The Washington-Moscow Seismic Hot Line

An international experiment involving exchanges of seismic data is the latest evidence of scientific progress on nuclear test ban verification

The first message from the Institute of Physics of the Earth, located on the outskirts of Moscow, arrived in the United States on the morning of 17 October. Under the heading SERS1 RUMS 171000, a list of numbers and phrases offered a detailed description of the local seismic signals created by a large earthquake in the South Pacific. Sent by satellite via Czechoslovakia, West Germany, and England, this information was received at a modern office building in suburban Washington. There, it was interpreted within hours by a team of seismologists at a research center financed and operated by the U.S. Department of Defense. On the previous day, similar seismic data, collected at six stations in the United States and Canada, had been sent to Moscow.

This extraordinary exchange is only the first of many scheduled before mid-December, as seismologists in 34 countries participate in a novel 3-month experiment organized by the Conference on Disarmament in Geneva. The purpose of the experiment is to rehearse a key mechanism for verifying compliance with a comprehensive ban on nuclear weapons tests. It was hatched more than 4 years ago, when worldwide interest in such a ban was at its peak, and negotiations were moving rapidly toward a successful conclusion. Given the failure of those negotiations to date, and the bleak outlook for their future, the experiment's very existence is a noteworthy achievement.

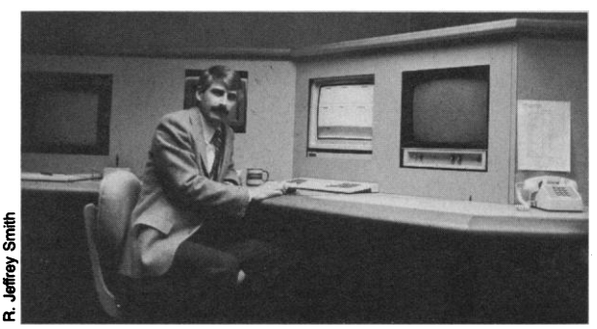
Although formal test ban negotiations began more than 20 years ago, the effort has been stalled largely because of Western desires to build new and better nuclear weapons (see box). This opposition is strengthened by a pervasive conviction that treaty compliance by the Soviet Union would be extremely hard to verify. The importance of the experiment stems from its relevance to the second of these problems. If it succeeds, it will go a long way toward establishing the viability of a verification system in which the entire world may join. At a minimum, it will result in the international exchange of unusually detailed scientific information. It will serve, moreover, as an example of other progress on the test ban verification problem and as a reminder that the major roadblocks in the path of a treaty are political—not technical.

The underlying theory of this verification mechanism is simply that nuclear explosions beneath the earth's surface generate characteristic seismic signals, and that a systematic worldwide effort to gather and exchange detailed seismic data will diminish the likelihood that such signals go undetected. Seismic data received and reported by Sweden, for example, will be contrasted with those reported by East Germany, Egypt, Peru, Japan, and Australia, in hopes of pinpointing the origin and character of a suspicious "seismic event," or disturbance of the earth's natural vibrations.

In order to widen participation and improve the system's reliability, the United States has made substantial efforts to provide as many countries as possible with the necessary sensors; earlier this year, it even shipped a copy of the analytical software to the Soviet Union. The protocol for the experiment, which was hammered out in Geneva last summer, stipulates that participants must attempt to record 52 different seismic measures for any event. The data are then transmitted daily through an existing Telex network originally designed for the international exchange of meteorological data. The result is that detailed seismic readings become available in an unusually short period in three specially designated centers in Washington, Moscow, and Stockholm.

In Washington, both domestic and international data are collated at the $5-million Center for Seismic Studies, created in 1982 by the Defense Advanced Research Projects Agency (DARPA) in order to gather data on Soviet nuclear weapons tests. Signals are received by six sensors, situated on prime geological territory in California, Ontario, South Dakota, Alaska, Texas, and New York. The most modern of these are ingeniously compact and largely self-sufficient, requiring only occasional replenishment of propane fuel to power a thermoelectric generator. The heart is a slender steel column buried 100 meters below the earth's surface, containing two seismometers and equipment capable of transforming the data into digital computer signals. Atop each column is a small satellite antenna for direct broadcast of the results.

As the signals flow into the Seismic Study Center's modern offices in Rosslyn, Virginia, three high-speed VAX computers scan automatically for unusual activity, and display the results on a sophisticated console in an adjacent room. (Although the same computers also store classified data from seismic stations operated in secret by the U.S. Air Force, the National Security Agency has written software that effectively bars disclosure to those without appropriate clearance.) Specially trained analysts sift through the data, fixing the time, location, magnitude, and character of specific events with the aid of extremely detailed geologic and seismic information stored in the computer memory banks.



R. Jeffrey Smith

Seismic data from all over the world can be rapidly displayed on these screens at the Center for Seismic Studies, according to Ralph Alewine, director of DARPA's geophysical sciences branch (shown in photo).

A seismic event in the Soviet Union, for example, is triangulated and then contrasted with relevant historical information. An explosion may be distinguished partly by the richness of the high-frequency energy it creates, partly by the shallow depth of its starting point, and partly by a characteristic regional expansion of the earth's surface. Errors are uncovered through vigorous cross-checking with data distributed by the

The Allure of Nuclear Testing

On 19 July 1982, at a meeting of the National Security Council, President Reagan formally decided to end U.S. participation in international efforts to ban all nuclear tests. In so doing, he eschewed a foreign policy goal of five previous administrations without immediately providing a clear explanation. News of the decision came not in a presidential statement or address but in a leak to a newspaper. Reporters were subsequently briefed by two Administration officials who insisted that their names not be disclosed. Vaguely, they indicated that talks had been halted largely out of concern that compliance with a test ban could not be adequately verified, and added that no talks would resume until the verification provisions of two existing treaties on nuclear testing, already signed by the United States and Soviet Union, could be renegotiated.

No one doubts that verification of a test ban treaty is a major Administration concern. But the primary reason for the decision to withdraw from the negotiations is clearly a powerful desire to continue testing new warheads. As the Arms Control and Disarmament Agency (ACDA) admitted to Congress in 1983, a test ban "continues to be a long-term U.S. objective, [but] nuclear tests are specifically required for the development, modernization and certification of warheads, the maintenance of stockpile reliability, and the evaluation of nuclear weapons effects."

In a recent interview with *Science*, Thomas Etzold, director of the multilateral affairs bureau of ACDA, expanded on this argument and said that a test ban has been rejected primarily because it would interfere with the development of exotic new weapons, including those needed for Reagan's recent "Star Wars" plan. He also specifically denied that the successful renegotiation of related testing treaties is a precondition for renewing talks about a comprehensive ban.

Etzold is the official with direct responsibility for the Administration's test ban policy, because ACDA fields the U.S. delegation to the Conference on Disarmament in Geneva. A former history professor at the Naval War College and Miami University, he came to the agency last May from the Center for Naval Warfare Studies, where he was involved in nuclear weapons planning and war gaming. He argues first that a potential benefit of a test ban—the barrier it might erect to the acquisition of a nuclear weapon by a Third World country—has been vastly overstated. "Frankly," he says, "it amazes me that 40 years after the first explosion, people still imagine that you need to conduct a test to have a nuclear weapon. Testing is simply not the crucial component of weapons development anymore." Treaty advocates argue, however, that if the bomb's intended use is political, not military, then a test ban might limit its attractiveness by denying the builders any chance to demonstrate their skill, short of actual combat.

Drawing a distinction between the initial development of nuclear weapons and their later refinement, Etzold argues next that testing is essential to modernization, and that a test ban is therefore not in U.S. interests. "When you think about the things that would make it possible for you to have fewer warheads and still meet your military needs under different scenarios, you think of things like . . . better control of how and where these things detonate . . . different combinations of blast and radiation effects, creating sustained instead of short-term effects, and so on. The problem we face now is that a great number of our friends as well as our adversaries would like to have a test ban of the sort that would preclude modernization. They think that qualitative improvements in weapons means that the arms race gets more acute. But they're missing a fundamental point here: that modernization is a way to get to lower numbers [of weapons] and that a reduction in numbers permits us to contemplate the transition from primary reliance on offensive weapons to primary reliance on defensive weapons." Modern warheads are generally more efficient than older designs, so fewer are needed to accomplish the desired effect, Etzold explains.

Modern warheads also generally use less fissile material, he says. "If people care about how much money gets spent on defense, they ought to care about this. If they care about how big the nuclear waste management problem is, they ought to care about this. If they are concerned about the cost of refurbishing a weapons system due to the decay of radioactive elements, they ought to care about this." In addition, he adds, modern warheads typically have lower yields, because they are more apt to hit their targets and therefore require less explosive force. Without testing, he concludes, the United States would be stuck with "large but inefficient inventories, dirty bombs, expensive warheads . . . [and] longer lasting, more widespread environmental effects in the event of nuclear employment." Treaty advocates such as Sidney Drell, codirector of Stanford's Center for International Security and Arms Control, disagrees. They argue instead that adequate safety and efficiency improvements have already been made, that the Soviets are presumably behind in warhead yield-to-weight ratios, and that a test ban could freeze in place an existing U.S. advantage.

Finally, Etzold argues that test ban verification problems are indeed serious. "There's a hell of an argument over whether or not a little bit of cheating on low yield tests is militarily significant, whether it should matter to us. My view is that it would. And we are not at a point where such a test regime could be confidently monitored." But even if the verification problems are resolved, he adds, "we still have to reach agreement on what it is we're trying to arrive at. By this I mean there's a lot of confusion over whether some total universal ban is necessary or whether you really only want to keep this down to some low yields. I think we should [only] have a regulated testing regime, because if you want to get this problem under control, if you want to seek lower and lower yields, the way you do this is not by quitting all testing."

Asked what yield would be acceptable as an upper boundary for U.S. nuclear tests, Etzold demurs. "I can't give you a number. All I can say is that there is one hell of a debate going on. I wouldn't rule out the possibility that some people think 150 kilotons is too low." One-hundred fifty kilotons is the limit presently imposed by the Threshold Test Ban Treaty, which was signed by President Ford but never submitted for Senate ratification. Despite the differences in U.S. and Soviet views on nuclear testing limitations, Etzold hopes that the United States and the Soviet Union "will be well along in the direction of an agreement" by the end of the decade.—**R.J.S.**

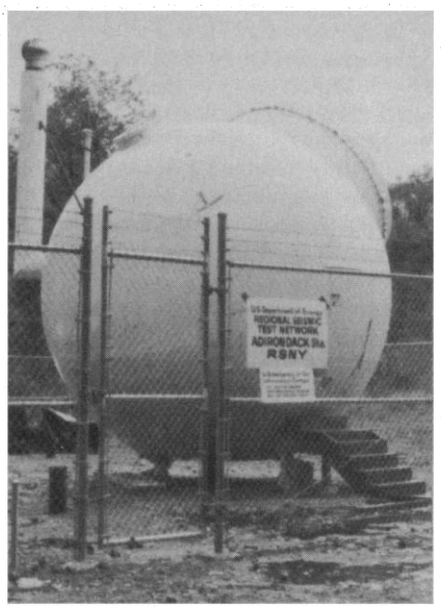
two other centers (a fourth center is planned for Melbourne). "In wide use, systems capable of analysis such as this will really help us to understand the patterns of earth tectonics," says Ralph Alewine, director of DARPA's geophysical sciences branch and one of the experiment's primary organizers.

He cautions, however, that even though the structure of the system being tested is identical to that envisioned for a test ban treaty, the United States would prefer under a real agreement to exchange more detailed information, such as computerized replicas of the seismic waveforms themselves, and to incorporate more modern sensors and communications equipment in the international network.

A relative lack of interest and funds on both sides combined to limit the sophistication of the experiment, according to Charles Archambeau, a professor of geophysics at the University of Colorado who is a visiting scholar at DARPA's center this year. "The exercise is actually rather primitive, when you compare it with what we would really like to do," he says. "These people have knocked themselves out, but it isn't as if our government has said, 'Let's go full bore and demonstrate our interest in a comprehensive test ban.' In fact, the government is not interested in such a ban, and it shows." He claims that the center is terribly understaffed and that related seismic research is seriously underfunded. "It's hard to extract money for this effort from ongoing defense programs," he says.

Ironically, DARPA's expenditures on geophysics research have decreased by $1.7 million in the 2 years since the Reagan Administration formally withdrew from the comprehensive test ban negotiations, citing the need to improve verification. Elsewhere, there have been sharper cuts. The Arms Control and Disarmament Agency (ACDA), for example, today spends one-tenth of the funds on nuclear test ban research that it did in 1979, during the negotiations.

Then, both sides agreed on a system of verification that would include not only the mechanism presently being tested, but also a system whereby the United States could place its own seismic sensors on Soviet soil, and the Soviets could do the same on U.S. territory. Both sides also agreed to allow on-site inspections to investigate suspected weapons detonations. Since the talks adjourned, Alewine says, the United States has substantially improved the technology on which these verification systems will depend. It has honed its techniques for discriminating between earthquakes and explosions. And it has developed dramatic new evidence that even surreptitious, low-yield explosions—perhaps as low as a kiloton or so—may be detected at a considerable distance.



A seismic sensor in the Adirondacks

The bubble contains a satellite antenna for direct transmission of underground signals.

According to Alewine, the new evidence comes from Kjeller, Norway, where DARPA and the Royal Norwegian Council for Scientific and Industrial Research are cooperating in a test of extraordinarily sensitive seismic sensors, developed specifically to capture the high-frequency signals created by decoupled nuclear explosions. (A decoupled explosion is one that might occur inside a huge underground cavern, such as a salt mine, which absorbs a good portion of its energy; their threat has long been the bane of treaty verification.) Thus far, the performance of the sensors, situated in a logarithmically spaced array, "is much better than we predicted," Alewine says. "They have picked up some incredibly small signals, and our ability to pinpoint the origin has improved by more than an order of magnitude."

Archambeau is even more enthusiastic, describing the new sensors as "maybe the breakthrough we've been waiting for." Along with Jack Evernden, a seismologist at the U.S. Geological Survey, he believes that placement of 25 of them in the Soviet Union could permit verification of an extremely low test limit. James Hannon, the program manager for seismic monitoring at Lawrence Livermore National Laboratory, says of the two researchers that "they're probably pretty close as far as seismic detection is concerned, but I am not sure about discrimination, and they've not proven that it's possible to find 25 sites with extremely low background noise in the proper distribution for a national monitoring network." After additional reflection, Hannon said that he is uncertain whether even a single low-noise site could be located.

Hannon suggests that teams of researchers conduct a systematic search for the requisite sites in the United States. "It would give us more confidence before we went to the Soviet Union with a proposal," he says. "If you can find these sites, it might indeed be a whole new ball game." He adds that the search could be conducted over 3 years at a cost of $10 million, but that with additional funds it could be completed somewhat sooner. Even Thomas Etzold, a test ban opponent who directs the multilateral affairs bureau at ACDA, agrees that "there is enough here so that we ought to be looking at it seriously."

While great strides have been made by the scientists, little has been accomplished by the politicians. Although some differences remained after the last round of bilateral negotiations—about such topics as the scope of an on-site inspection or the frequency and means of communication with seismic sensors—participants from both countries were optimistic that they could be resolved. Vladimir Shustov, who has followed the negotiations for the Soviet foreign ministry since 1959 and is now a deputy permanent representative to the United Nations in New York, says that "from the Soviet viewpoint, 90 percent was agreed upon with regard to verification." Paul Warnke, who was ACDA's director throughout much of the recent negotiations, says that a final agreement was just around the corner "when political pressures began to force a retreat." He characterizes the U.S. withdrawal from the talks as "a classic example of our unwillingness to take yes for a answer."

Now, in a multilateral forum, the talks have ground to a halt. Members of the Conference on Disarmament departed from the last session in utter disarray, unable to come to a simple agreement about the charter for the test ban working group. A group of 21 nations, led by Mexico, proposed that the group be charged with "the multilateral negotiation of a treaty," while the Socialist countries proposed that the group "carry out practical negotiations with a view to elaborating a treaty." The United States rejected both, and insisted that the group examine "substantive issues . . . with a view to negotiation," a compromise po-

sition that prompted considerable grumbling from diehard U.S. test ban opponents. No single view has yet prevailed, and the Conference, which operates by consensus, remains immobilized.

Some verification experts, such as Milo Nordyke at Livermore, are pessimistic that the remaining U.S.–Soviet differences may be easily resolved. The Soviets may not agree to search for 25 extremely quiet seismic sensor sites, he says. They might insist on a total test ban, not merely a limit of 1 or 2 kilotons. They might also oppose an indefinite moratorium on peaceful explosions. Shustov, of the Soviet Union, is vague about potential compromises on these topics, indicating only that "if the Western side were ready to finalize bilateral negotiations, we would be ready to go along." Actually, he says, "in this venture, we are ready to have bilateral, trilateral, or multilateral exchanges. All the talks about the complexity of verification are artificial ones. Our scientists are convinced that it is possible to verify a [comprehensive test ban], and there are no insurmountable difficulties about this."

He suggests that the Soviet Union would be willing to renew the negotiations even if Reagan declines to seek Senate ratification of the related Threshold Test Ban Treaty and the Peaceful Nuclear Explosions Treaty. "In my position it is difficult to give you a direct answer," he told *Science* recently. "But two things I can tell you very definitely. First, we would like to use all means for reaching an agreement on a comprehensive test ban. If there were sound proposals on the other side . . . and if they appeared to facilitate an agreement, I think we would view them positively. Second, we consider the ratification of what is already agreed upon to be useful." But he hints that the Soviet Union will oppose further activity by the Conference on Disarmament's scientific group if negotiations do not occur soon. "If the scientific discussion and experiment are used as a substitute for negotiation and agreement, then certainly this situation will be unacceptable," he says.

Clearly, the Soviet Union's commitment to a treaty will be measured in part by its performance in the ongoing experiment. Alewine is not encouraged by the fact that data are being sent by only one Soviet station, and that it somehow failed to pick up seismic signals generated by two Soviet nuclear explosions in late October. But a final assessment of their participation must await the next international meeting of the scientific group in March.

In the meantime, the test ban issue will probably attract renewed political attention. On the last day of the 98th Congress, Representative Dante Fascell (D–Fla.), the House Foreign Affairs Committee chairman, excoriated the Reagan Administration for withdrawing from the negotiations and announced that he intends to conduct a series of hearings on the test ban next spring. Representatives of nuclear freeze groups have also stated that a test ban will be at the top of their agenda next year.

Since the termination of formal negotiations, virtually the only activity in this area has been scientific, and most of the participants believe that their efforts have borne fruit. Hans Israelson, the delegate from Sweden to the Conference on Disarmament's Ad Hoc Group of Scientific Experts, says that treaty verification is no longer an indecipherable problem. "It is a political issue," he says. "It hangs on whether you'd like to have the opportunity to test." Only when both sides agree to forgo this opportunity will a treaty finally be reached.—**R. JEFFREY SMITH**

EPA Scraps Radionuclide Regulations

A staff proposal to limit airborne emissions of radionuclides will not be implemented; the decision is being challenged in court

The Environmental Protection Agency (EPA) recently decided to withdraw a staff proposal to regulate airborne radioactive emissions because, in its opinion, the health risks are small. Agency officials admit that the decision represents a departure from past policy regarding the regulation of public health risks, a change that has provoked unusually harsh criticism from environmental groups. The groups assert that the decision undermines the Clean Air Act and that people who live in sparsely populated areas and are exposed to high risks will not be protected. The Environmental Defense Fund has already filed a lawsuit to challenge the agency's decision.

Radionuclides are radioactive particles or gases emitted from a variety of sources, including processing plants that convert phosphate rock into elemental phosphorus, nuclear weapons plants, nuclear power plants, and related research facilities. Almost 5 years ago, EPA classified radionuclides as hazardous air pollutants and, last year, under court order, the agency proposed a set of regulations that would have required tighter restrictions on emissions. (At the same time, EPA proposed not to regulate radionuclides emitted by coal-fired boilers, plants that process phosphorus into fertilizer, and low-energy accelerators.)

Now EPA administrator William Ruckelshaus has overturned his staff's recommendation. Environmental groups argue that the decision fails to protect people who live in remote areas but are at high risk. Of particular concern are two plants in Idaho where 3000 people live in the surrounding area.

According to an agency analysis, individuals currently living near elemental phosphorus plants have an increased risk of dying from cancer of 1 in 1000. The agency proposal would have reduced the risk by three orders of magnitude, to 4 in 100,000. In the past, the agency has regulated hazards when the risk of cancer has been 1 in 1,000,000. The agency analysis says that the increased risk translates into only one case every 17 years.

An agency statement says that the "driving factors" in the decision not to regulate include "the high costs of controls versus public health benefits [and], the low aggregate risks . . . ." EPA staff estimates that the capital costs of instituting more pollution controls for radionuclides would have totaled $11 million.

The environmental groups take issue with this approach for two reasons. EPA should base its decision solely on the risk to individuals highly exposed rather than factoring in risk to the overall population, they argue. "Exposed people in sparsely populated areas deserve protection just as much as those living in big cities," says David Doniger, senior attorney at the Natural Resources Defense Council. "Protection you get from EPA