Independent Commission on the Verifiability of the CTBT

final report

Introduction

The Comprehensive Nuclear Test Ban Treaty (CTBT) bans all nuclear test explosions in the atmosphere, underwater and underground. It provides for the establishment of a verification regime capable of meeting the treaty's verification requirements at entry into force. Opened for signature in 1996, the treaty has not yet entered into force, but the establishment of the verification regime is proceeding.

This report assesses the verifiability of the CTBT—the extent to which compliance with the treaty can be verified. It examines not only the current and future capabilities of the treaty verification regime, but also the additional monitoring capabilities that states parties and others may draw on to assure themselves that the CTBT is being complied with.

The treaty verification regime

The treaty verification regime combines a global monitoring network with modern communications and data management techniques. It also includes consultation and clarification measures, the possibility of on-site inspections, and confidence-building measures. The regime will be managed by a CTBT Organization (CTBTO) in Vienna, Austria. The organisation will comprise a Conference of States Parties, an Executive Council, and a Technical Secretariat headed by a Director-General. A Preparatory Commission (PrepCom) and Provisional Technical Secretariat (PTS) are currently working to establish the regime.

Like all verification regimes, the design of the CTBT regime reflects considerations of political acceptability, technical capability and cost. Also like other regimes, it cannot provide 100 percent certainty that all treaty violations will be detected. Rather, the aim is that there will be a high probability of detecting violations, thereby deterring potential violators.

The International Monitoring System

An International Monitoring System (IMS), comprising 321 certified monitoring stations and 16 radionuclide laboratories located in some 90 countries, is being established. Four types of stations are involved:

- seismological;
- infrasound;
- hydroacoustic; and
- radionuclide.

A primary network of 201 stations will provide continuous data to the system. The other 120 are auxiliary seismic stations, which will supply data only on request. Some of the 321 stations already exist and can be incorporated into the system as they are, while others need to be improved or specially constructed. All stations need to be authenticated and certified by the PTS.

Cooperating National Facilities, employing IMS technologies and built by a state party at its own expense, may be used to supplement the IMS and must be certified in the same way as IMS stations.

The PTS reports that, as of October 2000, 62 percent of the site surveys for the 201 primary stations are complete, 16 percent of the stations are installed and are sending data to the International Data Centre (IDC) in Vienna, and three primary seismic stations have been certified. Of the 120 auxiliary seismic stations, 60 percent essentially meet PTS specifications; the remaining 40 percent will require some significant upgrades. Now that the PTS has experience in establishing them, the number of operational and certified stations will increase substantially over the next couple of years, as long as there is continuing financial support.

Data will be transmitted via a dedicated Global Communications Infrastructure (GCI) to the IDC at the CTBTO. The data will be collected, stored, analysed and transmitted to treaty parties. The PTS has already demonstrated that the IDC can receive and process data and distribute it in a timely manner to states parties. Global satellite coverage for the GCI was established in 1999 with the commissioning of four communications hubs with terrestrial links to Vienna. The IDC headquarters' facilities were completed in 1999 and are being progressively commissioned. Approximately 100 IMS stations are currently contributing data to the IDC. In February 2000, the IDC began distributing test products. At present, 44 states signatories are receiving IMS data and IDC products.

The system is expected to detect with a very high level of confidence—and hence deterrence—a non-evasively conducted explosion of at least one kiloton (kt). Because of the real possibility of detection significantly below this yield, there is also a considerable deterrent effect against clandestine testing below one kt. The IMS is expected to be able to determine the location of such events within 1,000 square kilometres, the maximum area permitted for an on-site inspection.

Seismic network

The global seismic network, which is designed to detect underground nuclear tests, is a key component of the IMS. Although the partially completed system has varying detection and location capabilities at the local, regional and global levels, in some regions the capability is already quite good. In the northern hemisphere, for example, explosions of 100 tons and below have been readily detected and located. Single array stations in central Eurasia are capable of detecting and providing an approximate location for explosions of around 10–25 tons with sufficient signal amplitude either to identify the source or arouse concerns as to the nature of the source. Three 100-ton seismic calibration explosions conducted in Kazakhstan in recent years were detected and located, as was a small explosion of around five tons in the Dead Sea. While it is not expected that the global detection threshold for the completed system will be this low, these examples demonstrate the capabilities of even a partially completed system.

To locate an event with an uncertainty of less than 1,000 square kilometres, it is essential to have the source region calibrated in order to map variations in seismic wave velocity. International co-operative calibration efforts are now taking place under PrepCom auspices. Once a region is calibrated, it has been shown, through simulation and the observation of events with a known location, that it is possible to achieve a location accuracy of better than 1,000 square kilometres for all continents and a good portion of the world's oceans.

The last remaining tunnel at the former Soviet nuclear test site at Semipalatinsk—now in Kazakhstan—is destroyed on 29 July 2000. The explosion helped to calibrate seismometers for the IMS.

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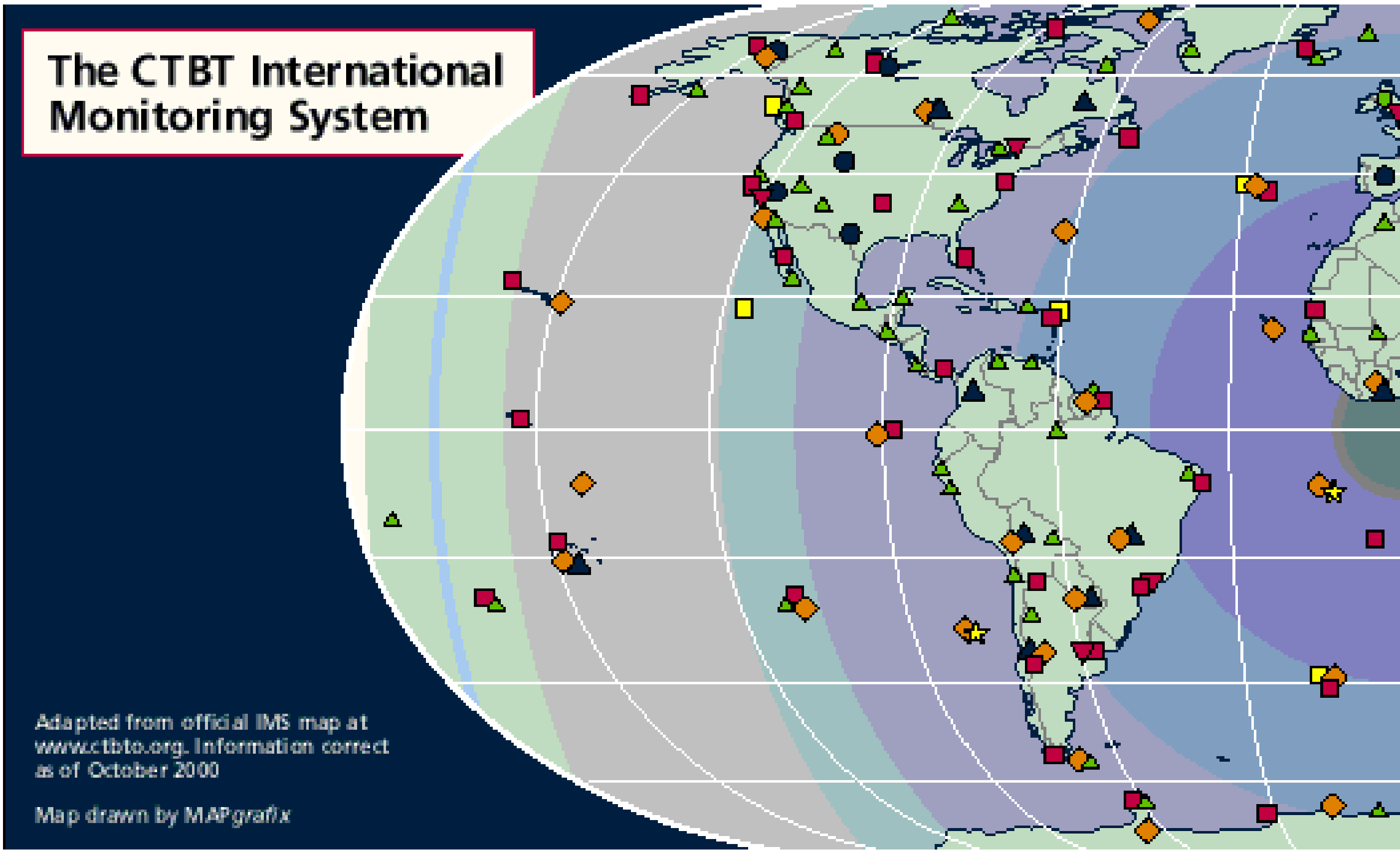
Hydroacoustic network

Explosions in the sea or on small islands are readily detectable by hydrophones tethered in oceans, and by high frequency seismometers (T-phase stations) located near steeply shelving coasts. Establishment of a network of six hydrophone stations and five T-phase stations, which will cover the oceans, has begun. At present three stations are contributing data to the IDC, providing a detection capability for the North Pacific, most of the Indian Ocean and parts of the North Atlantic. Determining the location of underwater explosions is currently only possible in association with data from the IMS seismic network. When all 11 stations are on line, nuclear explosions will be detectable in all oceans. These stations will facilitate discrimination between small sub-oceanic earthquakes and explosions, and, in conjunction with seismic data, enable accurate location of any nuclear explosion in the sea.



The CTBT International Monitoring System

Adapted from official IMS map at www.ctbto.org. Information correct as of October 2000

Map drawn by MAPgrafix

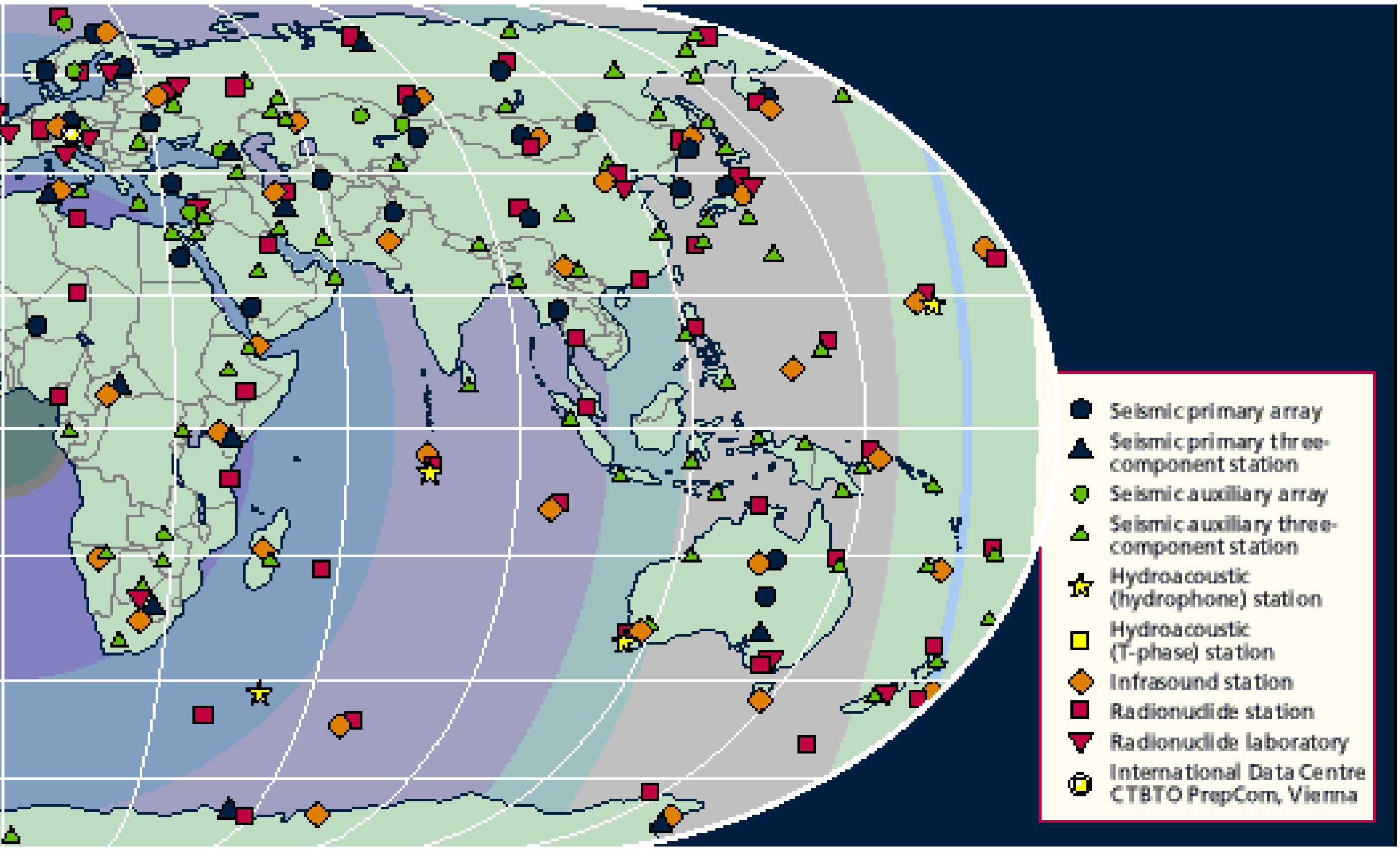
Infrasound network

The infrasound monitoring network of 60 land-based stations aims to detect and locate atmospheric nuclear explosions through the sound waves that they generate. The planned network is not yet complete. Nine stations, 15 percent of the future network, are likely to be operational by the end of 2000, while 29 are expected to be functioning by the end of 2001. The sensitivity and large dynamic range of the sensors allow detection of explosions a few thousand kilometres away. Using such technology, space shuttle launches in Florida have been detected as far away as Canada, and Concorde flights over the Atlantic have been detected in Germany.

Station locations have been selected to give as uniform coverage as possible. The detection and location capabilities of the network have been determined by modelling, based on data derived from past nuclear tests and atmospheric models. The network's detection capability when complete, defined as the minimum detectable explosion yield, is estimated at about one kt overall and less in some areas. The location precision is estimated to be within a radius of 100 km or less. The addition of more sensors to an array will increase the detection range of isolated stations and improve detection at windy sites where background noise is high.

Radionuclide network and laboratories

Eighty radionuclide stations will measure radioactive particulates and noble gases in the atmosphere from atmospheric nuclear tests or underground explosions that vent. Laboratories will analyse samples from these stations. Six particulate stations are installed and sending data to the IDC. Four recently developed noble gas detection systems are being tested alongside each other prior to deployment in 2001. The 16 radionuclide laboratories included in the system already exist, but need to be certified. Once the system is complete, there should be a high probability of detecting globally a one kt nuclear explosion within 14 days. The combination of particulate and noble gas detection will provide a very high probability of identifying an event as nuclear. The sensitivity limit for particulate detection systems is unlikely to improve significantly in the near future. The sensitivity limit for noble gases, however, could be improved by a factor of 10 using enhanced measurement



and gas purification techniques. The system will locate an event within a radius of 750 kilometres by determining the origin of the radioactive cloud. This will improve with research into atmospheric transport modelling—in collaboration with the World Meteorological Organization.

Synergies between IMS technologies

To improve verifiability and ensure a cost-effective IMS, treaty negotiators took full account of the potential for synergies between the four IMS technologies. The three waveform technologies—seismic, hydroacoustic and infrasound—operate synergistically to improve the detection and location of nuclear explosions. These technologies also operate synergistically with the radionuclide network. The detection of radionuclides may be vital in proving that an identified explosion was nuclear.

Consultation and clarification

States parties are encouraged by the treaty to try to resolve compliance issues among themselves or with the assistance of the Technical Secretariat or Executive Council, particularly before requesting an on-site inspection. Parties are obliged to respond to requests for clarification within a specified period, whether direct from a state party or via the Executive Council. The CTBTO Director-General is obliged to provide, on request, the appropriate information held by the Technical Secretariat to assist in resolving a compliance matter.

On-site inspections

When a state party to the CTBT, on the basis of information from the IMS or its own national technical means of verification (NTM), suspects that a nuclear explosion may have been carried out in violation of the treaty, that state may request an on-site inspection (OSI). Before proceeding, such an inspection must be approved by at least 30 of the 51 members of the Executive Council. The state party to be inspected is obliged to accept the OSI.

A well-prepared OSI regime should serve as a deterrent, discouraging any potential violator because of the high probability of exposure. Three elements for the conduct of OSIs are currently in preparation: the Operational Manual; equipment; and training. The purpose of conducting an OSI is to clarify whether a nuclear explosion in violation of the treaty has been carried out. A team of up to 40 inspectors is permitted to inspect an area as large as 1,000 square kilometres. The treaty provides for a balance of rights and responsibilities between the inspection team and the inspected state party. Different techniques are permitted during successive periods of the inspection, including position finding, radioactive measurements, and passive seismic and geophysical techniques. The final step may be the use of specialised drilling equipment to obtain radioactive samples, which may be the equivalent of a 'smoking gun'.

It is envisaged that OSIs will be used only on rare occasions, after other measures in the treaty, such as consultation and clarification, have been tried. A successful OSI is expected to provide significantly better knowledge about the event that triggered the OSI request. The main challenges confronting an OSI are the diverse environments that may be encountered and a lack of co-operation from the inspected state party.

Confidence-building measures

The purpose of confidence-building measures (CBMs) is to help reduce ambiguities and enhance confidence in treaty compliance through an exchange of data and information. While CBMs are not mandatory, states parties are invited to provide details of any activities that could give rise to potentially ambiguous signals detected by the IMS. For example, conventional explosions of 300 tons or greater, such as for mining operations, should be announced in advance, together with details like yield, location and purpose. In some circumstances the Technical Secretariat could be invited to visit the area of an explosion.

States parties are free to institute bilateral or multilateral CBMs outside the treaty framework in order to enhance their confidence in verifiability. Such measures might include: mutual visits to sites of potentially ambiguous conventional explosions; mutual monitoring of closed nuclear test sites; and mutual notification of sub-critical experiments and close-in monitoring of the area in which they are conducted.

Additional verification means

In addition to the verification means established by the treaty, there are many additional resources available to the international community to verify compliance with the CTBT. These may be owned and operated by governments, research institutes, universities, commercial companies and non-governmental organisations. Some of the data from these sources are classified, while the rest are openly available.

Today, tens of thousands of openly accessible scientific and environmental monitoring resources may record evidence of a clandestine nuclear explosion. Rapid advances in data processing technology should permit the integration of these vast and continually evolving sources of global information. Together, these resources provide a strong additional deterrent to any country considering a clandestine nuclear test.

National technical means

The CTBT provides that data obtained by NTM, consistent with international law, may be submitted by any state party during consultation and clarification procedures and (in conjunction with IMS data or alone) as the basis of an OSI request. States also use such systems unilaterally to monitor compliance with the CTBT.

National technical means may include the same types of technologies used by the IMS, as well as other information-gathering techniques. The United States operates the most sophisticated NTM, including satellite sensors (optical, infrared, visible, imagery, gamma ray and x-ray detectors) and an extensive seismic system, the Atomic Energy Detection System (AEDS). Several of the AEDS stations have been selected as IMS stations and are being upgraded to PTS specifications. Russia also operates a Special Monitoring System. Some

Russian, French and British NTM stations, along with those of other countries, have already been incorporated into the IMS.

The main limitation of NTM is that, since states mostly wish to keep their capabilities secret, it is difficult to assess independently their reliability and accuracy. Moreover, because governments operate them, they may serve national interests rather than those of the international community. However, technologically sophisticated states should be able to make a compelling case, using data from their NTM, in the event of a significant violation of the treaty. The capabilities and prevalence of NTM will continue to grow and spread to more countries, further building confidence in the verifiability of the CTBT.

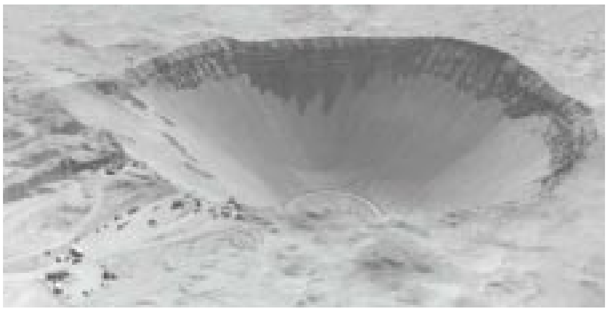
Satellite imagery

Satellites are non-intrusive and can monitor a large area of the earth's surface in a short time. There is considerable potential for detecting surface changes resulting from nuclear tests using the wide range of spectral sensors on satellites and differencing techniques for enhancing images. Such images can provide 'ground truth' for calibration experiments and for locating mining activity and earthquakes. They can also be used to locate a suspect site after a nuclear test has been conducted or, in some cases, pre-test activities. Satellites may also detect the flash of atmospheric explosions.

Although the CTBT does not currently provide for satellite monitoring, it does commit states parties to examine the verification potential of such technology (along with others such as electromagnetic pulse monitoring) in the future.

Commercial remote sensing satellites with high-resolution sensors are being launched and operated by an increasing number of states—currently Canada, France, India, Russia and the US. Civil radar satellites now have day and night and all-weather capabilities. The quality of data from civilian satellites has improved some 100-fold since 1972 when the US launched the first such satellite. Information acquired by them is available for purchase and the cost is declining. Any state or non-state actor now has access to such information to assist in monitoring compliance with the CTBT.

Country	Nuclear test sites
China	**Lop Nor**
France	**Muroroa/Fangataufa (closed)**
India	**Pokhran**
Kazakhstan	**Semipalatinsk (closed)**
Pakistan	**Chagai/Kharan**
Russia	**Novaya Zemlya**
US	**Nevada (also used by the UK)**



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Crater produced by the Sedan explosion in 1962, the first US nuclear experiment designed deliberately to produce a large crater. States attempting to evade the CTBT would need to avoid any detectable evidence of an underground blast.

Scientific networks

While the IMS seismic system consists of 170 stations, by the end of the decade there will be thousands of digital seismic stations worldwide collecting data in real or near-real time. In many areas, seismic stations installed for scientific purposes, such as studying earthquakes, already provide a capability that far exceeds that of the IMS. In Central Asia, for example, regional seismic networks have a detection threshold that, on average, is about 20 times better over large areas, including the nuclear test sites at Lop Nor and Semipalatinsk, than that expected for the IMS. Recent instances that have demonstrated the value of open data for nuclear monitoring include: determination of the source of a magnitude 3.5 seismic event on 16 August 1997 near the test site at Novaya Zemlya; and detection of the nuclear explosions conducted by India and Pakistan in May 1998.

Total verification resources and synergies

The total monitoring resources available to the international community—including the IMS, NTM and scientific instruments and networks—must be considered when evaluating the verifiability of the CTBT. There will be considerable synergies between IMS and non-IMS data from a variety of sources, which will increasingly enhance confidence in the verifiability of the treaty.

Evasion scenarios

The three most credible evasion scenarios that have been proposed to foil monitoring networks are decoupling, hiding a nuclear explosion in another event, and evading attribution. There are no credible examples of the latter two scenarios, and thus the focus has been on decoupling.

In theory, decoupling would work by conducting a test in a large underground cavity in an attempt to attenuate greatly the seismic waves. A large enough cavity at a sufficient depth would have to be found or constructed to permit such an attempt. Successful decoupling would require substantial financial, technical and human resources and would need to be conducted in complete secrecy.

Any state contemplating a decoupled test would face a verification gauntlet. A potential evader would not only need to attenuate significantly the seismic signal to avoid detection by the IMS and other seismic networks, but it would also have to ensure that all the radioactive particulate and noble gas debris produced by the explosion was completely contained within the cavity. Furthermore, the potential evader would need to avoid creating any surface evidence of the test. Only a few low-yield decoupling experiments have ever been conducted, by the Soviet Union and the United States. It is unlikely that an emergent nuclear weapon state would have sufficient experience or resources to conduct successfully a fully decoupled, completely contained clandestine nuclear test explosion. The most sophisticated nuclear weapon states would themselves have difficulty in carrying out such an explosion, even at low yield.

Conclusions and recommendations

The Commission concludes that:

- the overall resources available for verifying compliance with the CTBT comprise the IMS, NTM and other scientific instruments and networks;
- when fully in place, these resources will be capable of meeting the international community's expectation that relevant events will be detected, located and identified with high probability;
- overall verification resources will improve as more monitoring stations are installed, more research is carried out and global communications systems continue to expand;
- these global capabilities constitute a complex and constantly evolving verification gauntlet, which any potential violator will have to confront—together they will serve as a powerful deterrent.

The Commission recommends that:

- states should provide the necessary political, financial and technical support to permit the CTBT verification regime to be established as soon as possible;
- the international community should encourage the open exchange of data between the IMS and the global scientific community;
- states should support research to improve the scientific and technical underpinnings of global verification capabilities: as these are strengthened verifiability will increase.