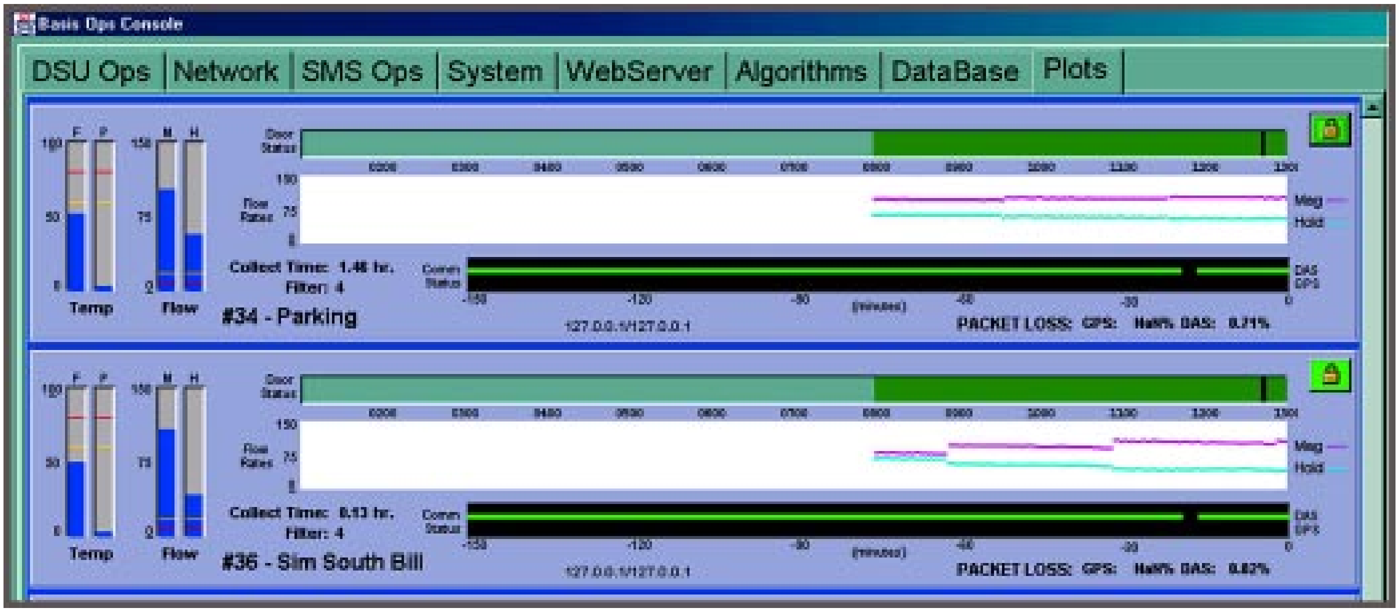
Simulation of the DSU Ops window of BASIS software. The map shows locations of deployed sampling units (DSUs) in Salt Lake City, all of which are functioning in normal air-sampling mode. The air samplers are color-coded by the green square icons on the map and the green numbered rectangles in the upper-left corner of the screen. Moving the cursor over each square icon brings up a small identifier window, such as shown for DSU 24 in the center right of the map. Clicking either this icon or the upper-left rectangular green box "24" opens the subwindow shown at the lower right, which provides instantaneous numerical filtering parameters for sampler 24. At the top, eight tabs provide single-click access to different data windows.

by the U.S. Army in threat-agent tests during 2001.

That the system must be infallible may be less obvious. Any technology that reports a terrorist incident where none exists may induce the very panic and social disruption it is intended to thwart. Therefore, the rate of false-positive alarms must be zero or very nearly so. During deployment in 2002, for about 100,000 screened filters, the rate of false positives in primary assays was less than 0.005 percent—that is, less than one false positive per 20,000 assays. Considering that primary hits on holder filters must be verified both by magazine-filter testing and secondary testing, these numbers should reassure Americans that their air quality is being monitored by a discriminating sentinel that is unlikely to set off false alarms.

Bio-Watch and Beyond

In this time of international uncertainty and heightened biothreat anxiety, BASIS is being rapidly deployed nationwide under the name

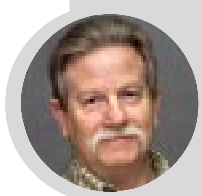


Simulation of BASIS Plots window. Plotted parameters for air samplers 34 and 36 provide a running historical record of filter flow rates, door status, and communication status since their startup. In addition, real-time airflow and temperature data are displayed in the left bar graphs. Red and yellow lines on the bar graphs indicate alert thresholds. At the top, eight tabs provide single-click access to different data windows.

"Bio-Watch." The deployment is designed to guard against large-scale urban attacks and began this past January in New York. By deploying a smaller, more-portable air sampler and using the testing laboratories affiliated with the Centers for Disease Control and Prevention to perform DNA analysis, the U.S. Department of Homeland Security has quickly pressed the BASIS technology into service.

And while BASIS extends its guard over the nation's airways, the BASIS team continues its research and development work, seeking to improve all aspects of system performance. Several new versions of BASIS software have already been implemented, and developers are constantly exploring ways to miniaturize samplers and improve their performance, particularly in smog-laden urban environments. Lightweight, unobtrusive samplers with higher airflow have already been designed and may soon be commonplace in our cities. ■

The Researcher



John Flower

J. Wiley Davidson received a bachelor's degree in engineering science and an M.S. and Ph.D. in nuclear engineering from the University of Texas, Austin. He served as the BASIS program manager from 1998 until 2002, when he became deputy director for the Los Alamos Center for Homeland Security. Previously, he was deputy group leader of the Systems Analysis Group.

The Los Alamos BASIS development team is a synergistic group of about a dozen individuals of diverse research backgrounds—in physics, chemistry, biophysics, and software engineering—who have melded their talents in the interest of domestic security.