MONITORING RESEARCH IN THE CONTEXT OF CTBT NEGOTIATIONS AND NETWORKS

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ABSTRACT

Since the last Phillips Laboratory conference there has been substantial progress at the Geneva Negotiations in the United Nations Conference on Disarmament on the subject of which types of detecting networks will be implemented as part of an international monitoring system (IMS), used to monitor a CTBT.

At the present time the United States is supporting the deployment of 4 networks, seismic, radionuclide, hydroacoustic, and infrasonic. In addition the US is supporting a strong on-site inspection regime, mandatory baseline notifications of the locations and blasting practices of mines which detonate explosions above some yield, and voluntary transparency measures such as calibration experiments and mine monitoring.

In this paper I will first briefly discuss the nature of these networks and practices, and discuss how they fit together to help the international community to deny an evader an opportunity to test. I then plan to step back and brieflydiscuss how the geophysical research community in the US can make a contribution to the CTBT.

Keywords: networks, monitoring, event detection, characterization

SEISMIC NETWORK

The seismic network, like the radionuclide network, the hydroacoustic network, and the infrasound network are described in the United Nations Conference on Disarmament Working Paper CD/NTB/WP.224 of 16 March 1995. The network comprises approximately 50 stations of which approximately 30 are seismic arrays. These stations are termed the "primary seismic network" and are to transmit their data continuously to an international data center (IDC). At the moment Vienna is the leading candidate for the location of the center. At the IDC the data will be used to produce a seismic bulletin in less than 2 days.

In addition to the primary network there is to be an auxiliary network of 100-150 3-component stations. The stations in the auxiliary network which are near the preliminary event location will be dialed up by the IDC at some point in the bulletin preparation and used to refine the bulletin. Data from these stations can be used to confirm the reality of the event, to improve the event location, and to supply additional data so that event discrimination can be performed.

The IDC-created bulletins and the seismic data recovered by the IDC will be available to National Data Centers (NDCs). (Not only the seismic data will be available by this route but also the data from the other networks and data sources.) Each nation which signs the treaty, if it wants the data, will set up an NDC; however, an NDC could range from a mailbox which receives monthly bulletins to an NDC which receives all the raw data and intermediate and final computed results of the IDC over a satellite link between the IDC and NDC. The US NDC at AFTAC is planned to be such an NDC.

DATA COLLECTION AND DISTRIBUTION

The current US concept of data collection and distribution of all the network's data revolves around a constellation of 3 geostationary satellites on which the international organization owns transponders. There are also to be 3 dedicated ground relay stations in the 3 regions of overlap of the satellite's footprints. The uplink antennas can be inexpensive and could be located at each station or perhaps at the NDC where a country's data are concentrated before transmission.

After uplink the data are subsequently relayed so that each satellite and relay station has available all the data. At this point it is clear that the IDC could be located at or near any of the relay stations; Vienna would be a suitable location. The relay stations could be at secure locations, perhaps as one example at an Austrian military base near Vienna with an optical fiber link to the IDC, so that the overall system would be less vulnerable to sabotage. The system will function without interruption if the IDC and any one of the 3 ground stations is destroyed, and, should a satellite malfunction it is possible to quickly substitute an alternate.

The data can be broadcast by the satellites, so that, with a relatively expensive receiving antenna and a small back-uplink for error control, any location could be the site of an alternate IDC. Or, since the US NDC plans to acquire all the data, it may acquire the data directly from the satellite, removing the risk that a disruption at the central point of failure potentially represented by the IDC would prevent access to all data.

After a few $M up-front costs, the total yearly costs to the international organization for data gathering would be less than $1M.

Each NDC will be responsible for distributing data to the citizens of its country; it may be that the treaty will permit an NDC to distribute the data to whomever it pleases. It is currently envisioned that the USNDC will use an interface similar to the World-Wide-Web page currently operating at the IDC to provide data access to all data received from the IDC. Data from other stations, and continuous data from the auxiliary stations, could only be obtained from other sources, for example from the IRIS DMC.

HYDROACOUSTIC NETWORK

There are several plans for hydroacoustic networks before the CD, one currently of interest to the US is one in which there are 6 single hydrophone stations with cabled connections to land The coverage of the six stations is strongly biased toward the Southern Hemisphere in part for the reason that testing in the oceans in the Northern Hemisphere is far less favorable to the evader due to the high concentration of inhabited land masses, ship traffic, and air-line traffic, as well as the proposed high density of radionuclide sensors.

The principal daily use of the hydroacoustic network is for purposes of simple discrimination of those oceanic earthquakes detected by the seismic system and which are clearly located away from land. The arrival time of the water-borne signal is predicted and if the signal does not have the high-frequency characteristics of an underwater explosion, then it is concluded that the event must have been an earthquake. A record at a single hydrophone is sufficient for this discrimination.

A lower-atmosphere explosion may not be detected by the seismic system, but may be detected by the hydroacoustic system. However, we do not yet know what the spectral or time domain characteristics of such a hydroacoustic signal will be so that we do not know if simple examination of the signal can reveal the type of source. The amplitudes of such a signal can be similar to those of various industrial explosions in the oceans, and since the single hydrophones provide no directional information, using such a sparse network to create a hydroacoustic bulletin with a low false alarm rate could be a daunting task. However, as we shall see, in conjunction with an infrasound system, the hydroacoustic system can greatly improve the locations of those events which it does detect.

INFRASOUND NETWORK

The Geneva Technical Experts have suggested a 60 or 70 station worldwide network of 4 element infrasonic arrays with spacings of 1-3 km. In theory this network can reliably detect a 1 kt atmospheric burst anywhere in the world. The US is currently interested in the possibilities of a much less expensive network, concentrated in the Southern Hemisphere for the same reasons discussed above for the hydroacoustic network.

This network would be comprised of 12 16-element stations in the Southern Hemisphere, and this network has a threshold below 1 kt in the Southern Hemisphere and less than 3 kt in the Northern Hemisphere.

It is thought that the false alarm rate for an infrasound network is quite low. Although storms do create acoustic waves, the resulting waves are continuous, not transient. Volcanos emit infrasound signals rarely, but it is usually clear that a volcano is the source. On the occasions when earthquakes or quarry blasts emit signals, the seismic source will also be located by the system and the source can be accounted for in that way.

The occasional multikiloton conventional blast in the atmosphere can be expected to be in inhabited areas, and to be pre-announced or to be the subject of extensive newspaper coverage.

The most serious potential false alarm problem is probably the signals generated by meteorites; these sources are also known as bolides. ReVelle (1995) estimates, using infrasound and satellite data, that these sources generate explosion-like signals worldwide at a rate of approximately 1/yr at 10 kt, and 10/year at 1 kt. On the occasion of detection of such a signal emanating from most locations, a plausible response would be closer inspection of downwind radionuclide sensors and the querying of ships, planes, and human habitations in the area. In locations, such as the oceanic Southern Hemisphere, where such resources are few, in addition to more closely inspecting the downwind radionuclide stations, there may be good reason to dispatch a plane to the general area to gather additional radionuclide data.

One would also want to closely inspect the hydroacoustic data and, if a signal is detected on the hydroacoustic sensors, to instruct the plane to drop a calibration explosive source into the SOFAR channel. This should enable absolute location of the original hydroacoustic source to within a few kilometers which can further direct the plane's search in real time. Detection by 3 hydrophones should pinpoint the location, and detection by two hydrophones should greatly reduce the area of the infrasound confidence ellipse.

If even a single sighting from a satellite were available, it would be very likely conclusively identify the event as non-nuclear, thus reducing infrasound false alarms to near-zero. It is to be expected that all such bolides will be detected since there is little possibility that a bolide would be hidden by clouds. Any such events not shown to be a bolide would presumptively be a kiloton-level atmospheric explosion, if not conventional then perhaps a nuclear explosion under heavy cloud cover or with a signal distorted by other means.

RADIONUCLIDE DETECTION NETWORK

The US has proposed a network of approximately 100 radionuclide detectors for the detection of radioactive particles, and 100 co-located radioactive xenon detectors for the detection of the xenon created by nuclear explosions.

The principal use of the particle detectors would be for detecting atmospheric explosions; the xenon detectors are aimed at the evasive underground test. It is thought that a decoupled test would be especially likely to leak, due to the absence of the explosion-created stress cage which serves to constrain leakage in fully tamped shots. Thus the xenon detectors are especially important in a comprehensive system.

Both systems, as planned, would be substantial advances in the state of the art of automation; both would produce and communicate data while unattended for many months.

BASELINE DATA, CALIBRATION AND MINE MONITORING

The US has also considered requiring that mines which plan to detonate explosives above a yield limit of several tens of tons reveal after the treaty enters into force the locations of these mines and the typical types of explosive practices at that mine. These mines would also be required to reveal the details of three of the largest shots in the year after entry into force; the idea here is, of course that these shots will be detected by the international seismic system and can serve as a calibration.

The US also wants to encourage voluntary calibration and mine monitoring on a bilateral basis in order to resolve questions which may arise about ambiguous results.

SUMMARY

The systems outlined above provide the infrastructure required to close the door, at some threshold, on the possibility of evasive testing underground, in the ocean and in the atmosphere.

However, in each field there are important research requirements. Just to cite a few, in seismic there is the challenge of discriminating poor S/N events at regional distances. In hydroacoustic there is the question of the hydroacoustic coupling and the waveform appearance of atmospheric explosions. In infrasound there is the development of new array designs and of new automatic detection algorithms. In radionuclide there is the excitement to come from an unprecedented look at world-wide background data, who knows what natural processes may be revealed?

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