Policing the Peace

How nations will monitor a nuclear test ban

By RICHARD MONASTERSKY

Inside the International Data Center.

Steven R. Bratt's belt started chirping as if on cue, precisely as he was boasting about a new global watchdog system for detecting nuclear tests. Bratt, a seismologist with the U.S. Department of Defense, retrieved the beeper from his hip and studied it for a few seconds.

"I've got an alert. It's from Lop Nor. Lop Nor is the Chinese test site," he explained.

Two stations in a worldwide network of seismometers had just picked up vibrations emanating from central Asia, near China's known nuclear facility. The shock was small, about magnitude 3.5. In bomb equivalents, it would correspond to less than a half kiloton explosion.

In this case, however, Bratt suspected the alert was just a minor earthquake. Timing provided an important clue: The shock had originated at 12:19 Greenwich Mean Time, which is not the kind of round, on-the-hour time that countries usually choose for performing a major weapon test.

Seismic analysts would later confirm Bratt's hunch when they determined that the Chinese vibrations actually originated at an unlikely place to stage a test, hundreds of kilometers away from the Lop Nor site.

The impromptu demonstration nonetheless made a good advertisement for the new international monitoring system—an ever-vigilant network of sensors strung around the globe, listening, sniffing, and waiting.

The system, which currently includes 140 stations, is a prototype of the one required by the Comprehensive Test Ban Treaty (CTBT), currently being negotiated in Geneva. After nearly 40 years of discussion, the world is moving toward adopting the treaty—if all goes well—as early as this summer, thereby prohibiting all nuclear testing.

To back up a ban on nuclear testing, the treaty calls for a four-part monitoring system consisting of seismic, hydroacoustic, infrasound, and atmospheric radionuclide sensors. According to sections of the treaty already written, all the data collected by this system will flow into an information hub called the International Data Center, a prototype of which is located in Arlington, Va. Bratt is the Defense Department's program director overseeing development of the data center.

Each element of the monitoring arsenal will patrol a different region of the planet, though they overlap to some degree.

The seismic network, the backbone of the system, will draw on 50 primary and 120 auxiliary stations to pick up vibrations from any underground tests. The hydroacoustic system will keep watch for ocean blasts using six underwater sound receivers tied in with five island-based seismometers. An infrasound network of 60 microbarographic pressure sensors will listen for atmospheric explosions. Lastly, 75 radionuclide stations will monitor the winds for the distinctive isotopic aroma vented into the atmosphere by atomic blasts.

The treaty bars all nuclear detonations, but economic, political, and technological constraints make it impossible to catch extremely small explosions.

"This is a zero-yield treaty, but there is no way that this system or any system is going to [monitor down to] zero. You would walk across continents stepping from seismometer to seismometer if you tried that," says Ralph W. Alewine III, the deputy assistant to the secretary of defense for nuclear treaty programs.

Recognizing the limitations on the numbers and locations of sensors, international negotiators have opted for a system that—in theory—can detect unmuffled explosions with yields down to roughly a kiloton, says Bratt. The United States has assumed responsibility for providing the prototype, with assistance from other countries.

Under normal circumstances, a yield of 1 kiloton (kt) creates seismic waves approximately equal to a magnitude 4.0 earthquake. (A kiloton is defined as 10^{12} calories of energy. The first U.S. nuclear detonation, the Trinity test, had a yield of 21 kt.) A country can, however, attempt to weaken the waves by conducting the test in a large underground chamber. Called decoupling, this difficult procedure could reduce the vibrations of a 1 kt test to the equivalent of a magnitude 2.5 quake.

According to Bratt, the completed seismic network will detect quakes and blasts of magnitude 4.0 or greater with a high degree of confidence, meaning that 90 percent of these events will trip at least three sensors. The system will also have the ability to pinpoint detections to a fairly small area, 1,000 square kilometers. This corresponds to a circle with a radius of 18 km.

Though 1 kt represents the nominal threshold, the monitoring system is designed to catch many smaller blasts as well. "Even at 300 tons, which is pretty small, we still have, say, a 50 percent probability of detecting it," says Bratt. Any potential evader must therefore weigh the odds of getting caught even when testing at low yields.

"We've had examples of detecting signals on Novaya Zemlya that we think are on the order of 10 to 25 tons," says Alewine, referring to events in northern Russia that were determined to be either earthquakes or explosions used in mining and other industry. "It's going to be a very capable system, but we're careful not to advertise too much about it," he adds.

The new system represents a departure from Cold War tactics, in which the United States and the other four nuclear powers focused their monitoring efforts on each other's known test sites. In contrast, potential testers of the future could come from a dozen or more different countries and would probably choose remote locations rather than known test facilities.

The trick will be distinguishing nuclear blasts from all other types of signals, such as earthquakes and conventional explosions. At larger energies, earthquakes and blasts look clearly different. To demonstrate, Bratt turns to a computer and pulls up seismic recordings from the second-to-last French nuclear test in the South Pacific on Dec. 27, 1995, which he estimates had a yield of about 50 kt.

(For more information on this test and worldwide earthquakes, see the International Data Center's home page at *http ://www.cdidc.org.*)

The magnitude 5.0 signal peaks immediately and then tapers off smoothly, as one might expect from an explosion, which releases most of its energy in less than a second. In contrast, earthquakes are messy. Ground on either side of a fault slips for many seconds, creating complex trains of seismic waves. The trace of a similar-size earthquake starts off much more slowly, grows in spurts, and then decays unevenly.

As magnitudes get smaller, however, the details of the seismic trace start to get washed out—unless sensors are located nearby, something not possible with a global network of only 170 stations.

At magnitudes below 3.0, conventional chemical detonations enter the picture. The world rings every day to hundreds of explosions from mining and other industrial activities. Although such blasts differ in detail from nuclear tests, it will be difficult in practice to tell just from the seismic, hydroacoustic, and infrasound data whether small explosions are nuclear or chemical, says Bratt.

Given such ambiguities, the radionuclide stations represent a key element of treaty enforcement. "It's the only smoking gun we have in the system," says Bratt.

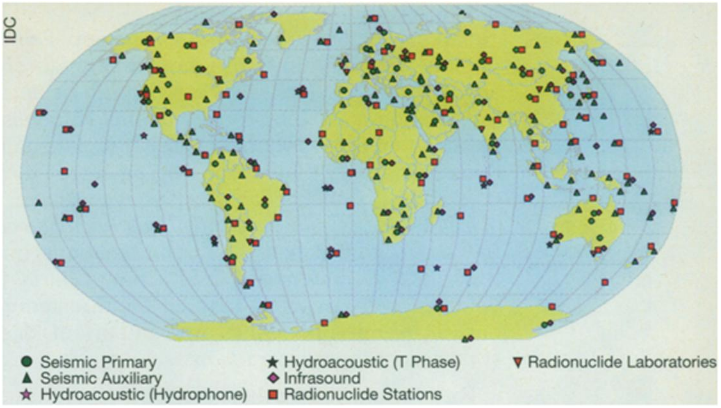
Like giant vacuum cleaners, these stations suck in more than 500 cubic meters of air per day, capturing particles on filter paper. At the same time, samplers collect small volumes of air for gas analysis. Germanium detectors measure the gamma-ray emissions from these samples, which identify the types of radionuclides present.

Analysts at the International Data Center sift through these recordings, looking for the particular combinations of isotopes produced by nuclear explosions. In the event of a suspicious reading, they can use sophisticated meteorological models to backtrack through recent weather patterns to determine the origin of the radionuclides.

This information, as well as data flowing in from the other three systems, does not provide absolute identification of nuclear blasts. Instead, it is intended to arm treaty nations with enough information to decide whether to follow up questionable events with on-site inspections.

If a team can arrive on the scene within a few days, it can set up portable seismometer systems to catch aftershocks, which help determine whether an earthquake or a blast has occurred. On the ground, investigators can also do a more thorough search for radionuclides.

Treaty participants may face trouble getting some countries to allow intrusive examinations. Those arguing for an inspection can strengthen their case with the treaty organization if they muster as much evidence as possible pointing to a possible violation, says Bratt.



Wiring the world: The proposed International Monitoring System includes more than 300 stations, most of them in the Northern Hemisphere.

Many countries have for decades maintained their own monitoring systems, which pull information from satellites, seismic networks, intelligence agencies, and other tools. The United States, for example, has a seismic network run by the Air Force called the Atomic Energy Detection System. This classified network has superior capabilities in some regions, compared to the new international seismic network planned for the CTBT.

A current sticking point in the ongoing treaty negotiations is whether countries can use information collected by their own "national technical means" as part of a call for on-site inspections. "The U.S. would like to be able to lay any data on the table," says Alewine. "It's just like when we spotted missiles in Cuba in 1962. We took the U2 [spy plane] photographs to the United Nations," says Alewine. Some nations, however, object to the use of information provided by individual countries because it may be of uncertain quality and not open to examination.

Even unclassified information can come into play. Many quake-prone nations have seismic networks that far exceed the regional sensitivity of the international seismic monitoring system. For example, in central Asia, Kyrgyzstan and Kazakhstan have networks that locally average 1.0 magnitude unit better than the prototype international seismic monitoring system, says Gregory van der Vink of the Arlington-based Incorporated Research Institutions for Seismology (IRIS), a consortium of U.S. academic institutions.

Van der Vink compares these regional networks to neighborhood watch programs that could augment the international system. "While the regional networks will not replace the formal monitoring system, just as neighborhood watch programs do not replace the police, they will provide a strong additional deterrent to any country considering violating the CTBT below the threshold of the monitoring system," he says.

In general, van der Vink gives high marks to the seismic section of the prototype international monitoring system, which puts out automated detections immediately and updates them 48 hours later with a listing of events reviewed by human analysts. At present, the data center team reviews on average 60 events each day. Seismologists at IRIS have found that this reviewed bulletin is at least as accurate as the one produced by the U.S. Geological Survey, which comes out with a lag of months as opposed to 2 days.

But van der Vink questions the advertised sensitivity of the completed international monitoring system. He predicts that the seismic network will have problems detecting events in some regions, such as central Asia, because political considerations in the negotiations determined the location of stations. "For several areas of the world, it's going to be hard for them to get down to magnitude 4.0 and 1,000 square kilometer error ellipse using the stations that are formally designated for the international seismic monitoring system," says van der Vink.

Whether this level of detection proves sufficient depends on who will be tempted to test nuclear weapons in the future. If history holds true, countries developing their first nuclear weapon will probably not be able to build a bomb with a yield under 1 kt. All known first-time tests have had yields greater than 10 kt.

Countries with advanced nuclear weapons programs can easily design devices well below the kiloton level. Yet they will have to gamble that neither the international monitoring system nor the intelligence assets of individual countries will pick up a small detonation, says Amy Sands of the U.S. Arms Control and Disarmament Agency, which is negotiating the test ban treaty in Geneva.

"What you're trying to do is set up a system that deters countries as much as detects and resolves ambiguities about these events, because countries won't know the capabilities of the U.S. system combined with the international monitoring system," says Sands.

In that sense, success for the treaty means constructing an alliance of observing systems so daunting that they are never called upon to identify a nuclear blast. Whether nations can meet this challenge remains the ultimate test. □