Major progress over the last decade: The International Monitoring System nears completion

by Denise Brettschneider

ONE OF THE MOST REMOTE ISLANDS IN THE WORLD, TRISTAN DA CUNHA IN THE SOUTH ATLANTIC OCEAN: HOME TO THREE IMS STATIONS.

Universal condemnation of the nuclear tests conducted by India and Pakistan in May 1998 clearly reflected the broad international support for ending nuclear testing. The tests not only broke the *de facto* moratorium that had been in place since the Comprehensive Nuclear-Test-Ban Treaty (CTBT) opened for signature in 1996 but also led to fears of nuclear conflict in the region.

At that time, only a small number of the 337 monitoring facilities foreseen in the CTBT, which bans all nuclear testing on Earth, were in place. Yet the Treaty's International Data Centre (IDC) in Vienna was already receiving data from a number of primary seismic stations at the end of May 1998 when Pakistan exploded a series of underground nuclear devices in reponse to India's nuclear tests two weeks earlier.

Over the next few years, the verification capabilities of the CTBT's International Monitoring System (IMS) improved considerably as the network expanded around the globe. Its facilities are located in 89 countries – some in remote areas such as Antarctica, Tristan da Cunha in the South Atlantic and Siberia – in order to provide complete global coverage and ensure that no nuclear test goes undetected.

The 2002 report *Technical Issues Related to the Comprehensive Nuclear Test Ban Treaty* by the U.S. National Academy of Sciences (NAS) stated: "Underground nuclear explosions can be reliably detected and can be identified as explosions, using IMS data down to a yield of 0.1 kilotons (100 tons) in hard rock if conducted anywhere in Europe, Asia, North Africa and North America."

> The IMS uses seismic, hydroacoustic, infrasound and radionuclide technologies to monitor underground, the oceans and the atmosphere for any sign of a nuclear explosion.

DPRK announced nuclear test detected by many IMS stations

When the Democratic People's Republic of Korea (DPRK) declared that it had conducted a nuclear test on 9 October 2006, the IMS was able to demonstrate the extent to which its detection capabilities had progressed. The event, which had an estimated yield of well below one kiloton, was promptly detected and identified by 22 of the IMS's seismic stations. The seismic findings also allowed for the identification of a possible inspection area of less than 1,000 square kilometres, which is the maximum area allowed for an on-site inspection (OSI) under the Treaty. Within two hours, the Member States of the Preparatory Commission for the Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO) received the first automatic analysis of the data, containing preliminary information on the time, location and magnitude of the event.

Radionuclide station registers high levels of radioactive noble gas

Two weeks later, the IMS's radionuclide noble gas station at Yellowknife, Canada – over 7,000 kilometres away from the DPRK - registered elevated levels of the noble gas, xenon-133, in the atmosphere. Since radioactive noble gases are a by-product of a nuclear explosion, noble gas monitoring enables verification of any violation of the CTBT.

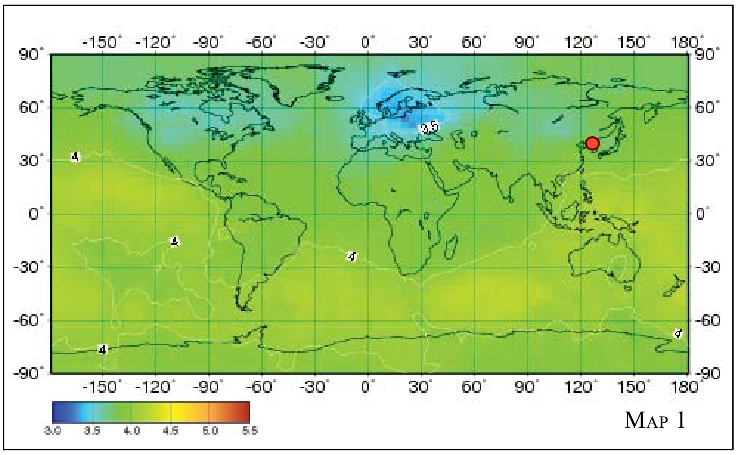
In order to locate the perpetrator of the announced explosion, atmospheric transport models were used to backtrack the dispersion of the gas. It was found to be consistent with a release from the location and time of the DPRK event, proving the ability of the IMS to detect such events from a great distance.

Although only 180 or 60 percent of the IMS stations had been installed in October 2006, the system exceeded the expectations of the Treaty negotiators in terms of sensitivity, reliability, precision, location and characterization.

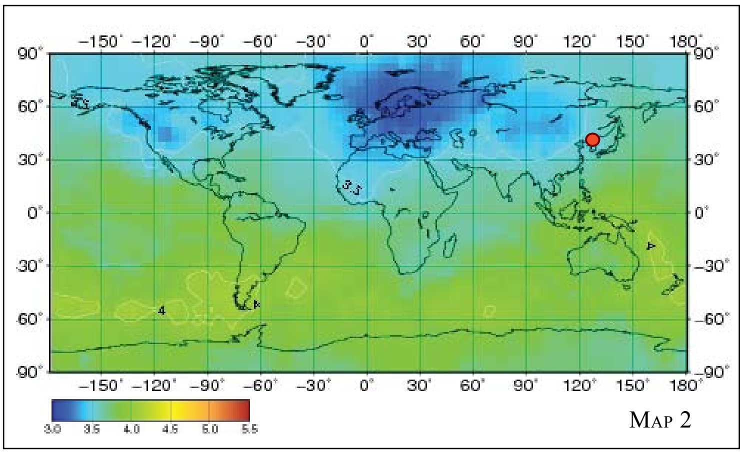
Extensive network now spans the globe for evidence of nuclear tests

There have been considerable advances in the sciences and technologies relevant to the detection and location of nuclear tests over the last decade, with a corresponding increase in the build-up of IMS facilities. Noble gas technology, which was at an experimental stage in the 1990s, has significantly increased the ability to detect and identify nuclear explosions. The different technologies, such as the radionuclide/noble gas and seismic networks, complement each other to an extent not foreseen in the 1990s by increasing verification capabilities.

By the beginning of 2009, 264 stations and radionuclide laboratories had already been installed, creating a network that is far more extensive and sensitive than anything one country could establish alone. 246 of these monitoring facilities have been certified as meeting the CTBTO's stringent technical requirements and operational performance. Certified stations transmit data automatically and continuously to the IDC in Vienna, except for auxiliary stations, which send data upon request. In total, almost 90 percent of the IMS facilities were certified, operational or under construction by January 2009.



Map 1



Map 2

Map 1 shows the average detection capability of the IMS primary seismic network on 09 October 2006. Magnitude 4 (light green to green) represents an explosion yield of roughly 1 kiloton. The capability of the system was clearly better than this in many parts of the world.
Map 2 shows the situation on 14 March 2009. The average detection capability of the system has been further improved by the incorporation of data from primary seismic stations added to the IMS network since the DPRK test, depicted by red dot.
The colour scale below the maps shows the detection threshold, calibrated to be consistent with the Reviewed Event Bulletin (REB) processing parameters.

Verification highlight

Certifications have reached over 80 percent in several regions

In North America progress has been particularly encouraging, with certifications standing at 90 percent. In Latin America, 83 percent of the IMS stations have been certified, 80 percent in Australia, and 70 percent in Africa. Most stations in Europe have been certified, as have 50 percent of the planned stations for the Russian Federation, many of them over the last year. Another fifteen stations have either been installed in the Russian Federation or are being tested and evaluated for certification, with the installation of four of these stations having been completed between July and September 2008.

Increase in noble gas capabilities

At the time of the announced nuclear test in the DPRK, only ten out of the planned 40 stations with noble gas measuring technology were operating in test-mode. By January 2009, the noble gas capabilities of the radionuclide network had doubled. By 2013, all noble gas systems should be in place.

Major advances in data transmission

With the recent initial data provision by China, stations hosted by all five nuclear weapon States now transmit data to the IDC in Vienna. The volume of data has tripled since 2004 and a new global communications infrastructure for relaying the data has also been installed. Data analysis has also improved significantly through more sophisticated computers and software.

On-site inspections: a powerful deterrent to would-be Treaty violators

Two years after the IMS's capabilities were tested in October 2006, the

INSIDE AN IN-GROUND VAULT AT AN AS104 ELEMENT, ESKDALEMUIR, SCOTLAND.

Integrated Field Exercise in 2008 (IFE08) provided yet further proof of the CTBT's verifiability. The exercise demonstrated that the final element of the CTBT's verification regime, on-site inspections, promises to act as a strong and reliable deterrent to potential violators once the Treaty enters into force (*see page 21 for more information about the IFE08*).

Seismic highlights

By the beginning of 2009, 80 percent of the network of 50 primary seismic and 75 percent of the planned 120 auxiliary stations had been certified - as many as 41 of them since October 2006. Another 27 seismic stations have already been installed or are under construction, including a primary seismic station in Turkmenistan in Central Asia.

Long-term quality monitoring is crucial

One of the most recent certifications was of primary seismic station PS37 at Ussuriysk in the Russian Far East, with North Korea to the South and China to the West, on 28 November 2008. As has been the case for many IMS stations, PS37 has been built from scratch. This involved an extensive site survey and the

Seismic Monitoring

The seismic network of primary and auxiliary stations monitors the Earth for underground explosions. The stations are equipped with seismic sensors, which measure waves generated by seismic events such as earthquakes or explosions. Measurements recorded at the stations help to identify the location, magnitude and nature of a seismic event.

installation of the equipment – much of which was imported from Canada and Austria – a lengthy process that required intensive preparation by the CTBTO. After certification, long-term quality monitoring ensures that high data quality standards and availability are maintained and that station performance is optimal.

The auxiliary seismic network's most recent certification

Auxiliary seismic station AS104 at Eskdalemuir in southern Scotland was certified on 17 February 2009. As well as detecting local and regional seismic disturbances, AS104 has a global monitoring capacity: it was designed to optimize the detection of seismic waves some 1000 km from the source. On 18 August 2000, the station detected the seismic waves generated by an explosion onboard the Russian nuclear submarine, *Kursk*, in the Barents Sea.

In the event of a catastrophic failure with one of the primary seismic stations in Europe, AS104 would temporarily transfer from its auxiliary role to act as a primary seismic station.

Hydroacoustic highlights

Ten of the eleven hydroacoustic stations have already been certified. All of these certifications have taken place since the late 1990s.

The ocean is one of the most inhospitable environments to work in and the station equipment must be of exceptional quality: it needs to withstand the huge pressure encountered in deep water, destructive waves near shore, strong currents and the sharp edges of undersea volcanic terrain, in addition to freezing temperatures and the saline corrosiveness of ocean waters. The underwater equipment is designed with longevity in mind: stations should last for up to 25 years.

WAKE ISLAND, NORTH PACIFIC OCEAN, HOST TO HYDROACOUSTIC STATION HA11 AND RADIONUCLIDE STATION RN77.

Hydroacoustic station at Wake Island, United States

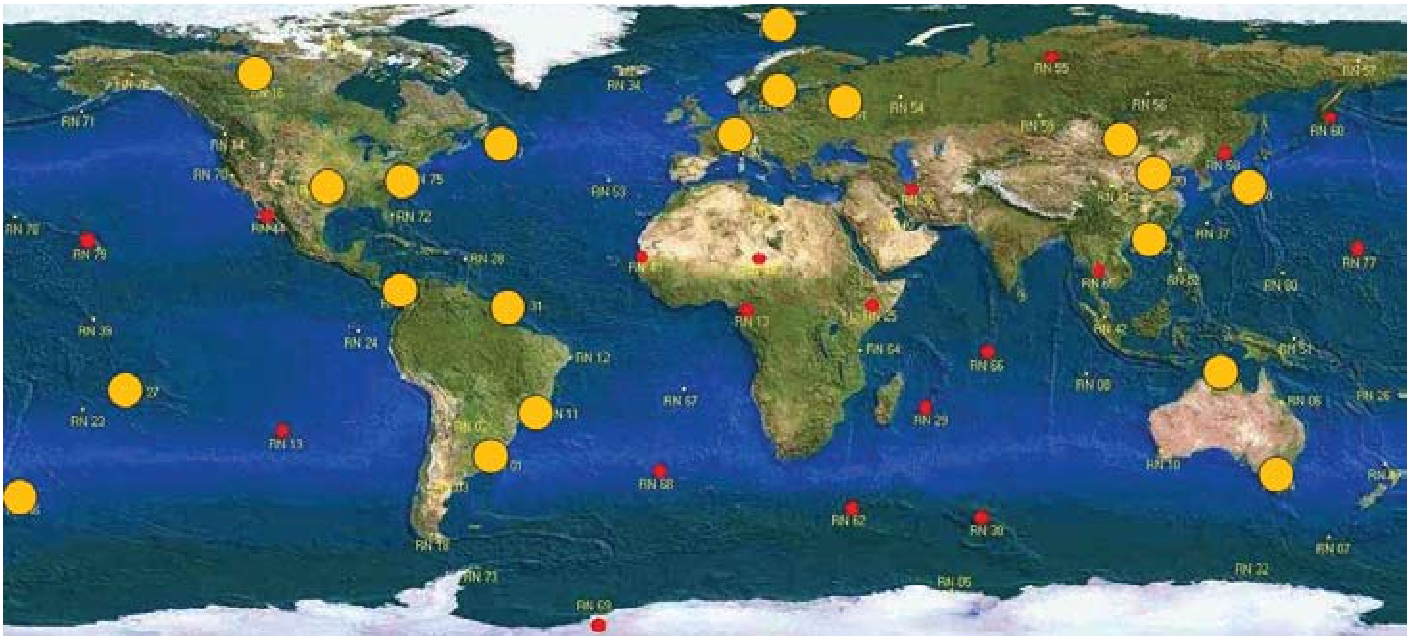
When hydroacoustic station HA11 at Wake Island became the tenth station to be certified on 8 June 2007, it represented a milestone for the CTBTO: the network's capabilities have been enhanced to such an extent that the chances of an underwater nuclear explosion going unnoticed have been virtually eliminated.

Located in the middle of the North Pacific Ocean, Wake Island is administered by the United States. HA11's remoteness and specialized requirements all contributed to make it the most expensive station ever constructed by the CTBTO at a cost of about US$ 18 million. The US Air Force Technical Applications Center (AFTAC) has provided both financial support and technical expertise.

Hydroacoustic Monitoring

The IMS hydroacoustic network is comprised of hydrophone and T-phase (seismic) stations. These stations monitor the world's oceans for evidence of nuclear tests by measuring changes in water pressure caused by sound waves emanating from underwater explosions. Few stations are required because water is a highly efficient medium for the transmission of sound.

Verification highlight



NOBLE GAS NETWORK. YELLOW CIRCLES DEPICT THE 20 RADIONUCLIDE STATIONS WITH NOBLE GAS EQUIPMENT INSTALLED AS OF MARCH 2009. THE RED DOTS REPRESENT THE REMAINING STATIONS THAT ARE YET TO BE EQUIPPED WITH NOBLE GAS CAPABILITIES. IN OCTOBER 2006 ONLY 10 OF THE PLANNED 40 STATIONS WERE OPERATING IN TEST-MODE.

Infrasound highlights

Since May 1998, 41 infrasound stations in 25 countries have been certified, meaning that almost 70 percent of the network's stations already comply with the CTBT's stringent requirements. Another five stations are currently under construction, bringing the target of 60 stations around the world even closer. None of these stations were in existence when the CTBT opened for signature.

The global distribution pattern of infrasound stations has resulted in a series of regional networks across North America, Latin America, Europe, Africa and Australia.

Six infrasound stations have been certified since October 2006. The most recent certifications were at IS45 at Ussuriysk in the Russian Federation, and at IS51 in Bermuda (British Overseas Territory), which both took place on 18 December 2008.

Infrasound Monitoring

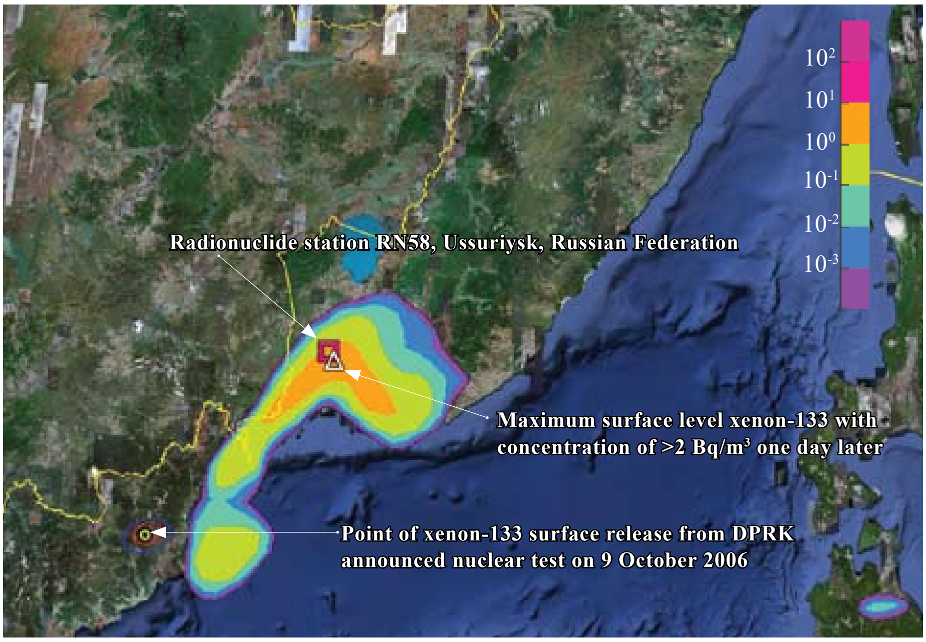
Infrasound is inaudible sound with frequencies below the human hearing threshold of 20 Hz. Sources of infrasound include nuclear tests, chemical explosions, sonic booms, severe weather, meteors, earthquakes, and volcanoes. Infrasound stations use infrasonic sensors to measure micropressure changes in the atmosphere generated by the propagation of infrasonic waves, which can be caused by atmospheric nuclear explosions or shallow underground explosions.

Infrasound station in Bermuda

Installing a monitoring station can be a challenging experience, especially in an area that is susceptible to hurricanes, like Bermuda. In order to ensure a constant data flow in the event of a hurricane or tropical storm, the CTBTO is working on emergency plans to prevent major damage to IS51. This will be achieved through the establishment of an additional virtual private network (VPN) link between the Central Recording Facility (CRF) and Vienna. What might constitute a potential danger for the maintenance of IS51, however, makes the station extremely interesting to the scientific community since it might contribute valuable data on hurricanes and tropical storms in the future.

Radionuclide highlights

A total of 55 radionuclide facilities in 26 countries have been certified over the last decade, with 15 of these certifications having



READINGS OF XENON-133 AT RN58 THE DAY AFTER THE DPRK ANNOUNCED TEST WOULD HAVE BEEN AT LEAST 500 TIMES HIGHER THAN THE CONCENTRATIONS ACTUALLY MEASURED AT YELLOWKNIFE, CANADA TWO WEEKS LATER.

PHOTO COURTESY OF ANDREAS BECKER, CTBTO.

taken place since the DPRK test. Five stations were certified in the Russian Federation in 2008, including RN56 in Peleduy in the middle of Siberia and RN60 in Petropavlovsk-Kamchatsky in the Russian Far East. RN60 is equipped with noble gas facilities and is strategically located to monitor the Pacific area. In addition, one radionuclide station was installed in the Russian Federation in 2008 and civil work contracts are underway for two more stations.

China hosts three radionuclide stations, which will transmit data to the IDC upon installation of a link to Vienna. China also contributes to the CTBTO by providing noble gas data to the International Noble Gas Experiment (INGE), which tests the detection and measuring of radionuclide noble gases.

Noble gas systems for Asia and Africa

RN58 at Ussuriysk, Russian Federation, has now been installed with noble gas equipment and would have played a crucial role in October 2006. According to the IDC's refined atmospheric transport calculations, RN58 would have picked up traces of xenon-133 from the DPRK announced test just one day later: readings would have been at least 500 times higher than the concentrations measured at Yellowknife, Canada two weeks later.

Radionuclide station RN13 in Edea, Cameroon, was certified on 30 November 2007 and will be the first IMS radionuclide station in Africa to be equipped with a noble gas detection system. Installation of noble gas equipment at RN13 is scheduled for 2009.

IMS expansion greatly reduces chances of nuclear test going undetected

When the CTBT's verification regime detected the DPRK's test, it added credence to the 2002 study by the U.S. National Academy of Sciences' conclusion that it would be very difficult for States with limited nuclear testing experience to avoid detection by testing weapons of one kiloton or less.

Given the considerable progress that has been achieved over the past decade and the experience gained, there is a very high probability today that States would be able to discover any nuclear test using data generated by the CTBT's verification regime and additional monitoring capabilities available to individual States. As the network of monitoring stations spanning the globe becomes more extensive, the chances of a nuclear test going unnoticed have decreased even further. ■

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Radionuclide Monitoring

By collecting and analyzing the debris of a nuclear explosion, radionuclide technology can provide conclusive evidence that an explosion has been nuclear in nature and is therefore of crucial importance to the entire verification effort. Any potential violator would need to consider that any radioactive gases vented from a clandestine nuclear test would be detected by the IMS.