Toward the end of 2004, the then Executive Secretary of the Preparatory Commission for the Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO), Wolfgang Hoffman, claimed that the Provisional Technical Secretariat’s Vienna-based global monitoring system had achieved global coverage. The statement sounded good, and was clearly designed to grab the media’s attention. But it was also grounded in fact. The monitoring system, designed to verify compliance with the 1996 Comprehensive Nuclear-Test-Ban Treaty (CTBT), has an impressive global reach. The organization is looking to 2008 for the system to be as complete as it can be, but it is already exceeding the verification capabilities envisaged by its designers. When finished is likely to be significantly more powerful.

Thus, while fundamental political will to bring the regime into legal reality is still lacking, the verification system is on the brink of completion. The complete verification regime will consist of four major elements: an international monitoring system, consultation and clarification procedures, on-site inspections and confidence-building measures. The concepts, methodologies and technologies underpinning this regime are impressive, and merit further examination. This article examines the International Monitoring System and its International Data Centre. It then looks at the development of on-site inspections before concluding with a short discussion on the future of the verification regime.

The International Monitoring System and the International Data Centre

The keystone to verification of compliance with the CTBT is the International Monitoring System (IMS). The IMS is designed to detect nuclear tests conducted in any environment anywhere on Earth. It is a complex mechanism but the fundamental principle is quite simple. Remote monitoring stations using four different technologies will monitor the world for any suspicious behaviour. The monitoring process is largely automated and the product of the process is intended to be used to trigger on-site inspections.

Importantly, the CTBTO itself is not involved in determining whether an on-site inspection is warranted. The organization simply conveys information. Compliance determination is left to the states party to the treaty.

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THE IMS IS ACHIEVING GLOBAL REACH

In terms of global reach and interconnectedness, the IMS is the most ambitious remote monitoring infrastructure envisaged for a multilateral arms control or disarmament agreement. Its global network will eventually comprise 321 monitoring stations and 16 radionuclide laboratories located in some 90 countries. This network will transmit vast amounts of data via a dedicated Global Communications Infrastructure (GCI) to the International Data Centre (IDC) in Vienna, Austria, for compilation and analysis.

While coverage in some areas of the globe remains patchy, the system has proved to have remarkable accuracy in other territories, managing to pinpoint seismic events to within some 5km. By May 2006, 159 IMS stations had been certified for use, and another 63 stations had been found to substantially meet CTBTO specifications (i.e. close to certification). The pace of development remains rapid, and the system is due to be as complete as it can be in just a few years’ time.3

COMPONENTS OF THE INTERNATIONAL MONITORING SYSTEM

The IMS has posed management and engineering challenges unprecedented in arms control verification, with monitoring stations scattered around the globe, many in remote and inaccessible locations (such as Tristan da Cunha in the South Atlantic, 2800km from the mainland). Some of the stations already existed when the IMS was envisaged, but most have had to be constructed from scratch or substantially upgraded. The IMS uses three waveform technologies to accomplish its task: seismic, hydroacoustic and infrasound monitoring. This is complemented by a radionuclide monitoring network, designed to detect particles released into the atmosphere by a nuclear test.

Detecting movements in the Earth: seismic monitoring

The largest and most important part of the IMS, the seismic network is intended to comprise 50 primary and 120 auxiliary stations. By 10 May 2006, 32 primary and 49 auxiliary stations had been certified for use. Others have been installed and are in the process of being certified.

Since the CTBT was first mooted in the 1960s, the ability to detect and identify underground nuclear explosions by seismic means has improved enormously. Very small seismic events are now readily detectable and attributable to earthquakes, nuclear blasts or chemical explosions for mining or engineering purposes. For instance, the IMS detection threshold is below 0.1 kilotons for all of Eurasia and below 0.2 kilotons for all continents.

Detecting underwater sounds: hydroacoustic monitoring

The treaty calls for the establishment of 11 hydroacoustic stations capable of detecting underwater sounds that may indicate that a nuclear detonation has occurred either under water or on nearby land. Although the hydroacoustic network is small compared with the seismic network, its detection capability is considerable because water allows sound to travel for long distances with little energy loss. Hydroacoustic stations can detect nuclear explosions with a yield as small as a few kilograms from thousands of kilometres away. By 10 May 2006, all but three stations had been certified for use. These remaining three are under construction.
Low-frequency sound in the atmosphere: infrasound monitoring

The treaty also calls for the establishment of 60 infrasound stations capable of detecting very low-frequency acoustic signals from atmospheric explosions as well as from shallow underground and near-surface underwater explosions. Infrasound technology has proved increasingly powerful in its detection capabilities: for instance, it has been able to detect take-offs and landings by Concorde aircraft from great distances. As of 10 May 2006, 33 infrasound stations had been certified for use, representing more than half the network.

Drifting particles: radionuclide monitoring

Although seismic, hydroacoustic and infrasound stations may be able to detect a suspicious event and possibly classify it as a nuclear explosion, they may not be able to conclusively differentiate between a conventional and a nuclear explosion. To help detect the definitive signs of a nuclear test (the release of radioactive nuclear particles) the treaty envisages the establishment of 80 radionuclide stations. The samples taken from the radionuclide monitoring network will be analysed in designated radionuclide laboratories. By 10 May 2006, 37 radionuclide stations and 8 laboratories had been certified for use.

Collecting the information: the role of the International Data Centre

The IDC was inaugurated in January 1998 and started to operate in May of that year. The centre collects, processes, analyses, reports on and archives data from the IMS. Data are initially processed automatically, with the first products (such as integrated lists of all signals detected, as well as standard event lists and bulletins) being available within two hours. The IDC is also tasked with producing certain manual products for distribution via the Global Communications Infrastructure to states parties. One important product is the Revised Event Bulletin, which, if compiled from data from seismic, hydroacoustic and infrasound stations, can be available 4–6 days after an event. Radionuclide data, on the other hand, may take up to two weeks to compile, since samples have to be physically collected at the monitoring site and sent for laboratory analysis. However, the CTBTO’s Provisional Technical Secretariat (PTS) aims to automate the radionuclide process using new on-site data processing technologies.

The IDC has been providing data and products to states signatories on a trial basis since February 2000. The CTBTO now has nearly 200 subscribers to its data, and seven countries are subscribing to so-called “real-time data forwarding”. This means that data are transmitted from their origin to their final destination within seconds. Since the treaty gives states parties, not the treaty’s verification body, the responsibility for drawing conclusions about the perpetrator of any treaty violation, products are provided by the IDC without prejudice to final judgements concerning the nature of any event.

Progress and effectiveness of the IMS

Significant progress has been made in establishing the IMS as envisaged in the treaty. More than half the system is now installed, the IDC and GCI are fully functional and the PTS is continually gaining...
experience in running these elements. As of 17 May 2006, 162 stations were sending data to IDC operations. Recently, the CTBTO set up a provisional operations centre in its headquarters and a state-of-the-art operations centre should be completed in 2006. The PTS estimates that the system will be 83% complete by the end of 2006. The first system-wide performance test took place during 2005: 163 IMS stations and 5 radionuclide laboratories (about half of the entire monitoring system) took part. The test provided a framework and data for further evaluation and assessment of the verification system.

However, the system is already ageing: some of the first installed stations are already 8 years old, and some of the auxiliary seismic stations are 20 years old. Stations have suffered accidents: for instance, a station constructed in the Pacific has been struck by lightning, and a hydroacoustic station in South America had a cable ripped apart by an anchor. Little critical attention has been given to wear and tear, and repairing a station can be both expensive and time consuming. A study was, however, carried out in 2004 on the centralization, formalization and standardization of existing operation and maintenance processes. Some CTBTO personnel estimate that around 8–10 stations will normally be malfunctioning to some degree at any given moment when the system is fully operational. As of May 2006, fewer than 10 installed stations were not working for one reason or another.

It is difficult to precisely pinpoint the effectiveness of the system in detecting and identifying illicit nuclear tests, as no nuclear tests are currently being conducted, and because the system is constantly improving. It is clear that the IMS is already exceeding the estimates its designers, the Group of Scientific Experts (GSE), made during the CTBT negotiations in the early 1990s. This is due to the benefits being derived from synergies between the various types of IMS data, advances in monitoring and communications technologies since the system was first envisaged, and the experience being gained in testing and developing the system.

Even in its unfinished state, the probability of the IMS detecting a one-kiloton nuclear explosion by seismic means alone is very high (militarily significant tests are likely to have yields of 5–10 kilotons). The capabilities of the IMS vary in relation to different types of tests and regions. Underground explosions in hard rock can be reliably detected and identified down to a yield of 100 tonnes. In some locations, such as the former test site at Novaya Zemlya, this shrinks to 10 tonnes or less. In any case, as noted by the US National Academy of Sciences, a nuclear explosion with a yield of 1 kiloton or more can be detected and identified with high confidence in all environments. Atmospheric nuclear explosions are in any event likely to be detected due to the radioactive fallout they produce. Underwater explosions in the ocean are likely to be reliably detected and identified as nuclear explosions at yields down to 1 tonne or even lower, some scientists even estimating that the IMS may pick up sub-surface explosions with yields as low as 60kg anywhere on the globe.

In any assessment of verifiability, it needs to be remembered that the official treaty regime will be supplemented by other verification capabilities. The global network of scientific seismic stations that are not part of the IMS will add substantial capacity to CTBT verification. (Some observers, including those at the Washington-based Incorporated Research Institutions for Seismology, maintain that the non-IMS system's capability exceeds that of the IMS.) Other verification capabilities include the national technical means available to individual countries, in particular those of the United States, which runs its own network of seismometers, radionuclide detectors and satellite-based sensors.

Although there have been various scenarios posited over the years as to how a state might attempt to evade detection, these have been effectively debunked and today have little credibility. The most persistent has been the idea of "decoupling"; conducting an underground test in a salt cavern in an attempt to muffle its seismic signature. This is not a simple task: the cavity would need to be sealed to prevent radionuclides from escaping and large enough to dampen the seismic waves without overstressing the rock. This technique requires specialist knowledge and equipment and a not insignificant number of skilled personnel. In addition, successful decoupling requires a precise estimate of the
likely yield of the device, so only states with significant testing experience are likely to be able to accomplish it.

At this stage it is safe to say that the IMS, once fully functional and upon entry into force of the CTBT, will have achieved, even surpassed, its originally planned capabilities. As far back as 2001, the Independent Commission on the Verifiability of the CTBT concluded that the CTBT could be verified “with high probability”.9

The Global Communications Infrastructure

Detecting data is of no use if the data cannot be transported reliably and securely. The data must be protected from tampering or corruption. The IMS facilities transmit data in near real time to the IDC in Vienna via the Global Communications Infrastructure (GCI). The infrastructure became functional in mid-1999 thanks to the system’s innovative use of very small aperture terminal (VSAT) technology. Five geosynchronous satellites enable IMS facilities and states parties around the world to exchange data via their local VSAT Earth stations. Transmissions are routed from the satellites to hubs on the ground, which forward the data to the IDC using terrestrial links. By the end of 1999, 11 North American stations were sending data to the IDC on a test basis.

HOT Telecommunications Ltd, a company based in Canada, was awarded the contract to design, install, manage, operate and maintain the GCI in 1998. In 2001, the Provisional Technical Secretariat launched a project to consolidate management of the system and strengthen the level of service. The PTS has taken great care to ensure that it stays up to date on the latest developments. The use of internet-based transmissions over virtual private networks from some 100 IMS sites was also considered to improve cost efficiencies of remote monitoring implementation. The IMS internet link has been upgraded from 2 to 5 megabits per second: internet reliability is high and consistent, with an overall availability of 99.9%. The PTS has recently taken successful initiatives to improve coordination between the Secretariat, the GCI contractor and station operators in order to sustain the expanding network.

By September 2005, 197 VSATs had been installed of the envisaged total of 248 (some 79% of the infrastructure). By 17 May 2006, 162 IMS stations were sending data to the International Data Centre. The data traffic carried by the GCI was almost 8 gigabytes per day in 2004 and obviously this figure will increase as the IMS approaches completion. The transmission rate is impressive, given that a lot of traffic is going via satellite and other traffic is being routed through national telecommunications networks of varying quality.

The construction and performance of the GCI is reviewed through, among other things, a series of PTS-organized workshops attended by participants from states signatories. The contract with HOT Telecom will expire in 2008. The PTS took advantage of this opportunity early on to assemble a group of experts from signatory states to define future GCI performance requirements and technology options. Based on this report, the PTS invited suppliers to announce their interest in becoming the next GCI contractor in December 2004. By March 2005, the PTS had received an excellent response and the process is expected to conclude by the end of 2006.

On-site inspections

The purpose of on-site inspections (OSIs) is, according to the CTBT, “to clarify whether a nuclear weapon test or any other nuclear explosion has been carried out in violation of Article I and to gather
facts, as far as possible, which might assist in identifying any possible violator.10 Any state party may invoke an OSI. The request may be triggered by an ambiguous IMS finding or by information obtained through established national technical means of verification.

A request for an OSI must contain detailed information about the event and the site to be inspected, as well as any results of a preceding consultation and clarification process or any explanations given by the state to be inspected. The request is presented to the organization’s Executive Council for evaluation, and to the Director-General of the Technical Secretariat. After the Executive Council receives the OSI request, it commences a process aimed at fielding an inspection at the earliest opportunity. The treaty emphasizes speed. For instance, once a request for an on-site inspection arrives, it has to be communicated to the state party to be inspected within six hours, and to the Executive Council and all other states parties within 24 hours.

The Director-General then seeks clarification from the state party subject to the inspection. The state must provide a response within 72 hours. Any additional relevant information from the IMS or any state party or the Technical Secretariat is then transmitted to the Executive Council. Unless the requesting state party changes its mind, the Executive Council decides whether or not to approve the OSI. This decision has to be taken within 96 hours of receipt of the request. An approval to inspect requires at least 30 votes from the 51 members of the council. If the council decides to field an inspection, it also sets the parameters for it. The council has the authority to determine how the OSI will be executed and when it will be terminated. The requesting state party and the state party to be inspected may participate but not vote in the deliberations of the council or any subsequent discussions related to the inspection.

The Director-General then issues a mandate for the conduct of the OSI. At this stage, the Director-General notifies the state party to be inspected of the team at least 24 hours prior to arrival. The team should be on the ground within six days of the request. The physical area to be inspected is broadly defined in paragraph 2 of part II of the treaty’s protocol. It stipulates that “the area of an on-site inspection shall be continuous and its size shall not exceed 1000 square kilometres”, and that “there shall be no linear distance greater than 50 kilometres in any direction”. The effectiveness of the inspection will in part depend on the ability of the IMS to accurately pinpoint the suspicious event. At present, the IMS is reputedly able to locate a nuclear explosion within a radius of 3–5km (in certain areas of the world).11

OSI TECHNIQUES AND TECHNOLOGIES

The techniques and technologies to be used in inspections are specified in paragraph 69, part II of the protocol. The protocol indicates that the list of techniques and technologies is exhaustive. The techniques and technologies are:

- visual observation;
- video and still photography;
- multi-spectral imaging (including infrared measurements);
- gamma radiation monitoring and energy resolution analysis;
- environmental sampling;
- analysis of liquids, solids and gases;
- passive seismological monitoring for aftershocks;
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- resonance seismometry and active seismic surveys;
- magnetic and gravitational field mapping;
- ground penetrating radar;
- electric conductivity measurements; and
- drilling.

**THE OSI TEAM**

The treaty protocol provides that an inspection team should consist of qualified inspectors, who may be assisted by inspection assistants. Inspectors and assistants are either nominated by the states parties or, in the case of staff of the secretariat, by the Director-General. They are selected on the basis of expertise and relevant experience. Notification to the Director-General by the states parties of the list of inspectors and assistants including relevant facts must occur within 30 days of entry into force of the treaty. Within 60 days, the Technical Secretariat must communicate the initial list to all states parties. Unless a state party objects to the designation of any inspectors or assistants within 30 days of acknowledgement of receipt the list is regarded as accepted.

**OSI FIELD EXPERIMENTS**

A number of field experiments to simulate OSIs have been conducted to assess the effectiveness of the OSI regime. In October 1999, the first field experiment was conducted at the Semipalatinsk site in Kazakhstan. The initial event was a 100-tonne non-nuclear explosion conducted in an underground tunnel. The inspection team consisted of 12 participants from various countries. The setting accurately simulated the conditions that might be faced by a real inspection team.

A second field experiment took place in Slovakia in 2002. This tested the effectiveness of the Seismic Aftershock Monitoring System, the purpose of which is to localize the search area and facilitate determination of the nature of the event triggering the OSI request. In September–October 2002, a successful large-scale field experiment was conducted in Kazakhstan, which involved the simulation of an underground nuclear explosion using 12.5 tonnes of chemical explosives. More than 25 inspectors participated in this experiment, and techniques were for the first time performed and examined in an integrated manner to assess the synergy between them.

During 2003, the PTS made a comprehensive evaluation of the preceding year’s experiment in Kazakhstan. One of its major findings was that field analysis of very minor seismic events following small underground explosions imposes requirements on the available equipment that are very different from the requirements for natural seismic events. So the PTS began to plan an exercise directed at examining alternative seismic software for on-site inspections.

In 2004, an exercise took place near Bratislava, Slovakia, which concluded that reliable after-shock monitoring may require a passive seismic network, deployed during on-site inspections, that is two to three times denser then originally anticipated. The issue of seismic data processing was also addressed and some key features for future software development were identified.

A further exercise was conducted in Kazakhstan in 2005. It focused on the technical and procedural points of initial and additional aerial overflights, on gamma survey and on environmental sampling activities.
The completion of the OSI Operational Manual remains one of the major tasks of the CTBTO. The manual is to cover important technical issues such as procedures for overflights; deployment and redeployment of seismic, radionuclide and soil gas sensors; and collection, handling and analysis of samples. It will include a list of inspection equipment, as well as procedures for calibrating, checking and protecting such equipment. The manual will also deal with issues such as communications between the inspection team and the Director-General; health and safety provisions for the team; managed access and other measures for protecting confidential data, findings and information not related to the purpose of the inspection.

Some progress has been made. By 1998 the secretariat had completed a draft outline, as well as the first two chapters, which deal with rights of concerned parties during the conduct of OSIs. In 1999 the CTBTO decided to give the manual greater priority and it created a “Programme Coordinator and Friends” group. This group held five sessions and the PTS provided important technical and substantive support. By the end of the year, 75% of the material for the manual was in place. A CD-ROM reference tool was created for the elaboration of the manual, and a workshop on “OSI Technologies: Methodologies and Techniques for Application” was held in Vienna. Several logistics exercises, methodology and field experiment developments, such as the lessons learned from the 1999 Kazakhstan experiment, provided additional material.

The main achievement in 2001 was the completion of the initial draft rolling text (IDRT) of the OSI Operational Manual. The PTS provided legal consultations during the meetings of Working Group B (which deals with the examination of verification issues, including drafting the OSI manual), and assisted in processing states signatories’ comments on the IDRT. A workshop in Beijing focused on field experiments and tabletop exercises, the managed access regime (the regime limiting on-site inspectors’ access to sensitive areas unrelated to their mission), overflights and equipment issues.

In 2002 drafters completed Chapter 5 (Inspection Preparations) based on the IDRT, and began work on Chapter 6 (Inspections for Underground Event within the Territory of a State Party). A workshop in Vienna also took the manual into account. The main outcomes included specific suggestions on Chapters 3 and 4.

In 2003 Working Group B (WGB) had covered approximately two-thirds of the input for the manual. It turned to issues such as supplementing the manual with additional subordinate documents (covering operational, technical and administrative details), entrusting the PTS with more drafting and related tasks, and exploring other options to continue the elaboration process. The CTBTO encouraged states signatories to continue to contribute to the development of the manual, while the PTS prepared material based on the results of field experiments, tabletop exercises and workshops. A workshop in Hiroshima looked at topics such as confidentiality, the results and lessons from field experiments, and testing equipment.

In 2004, as WGB approached the end of its first reading of the main body of the IDRT, states signatories began to explore practical ways to speed up the elaboration of the draft manual. A workshop held in Vienna in October dealt with the manual. In June 2005, at its twenty-fourth session, WGB completed its first reading of the IDRT, recording its results in an annotated draft rolling text (ADRT). The ADRT provides the basis for the second round. The test manual is expected to be ready for WGB’s twenty-seventh session in September 2006. An Integrated Field Exercise will be held in 2008 to test the procedures contained in the draft manual.
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The future of the CTBT verification regime

The primary obstacle for the verification regime lies not in technical limitations. The system is being constructed in accordance with carefully laid plans, and the CTBTO is mindful to incorporate new ideas and technologies. The primary obstacle lies on the political level: on the entry into force of the treaty, and thus of the verification regime.

There is still a very long way to go for the test ban to become legal reality. But since Article IV provides that at entry into force, “the verification regime shall be capable of meeting [the treaty’s] verification requirements” there has been a natural inclination on the part of the CTBTO to complete the verification system as soon as possible. As a result, the treaty is in the unusual position of having an almost fully-fledged verification system, but, as it is not in force, nothing to verify.

Thanks to the rapid development of the regime, the CTBTO’s budget has grown from US$ 27.7 million in 1997 to US$ 88.5 million in 2003. A steep rise in the first few years reflected the rapid growth of the new organization and the high establishment costs of a global verification system. The budget for 2006 is approximately US$ 50.9 million and 44.4 million euros, totalling approximately US$ 104 million.

While the rate of collection of assessed contributions from member states remains unusually high for an international organization, with approximately 90–97% of the budget collected annually (94.5% in 2003), some states are now beginning to question whether, in light of the protracted—perhaps indefinite—delay in achieving entry into force, work should continue at the same pace as in the past.

Counter to this argument is the view that as the regime is providing constantly improving verifiability, and is increasingly proving capable of providing valuable scientific and civil benefits, the investment is worthwhile. For instance, the IDC received data on the 26 December 2004 tsunami off Sumatra. These could have saved thousands of lives, but the CTBTO did not have the resources or procedures in place to react to an event that was over in but a few hours. As CTBTO spokeswoman Daniela Rozgonova put it, “the whole system has not been set up to warn for natural disasters”. Data produced by the IMS can also assist in air crash investigations or warn air traffic of volcanic eruptions.

Some observers have called provisional entry into force of the CTBT to be considered. From a verification perspective it would be preferable, as the verification system could then be fully used in an official, legally binding way. Others have said, however, that provisional entry into force, even if politically and legally achievable, may relieve pressure on non-signatory states. But international politics are notoriously unpredictable, and the opposite may well be true. If the majority of the world is signed up and committed to the test ban, would that not create pressures on the remaining few to sign up?

Some, including the Verification Research, Training and Information Centre in the past, have argued that a formal move toward provisional implementation is unnecessary, as significant elements of the regime are already being provisionally implemented: the nascent verification body is in place, the monitoring system is largely functional and states are already receiving data. The taboo against nuclear testing is so strong that entry into force of the treaty, while highly desirable, may not be absolutely necessary for the verification and compliance system to function virtually as planned.

On the other hand, it is argued that international custom could not practically substitute an international agreement. International custom is very difficult to establish and maintain, and at the end of the day, a legally binding convention will be preferred over an uncertain customary norm. Moreover, the verification regime has been designed and set up to monitor compliance with an international treaty, not an unwritten international norm. Therefore, the regime will not be able to function fully

The regime is providing constantly improving verifiability, and is increasingly proving capable of providing valuable scientific and civil benefits.
until the treaty enters into force. It will not be possible to trigger formal consultation, clarification and compliance mechanisms or to use on-site inspection provisions. We thus return to the initial problem regarding the future of the regime: without entry into force of the treaty for which the verification regime was designed, doubts are bound to be raised about continuing funding for operations and maintenance.

On a positive note, the fact that entry into force remains below the horizon means that there is ample time to perfect the verification regime for the day political will again materializes and the treaty does become full reality. States, and perhaps even the PTS itself, have only started to realize the immense scientific and technical benefits the regime may produce. Despite the fact that the regime is not yet fully functional, the concept of real-time monitoring of a treaty commitment is appealing, and the success of the CTBT in that respect remains a source of inspiration for those who are interested in treaty compliance in general, and verification in particular.

Notes

3. It is unlikely to be entirely complete because construction is necessary in some non-signatory states, and this cannot begin until they have signed the treaty.
6. David Hafemeister, op. cit.
11. Interview with CTBTO official.
14. For a full discussion of provisional entry into force of the CTBT, see the article by Rebecca Johnson in this issue of Disarmament Forum.