IRIS AND OTHER OPEN SEISMIC NETWORKS COULD BE CRUCIAL TO TEST-BAN REGIME

On 25 January 1994 multilateral negotiations aiming at the prompt conclusion of a comprehensive ban on testing nuclear weapons will begin in Geneva, under the auspices of the Conference on Disarmament, an ongoing forum supported by the United Nations for this kind of task. In the estimation of individuals who have devoted much of their adult lives to this issue, the time may be ripe at last for a comprehensive test ban to be concluded.

"Never in 30 years have we been so close to achieving a CTB," said William Epstein, the former director of the UN Disarmament Division and the author of one of the first major books on nuclear proliferation, at a meeting of nongovernmental organizations held at the UN in New York City on 27 October.

Russia and France declared test moratoria in 1992, and the same year legislation sponsored by Senators Mark Hatfield and George Mitchell forced a US moratorium. In spring 1993 the Clinton Administration decided after some internal debate to extend the US moratorium; Britain, which depends on the Nevada test site, followed suit.

While the People's Republic of China resumed nuclear testing this year, its decision to do so came in for round international denunciation. Its big test on 5 October "went much against the trend," Yoshitomo Tanaka observed, also on 27 October, with characteristic Japanese understatement. Tanaka is the chair of the UN Disarmament Conference's Ad Hoc Committee on a Nuclear Test Ban.

The verification conundrum

Besides the end of the cold war, the major reason why seasoned disarmament experts like Epstein and Tanaka are once again setting their sights on a CTB is this: In March 1995 the members of the Nuclear Nonproliferation Treaty will convene for a 25-year review of the treaty, amid some concern that complacency or carelessness could result in a movement to weaken or constrain the NPT. Because a CTB has always been the leading demand from the treaty's non-nuclear parties upon the nuclear-weapons states, achievement of a ban may be essential to shoring up support for continuation of the NPT.

But a test ban also is in and of itself a significant constraint on proliferation, even if testing is not essential to construction of a working and reliable nuclear weapon. And so at a time when proliferation is displacing strategic nuclear weapons at the top of the arms control agenda, pressure for a test ban has grown in tandem. (Similar considerations contributed to President Clinton's proposal earlier this year at the UN to negotiate an international ban on production of any further plutonium or highly enriched uranium for nuclear weapons.)

As even the most casual student of nuclear arms control appreciates, uncertainties associated with verification have been the major stumbling block to a CTB ever since the first test-ban talks were held in Geneva in the 1950s, though the Reagan and Bush Administrations took the position that a comprehensive ban was inherently undesirable as long as the US relied on nuclear weapons. (For background, see Chapter 2 of *Physics and Nuclear Arms Today,* David Hafemeister, editor [AIP, New York 1990].)

A significant breakthrough in verification occurred in 1986 and 1987, when the Natural Resources Defense Council, a US nongovernmental organization, reached agreements with the USSR Academy of Sciences to jointly operate on-site seismic monitoring stations first at three and then at five sites in the USSR (see PHYSICS TODAY, November 1987, page 83). The agreements showed that on-site verification was not an insuperable obstacle to a US–Soviet agreement, and the field methods employed by the NRDC–Academy teams exploited important developments in the science of seismic verification, in particular the recognition that regional high-frequency waves could be crucial in distinguishing nuclear explosions from other events such as earthquakes.

The collapse of Soviet communism and the emergence of nuclear proliferation as a more urgent concern both simplify and complicate the verification problem. Gone, perhaps, is the obsession with being able to detect with nearly 100% reliability—basically a technical impossibility—any Soviet misdeed. Arrived, on the other hand, is a much greater worry about being able to detect covert tests at potentially unidentified testing sites any place on the face of the Earth.

In the context of this new worry, large networks of seismic stations that provide data openly to all comers—notably the networks coordinated by the US Geological Survey and by the research consortium IRIS—are of special interest.

IRIS

IRIS, or Incorporated Research Institutions for Seismology, originated as a purely scientific endeavor, and it still serves primarily as an instrument for geophysicists studying the Earth's core and crust. According to Tom McEvilly of the University of California, Berkeley, who was the first board chair and first acting president of the consortium, seismologists started talking in 1982 about creating a new network to replace the increasingly obsolete Worldwide Standard Seismologic Station network, which consisted of 125 analog stations.

The objectives of the new network, as they emerged in discussions among seismologists, were to set up 100 digital stations around the world, to create a 1000-element array of portable instruments (known by the

Joint Seismic Program

Stations in former Soviet states	Stations outside FSU
Garm, Tadjikistan	Seychelles Islands
Kislovodsk, Russia	Tennant Creek, Australia
Arti, Russia	New Delhi, India
Obninsk, Russia	Nairobi, Kenya
Talaya, Russia	Quetta, Pakistan
Ala-Archa, Kirghizia	Canary Islands, South Atlantic
Garni, Armenia	Kevo, Finland (upgrade)
Novosibirsk, Russia	Falkland Islands
Yuzhno-Sakhalinsk, Russia	Kodiakanal, India
Lovozero, Russia	Saudi Arabia
Norilsk, Russia	Sutherland, South Africa (upgrade)
Alibek, Turkmenistan	
Yakutsk, Russia	**Seismic networks and arrays**
Petropav.-Kamchat., Russia	Pinyon Flats, California-high frequency
Magadan, Russia	Pinyon Flats, California-broadband
Tiksi, Russia	Garni array, Armenia
Provideniya, Russia	Kirghizia network
Karkaralinsk, Bayanoul, Kazakhstan	Caucasus network
Borovoye, Kazakhstan	Turkmenistan array
	Borovoye 3-element array

acronym PASSCAL) to probe the deep Earth, and to make all data openly accessible in real time to scientists everywhere via the most advanced and efficient electronic means available.

Starting with modest funding from the National Science Foundation on the order of $5 million per year, with increments first from the Defense Advanced Research Projects Agency and then from the Air Force, which has principal responsibility for nuclear test detection, the network currently is being expanded to include 128 permanent stations, with 15 already in place in the former Soviet republics. PASSCAL has evolved into two major instrumentation centers, one at Lamont–Doherty Earth Observatory in Palisades, New York, and one operated by Stanford University and the US Geological Survey in Menlo Park, California.

Database management for the whole network is centered at the University of Washington, Seattle, and is done in close cooperation with USGS offices in Albuquerque, New Mexico, and Golden, Colorado.

With more than 80 members, IRIS probably is the largest scientific consortium of universities, and yet it has received little attention, even in the science press. One reason for this, McEvilly speculates, is that the network has become a "background operation." That is, with usage growing exponentially and monthly requests for time and data now numbering in the thousands, everybody uses it and nobody thinks about it.

"It's the meat and potatoes of current seismology," says Paul Richards of Columbia University and Lamont–Doherty. Richards right now is on a one-year leave with the US Arms Control and Disarmament Agency, where he is working, of course, on test verification issues.

USGS and IRIS system

The 15 stations in the former Soviet states, which constitute the Joint Seismic Program, are direct descendants of the NRDC–Academy test program and represent the part of IRIS that is most relevant to test detection and especially identification. As the NRDC project evolved, its objectives were to provide verification for a low-threshold test-ban treaty and to support intergovernmental exchanges of seismic data under the auspices of the Ad Hoc Group of Scientific Experts of the Geneva Disarmament Conference. Charles Archambeau of the University of Colorado, Boulder, had overall scientific responsibility for the NRDC project and remains heavily involved in the supervision of the Joint Seismic Program.

Apart from the Joint Seismic Program, IRIS's utility to a test-ban regime may be limited mainly to R&D for design of other networks. Richards says that a CTB probably would require reliable monitoring worldwide of seismic events down to about magnitude 4; IRIS, he says, will be able to provide coverage only down to 5–5.5, even when all 128 stations are completed. And so data from other networks such as the USGS National Earthquake Information Center will remain crucial.

The USGS center receives data from about 2000 stations around the world and publishes a list of seismic events, which average about 50 per day. Most of these are small earthquakes below magnitude 4. IRIS stations play a significant secondary role because they can be remotely interrogated, a technique IRIS pioneered.

The Group of Scientific Experts of the Geneva Disarmament Conference currently is planning to put together a global network of stations on an experimental basis in 1994–95 to support the test-ban talks. This network will consist of both "alpha" stations (like the USGS ones) that provide data continuously and "beta" stations (like the IRIS ones) that provide data on request. The alpha stations might consist of seismometer arrays much like the ones the US Defense Department has relied on in past decades for Soviet test estimation.

Such arrays, designed to maximize signal-to-noise ratios and to triangulate signal sources, have been the province of DARPA (now called ARPA) in the US; ARPA is responsible for the US contribution to the system being planned by the Group of Scientific Experts.

Future of IRIS

In October, in recognition of its test-ban potential, IRIS received a special Congressional appropriation of $21 million. The money will be used to complete continental coverage of the global network, to make coverage more dense in proliferation-sensitive areas and to upgrade stations specifically for test monitoring. All funds will continue to be channeled to IRIS via NSF, which peer reviews proposed outlays.

Only the very naive would suppose, however, that the existence and expansion of this network, together with the USGS and GSE systems, will lay the verification issue to rest. Although the networks may improve the detectability of tests by as much as an order of magnitude versus the situation 10 years ago, the question of how confident we need to be of identifying a test will remain a highly controversial matter.

Here in the US and elsewhere it seems that potential opponents or critics of a test ban have yet to get organized and to formulate a position, and so it is hard to know what kind of confidence levels people will claim are essential. For this reason alone, there is no saying whether we are likely to see in the next year the negotiation of a relatively simple test-ban treaty, in which the signatories agree to aim for some arbitrarily defined level of confidence at some projected cost, or whether the treaty will involve negotiation of very complicated verification provisions of a kind that has ended up dooming earlier efforts at a ban.

Epstein, the emeritus leader of the UN disarmament staff, has argued that the quickest and surest route to a CTB would be to amend the partial test-ban treaty and leave verification for follow-on negotiation. But even that, Epstein would be the first to concede, is a tall order.

—WILLIAM SWEET

OSA PRESENTS FIRST BURLEY PRIZE AND BELLER AWARD

The winners of two new prizes of the Optical Society of America were recently announced: Erwin G. Loewen has been named the first recipient of the Robert M. Burley Prize of the Joseph Fraunhofer Award and Robert Greenler is the winner of the first Esther Hoffman Beller Award.

The Burley Prize, which recognizes contributions to optical engineering, is named for the late Robert M. Burley, who was a senior optical designer for Baird Corp until his death in September 1990. In 1982 he was named the first recipient of OSA's Fraunhofer Award, for which the Burley family created an endowment of $15 000 to support future awards.

Erwin G. Loewen was cited for "recent fundamental technical contributions and teaching that have furthered the application of the principles of precision optical engineering, particularly with regard to the theory, design and manufacture of diffraction grating structure."

Loewen was director of the grating and metrology laboratories at Milton Roy Company until retiring in 1987.

The Esther Hoffman Beller Award, honoring excellence in optics education, was made possible through a $75 000 bequest from Beller, who died in 1991. Beller earned a master's degree in education from Columbia University's Teachers College, and she taught music and art to young adults and adolescents. Her bequest to OSA was made in recognition of her husband's interest in optics.

Greenler, the Beller Award winner, was cited for "extraordinary leadership in advancing the public appreciation and understanding of science and the scientific method through his lectures and demonstrations of optics to diverse audiences, his writings and his advocacy for science and education."

Greenler is now a professor of physics at the University of Wisconsin, Milwaukee.

The awards, which were presented at the OSA annual meeting in Toronto in October, each consist of a medal and a cash prize.

ASA PRESENTS FIRST SCIENCE WRITING AWARDS

The Acoustical Society of America has announced the recipients of its recently created Science Writing Award for Journalists and Science Writing Award for Professionals in Acoustics: Malcolm W. Browne of *The New York Times* and Thomas M. Georges of the National Oceanic and Atmospheric Administration's Wave Propagation Laboratory in Boulder, Colorado. ASA created the awards to recognize outstanding articles, books, films, audiotapes and videotapes about acoustics that are intended for the general public.

Browne was chosen for four articles that appeared in the *Times* in 1992: "Cooling with Sound: An Effort to Save Ozone Shield," "Using Natural Sounds, System Tries to See Objects Deep in Ocean," "Clues to Quality Heard in the Sound of Corn" and "Ear's Own Sounds May Underlie Its Precision." Browne has been a reporter at *The New York Times* since 1968.

Georges received the writing award for acousticians for his article "Taking the Ocean's Temperature with Sound," which described the Heard Island feasibility test to monitor the effects of greenhouse warming on the oceans. It appeared in the July 1992 issue of *The World and I* magazine.

Georges is currently a physicist at the NOAA Wave Propagation Lab, where he does research in radar oceanography and ocean acoustics.

The awards, which consist of a $1000 prize and a certificate, were presented during the ASA meeting in Denver in October. ■