SEISMOLOGY

Data Treasures of the Test Ban Treaty

A network of sensors meant to detect nuclear blasts could help scientists study everything from whales to volcanoes. But will they be allowed to use it?

VIENNA—At the height of Mount Etna's eruptions in July 2001, magma tore from the cones at terrific speeds, unleashing booms that thundered in the villages at the volcano's base. Although the sound-and-light display was for locals only, scientists hundreds of kilometers away were tuning in to Radio Free Etna. The shaking mountain, with its roiling ash cloud, acted like a gigantic transmitter, triggering pressure waves that undulated through the atmosphere. These waves, with wavelengths measured in hundreds of meters, were below the threshold of human hearing. But, in the Netherlands, a new infrasound detector array registered the waves and pinpointed their origins to Sicily.

The Etna data are the latest in a series of dazzling observations suggesting that a global surveillance network, designed to eavesdrop on clandestine nuclear tests, could become a powerful new tool for the scientific community.

Wiring the world. Test ban treaty staff check out an infrasound station in Greenland (above) and lay cables for a hydroacoustic station in the Indian Ocean.

CREDITS: CTBT PREPARATORY COMMISSION

To verify that countries adhere to a test ban, the Comprehensive Nuclear Test Ban Treaty (CTBT) of 1996 mandates stringing Earth with listening posts for the telltale signatures of nuclear blasts. According to Peter Marshall, a forensic seismology expert at the Atomic Weapons Establishment in Aldermaston, U.K., the 321-station network of detectors for seismic, infrasound, and hydroacoustic waves and radionuclides, called the International Monitoring System (IMS), will provide "a view of the globe we have never had before."

That is, if the network's political masters allow that to happen. About a third of the planned $250 million IMS network is now up and running, but data are being fed only to government-run centers in a few dozen nations that have signed the treaty. The Etna findings, which came from the Royal Netherlands Meteorological Institute's infrasound station—one of the few that's not part of the IMS network—only hint at the IMS gold mine that's tantalizingly out of reach.

Even government researchers at labs in CTBT countries must jump through a series of hoops to get their hands on the data. "Access to data is very cumbersome," says Domenico Giardini, director of the Swiss Seismological Service in Zurich. Only the CTBT parties can authorize the data's release, on a case-by-case basis. Negotiations under way on a common release policy are contentious.

But the scientific community at large has an unlikely ally in the quest to plunder this data treasure trove: uncertainties about the future of the CTBT itself. For the treaty to come into force, 44 countries that possess nuclear weapons or research reactors must ratify it. So far, 31 have, but the present government of one dominant member of this elite group—the United States—opposes ratification, leaving the treaty in limbo. With realization dawning that the IMS might not be called upon to verify treaty compliance for years to come, scientists both inside and outside the CTBT Preparatory Commission are building a case for civilian and scientific uses for the network, which is being funded by the treaty parties in anticipation of eventual ratification. Possible uses range from tracking whale populations to providing early warnings of volcanic eruptions that threaten airplane routes.

Casting a wide net

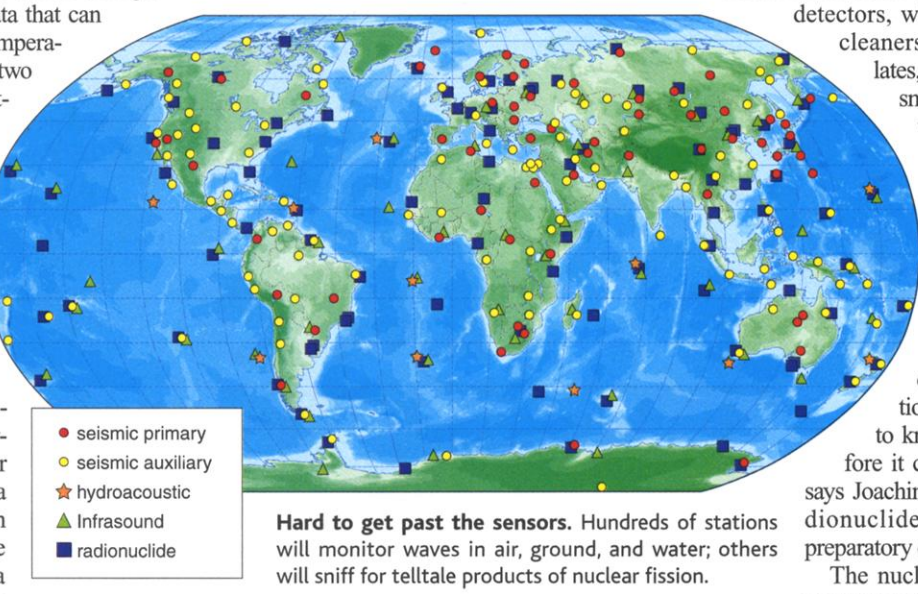
Expected to be fully working by 2007, the IMS is shaping up to be the most extensive network of geophysical stations ever built (see map on p. 43). Currently, a few dozen stations each day pump about 4 gigabytes of data to a processing center at the CTBT office in Vienna, Austria. Here, analysts screen out false hits and waveforms that are clearly of natural origin—such as earthquakes that occur so far below Earth's surface that they couldn't conceivably be clandestine tests—then compile daily reports on about 50 geophysical disturbances. These "events" include everything from moderate-sized earthquakes to streaking meteors. The young network, along with independent seismic stations, also spotted the nuclear tests conducted by India and Pakistan in 1998.

One of the mightiest assets of the full IMS will be coverage so complete it would make the likes of Motorola salivate. "This is the first time we'll have a global seismic network in real time," says Sergio Barrientos, chief of seismic monitoring at the CTBT Preparatory Commission. Because the most likely place for a country to try to hide a nuclear explosion is underground, the treaty calls for a globe-girdling web of 50 seismic wave detectors, some in extremely remote locations. If any detector gets a hit, a computer in Vienna springs into action, requesting supplementary readings from the nearest detectors in an auxiliary network of 120 existing stations.

In a closed meeting held in London last May to discuss civilian and scientific applications of the IMS, experts agreed that the network could provide valuable data indeed. Real-time IMS seismic data "would greatly improve the accuracy and timeliness of reports on earthquake location and magnitude" and can help direct relief efforts after large earthquakes by estimating the size and frequency of aftershocks, according to a meeting summary obtained by *Science*. Seismologists are hungry for data—in particular, from the subset of IMS stations set up as arrays, in which a number of identical sensors are positioned hundreds of meters apart. This slashes noise dramatically, giving a precise location of the origin and direction of a seismic wave. Such data can help map the geometry of faults and perhaps lead to insights about how they rupture. "All the classical fields of research in seismology are interested in these data," says Michel Granet of the Institut de Physique du Globe in Strasbourg.

Existing seismic networks simply can't match the IMS for its global coverage, real-time data retrieval, and the tens of millions of dollars being spent on detectors and installation. "We have always struggled to get instrumentation like this," says Giardini. The technical specs are truly impressive, he adds: "If they drill a hole, they drill it deeper than other networks [do]."

Demand is already high for data from the hydroacoustic sensors, which can do more than just listen for muffled undersea explosions. Scientists with the Acoustic Thermometry of Ocean Climate (ATOC) project—which uses low-frequency pulses to measure ocean temperatures—are now negotiating with CTBT officials over access to high-resolution hydrophone data that can help refine their ocean temperature measurements. And two IMS hydrophones operating in the Indian Ocean last March picked up the underwater groans of the Larsen B ice shelf before a chunk bigger than Luxembourg broke away. The hydrophones and t-phase stations—designed to detect the conversion of hydroacoustic energy to seismic energy when underwater sound waves impinge on a land mass—also listen in on the chatter of marine mammals and thus offer a way to track population groups, says Marta Galindo, a hydroacoustic expert with the CTBT Preparatory Commission. "We detect a lot of biological activity," she says. Emergency officials also could use the data for early warnings of tsunamis and to warn ships about the activity of underwater volcanoes.



Hard to get past the sensors. Hundreds of stations will monitor waves in air, ground, and water; others will sniff for telltale products of nuclear fission.

SOURCE: CTBT PREPARATORY COMMISSION

Perhaps the greatest uncharted horizons lie in the exploitation of infrasound. Such waves escaped detection well into the 20th century, but they are now known to emanate from everything from nuclear explosions and airplanes to earthquakes and auroral displays. Researchers want to use the strong infrasonic waves generated by severe storms to refine models of how hurricanes and typhoons develop. Crude infrasound stations were set up in the 1950s and 1960s to detect atmospheric bomb blasts, but they were neglected after atmospheric testing was banned. "A lot of knowledge was forgotten," says Thomas Hoffmann, an infrasound specialist with the CTBT Preparatory Commission.

The main challenge for the infrasound arrays is latching onto the airborne waves—"a very strange beast," says Hoffmann. Windows and building walls, for example, are practically transparent to the waves, which are perturbed easily by wind and atmospheric disturbances. The detectors are composed of vertical inlet pipes laid out in cloverleaf formations on the ground, as if they're catching water. Design improvements and better analytical computer programs have helped home in on the origins of signals, as in the Etna observations. Infrasound data could help steer planes clear of volcanic plumes, particularly in remote regions such as the Russian Far East. "There's an interest in the aviation industry in knowing where these ash clouds go," says Hoffmann.

Moreover, Hoffmann adds, "there are a lot of applications that nobody has thought of before." For instance, because the upper atmosphere reflects infrasonic waves, these can be used to probe conditions in a region much higher than where weather balloons can reach. And infrasound sensors in Canada, Germany, California, and Hawaii last year detected the titanic explosion of a huge meteor over the Pacific.

The CTBT parties hold the key to probing many of these promising research avenues. They're due to discuss data access issues at a CTBT conference in Vienna next month, although a policy is not expected to materialize imminently. While opposed to the treaty, the Bush Administration backs the IMS. "It's a fantastic resource, and we're committed to seeing it completed and the data available to the public," says an official at the U.S. State Department. It's in U.S. interests to sustain the IMS, point out observers, as the network is a unique source of data from sensitive regions such as China and Russia.

But China and a handful of other countries argue that IMS data should generally be reserved for their intended uses and should not be distributed to states that are not CTBT parties, except for relief after disasters such as large earthquakes. China has argued that data release could compromise national security, says Oliver Meier, an arms control expert at the Verification Research, Training, and Information Centre in London. Other nations have expressed concern that nongovernmental groups could use data to level false allegations at states. So far, China has blocked release of IMS data beyond governmental data centers in each of the 53 countries now registered to receive data. Parties that back open scientific access will have to overcome these objections before a common policy emerges, as the CTBT parties make decisions by consensus.

Perhaps the most sensitive information is in the radionuclide data. These 80 planned detectors, which act like vacuum cleaners sucking up particulates, are designed to collect smoking guns of a treaty violation: short-lived radioisotopes that could be spawned only in a fission reaction. Providing free access to such data is unlikely, as it could tip off watchdogs to nuclear accidents or routine pollution. "Governments want to know about the data before it comes to public light," says Joachim Schulze, chief of radionuclide monitoring at the preparatory commission.

The nuclear power industry is wary as well. "A director of a nuclear facility wouldn't want to be confronted with data," Schulze notes. Nevertheless, says one official, this information "would be of great value if there were another Chernobyl-type disaster." But scientists are clamoring for at least one set of radionuclide data: levels of the noble gas xenon. Because xenon doesn't readily react with other molecules, the data could come in handy for calculating the wind patterns that sweep molecules across the globe.

The IMS might indirectly help overcome opposition to the treaty itself by building confidence in the technology. The Bush Administration and other critics argue that the treaty is not verifiable, as the IMS network might miss very low-yield nuclear tests or blasts that are "decoupled" from the environment, say in an underground cavern built to dampen a blast's energy. But, although the treaty has stringent minimum requirements for IMS sensors—the network is designed to detect explosions of at least 1-kiloton yield—the IMS has shown that it is sensitive enough to detect energy releases on the order of tens of tons. And there's nothing stopping the preparatory commission from upgrading the IMS to even sharper eared sensors. Even without upgrades, says Marshall, scientists have much to look forward to. "It's just mind-boggling what might be achieved," he says.

–RICHARD STONE