A New Look at the Comprehensive Nuclear-Test-Ban Treaty (CTBT)

International Group on Global Security
(IGGS)

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Abbreviations and Technical Terms

After entry into force of the Comprehensive Nuclear-Test-Ban Treaty

CTBT	Comprehensive Nuclear-Test-Ban Treaty 1996, prohibiting any nuclear weapon test explosion or any other nuclear explosion
CTBTO	CTBT Organization, based in Vienna, Austria
States Parties	States that have ratified the CTBT
CSP	Conference of States Parties, consisting of all States Parties to the CTBT
EC	Executive Council of the CTBTO, consisting of 51 of the States Parties elected by the CSP
TS	Technical Secretariat of the CTBTO
DG	Director-General of the Technical Secretariat

Before entry into force of the CTBT

States Signatories	States that have signed the CTBT
Ratifiers	States that have signed and ratified the CTBT (will automatically become States Parties upon Entry into Force of the Treaty)

PrepCom	Preparatory Commission for the CTBTO, consisting of all States Signatories and Ratifiers of the CTBT, hereafter referred to as Member States of the PrepCom (website www.ctbto.org)
PTS	Provisional Technical Secretariat of the PrepCom
ES	Executive Secretary of the PrepCom
EIF	Entry into force of the CTBT

Verification elements of the CTBT

IMS	International Monitoring System, consisting of four worldwide monitoring networks (seismological stations, radionuclide stations, hydroacoustic stations and infrasound stations) with a total of 321 monitoring stations as well as 16 radionuclide laboratories
GCI	Global Communication Infrastructure, used to transmit data from the monitoring stations to Vienna
IDC	International Data Centre, part of the TS, which receives and processes the data from the IMS and other sources, and provides Member States of the PrepCom, and after EIF States Parties, with raw and processed data
NDC	National Data Centre, point of contact between the IDC and an individual State for the transmission of data
OSI	On-Site Inspection, only possible after EIF, and to be requested by a State Party and approved by the EC
NTM	National Technical Means of verification, verification assets of individual States, including satellites and other monitoring equipment
CBM	Confidence Building Measures

Other abbreviations

CWC	Chemical Weapons Convention 1993
IAEA	International Atomic Energy Agency, Vienna, Austria
NPT	Treaty on the Non-Proliferation of Nuclear Weapons 1968
NWS	Nuclear-Weapon State which is a Party to the NPT
NNWS	Non-Nuclear-Weapon State which is a Party to the NPT
RRW	Reliable Replacement Warhead (US)
SSP	Stockpile Stewardship Program
UN	United Nations
UNTS	UN Treaty Series
CD	Conference on Disarmament

Vienna Convention	Vienna Convention on the Law of Treaties 1969
WMO	World Meteorological Organization, Geneva, Switzerland

Foreword

The proliferation of Weapons of Mass Destruction is a major threat to global security. An important effort to fight this threat is the development of effective, multilateral non-proliferation instruments. The Comprehensive Nuclear-Test-Ban Treaty (CTBT) is one of these instruments. The CTBT bans all nuclear (test) explosions, both for military and civilian purposes. The treaty was opened for signature in 1996. Today, the CTBT has been signed by 178 states and ratified by 144. India and Pakistan, though not nuclear weapons states as defined by the Non-Proliferation Treaty (NPT), did not sign; neither did seventeen other states, among which is North Korea.

The CTBT has, however, not yet entered into force. This will only happen 180 days after the 44 states listed in Annex 2 of the treaty have ratified it. Nine of these states have not yet done so, including two nuclear weapon states under the NPT (the United States and China) as well as four states outside the NPT that have or possibly have nuclear weapons (India, Pakistan, Israel and North Korea). Nevertheless, a lot has already been achieved. Especially setting up the impressive verification system of the treaty has been quite successful. Geophysical and other technologies are used to monitor for compliance with the CTBT. The monitoring network consists of 337 facilities located all over the globe and some 70 percent of the monitoring stations is already operational.

Only when the merits of the CTBT receive attention at the international political level, more states may be convinced of the need to ratify. This Clingendael Security Paper is a modest attempt to contribute to this aim. In this paper the International Group on Global Security (IGGS) takes a fresh look at both the claimed merits and possible shortcomings of the CTBT. The authors present a number of interesting ideas to further improve the verification system. They also discuss some legal issues about the possible effects that ratification of the CTBT could have on the security of countries that, as yet, seem unwilling to ratify. As such, the paper is not only informative, but also thought provoking to anyone who is involved in the field of disarmament and non-proliferation of Weapons of Mass Destruction.

The Netherlands Institute of International Relations 'Clingendael' is pleased to publish this report of the IGGS within its Clingendael Security Paper series. The paper can be a useful contribution to the debate of the vital issue of global non-proliferation and disarmament.

Prof. Dr. Jaap W. de Zwaan
Director, Netherlands Institute of International Relations 'Clingendael'

1. Introduction

The prohibition of nuclear weapon tests was first proposed by Prime Minister Nehru of India in 1954 and, after several sets of negotiations, the Comprehensive Nuclear Test Ban Treaty (CTBT) was opened for signature in 1996.[1] It is still seen, along with the Nuclear Non-Proliferation Treaty, as a critical factor in non-proliferation and nuclear disarmament. The Treaty includes extensive and sophisticated verification provisions, and 80 percent of the 321 state-of-the-art monitoring stations have been installed around the world. All of the five permanent members of the United Nations Security Council have signed the Treaty. However, to achieve entry into force, 44 specific countries – possessing nuclear power or research reactors – must ratify, and at this time 9 are still missing: China, the Democratic People's Republic of Korea (DPRK, North Korea), Egypt, India, Indonesia, Iran, Israel, Pakistan and the United States. It is an ironic twist that India, which first urged the Treaty, and the U.S., which played the leading role in its negotiation, are among those subsequently opposed to it.

In January 2007 and again in January 2008, four influential senior former U.S. government officials called, inter alia, for the ratification of the CTBT by key States, taking advantage of recent technical advances. In their articles entitled 'A World Free of Nuclear Weapons' in the Wall Street Journal, former Secretaries of State Henry Kissinger and George Shultz, former Secretary of Defense William Perry and former Chairman of the Senate

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[1] See website www.ctbto.org.

Armed Services Committee Sam Nunn sparked a spate of events, reports and debate around the world. Subsequently, a number of follow-up activities to further the objectives enumerated in their Op Ed pieces, as well as a major study,[2] have triggered interest in new thinking on this Treaty.

This paper describes the provisions of the Treaty and what has been achieved in setting up the elaborate verification system. It examines the capabilities of this system, which are reported to be significantly beyond what was expected when the Treaty was negotiated. The paper presents some ideas to further improve the verification system as well as some legal issues. Further, the paper addresses concerns that have been expressed about deficiencies in the verification system of the Treaty. The paper summarizes extensive studies conducted in the United States about the possible effects on the security of that country if it would – or would not – ratify the CTBT. It notes that important elements of the Treaty cannot be implemented in the present situation without entry into force: for example, the On-Site Inspection (OSI) regime, which can be vital to establishing without doubt whether a nuclear explosion has taken place and/or who was the originator of such an explosion.

In addition, an independent scientific study to evaluate the capabilities of the verification system of the CTBT was commissioned in 2008 by the Provisional Technical Secretariat (PTS) of the Preparatory Commission (PrepCom). Scientists from national institutions around the world began the study in March and will present their results at a conference in Vienna in June 2009. They will address the readiness and capability of the global system that is being built to detect nuclear explosions worldwide.

The U.S., the Russian Federation and the UK have not tested since 1992, when a moratorium on nuclear testing went into effect. France and China have not tested since 1996, when they joined the moratorium. However, India, Pakistan and North Korea, which have not signed the Treaty, have each conducted nuclear tests since the CTBT was signed, causing worldwide concern. In addition, the threat of terrorism, and especially nuclear terrorism, has become a major issue in many countries.[3] Since the adoption of the CTBT in 1996, there have been significant developments related to the reliability of nuclear weapons stockpiles and the ability to detect and identify

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[2] See George P. Shultz, Sidney D. Drell, and James E. Goodby, *Reykjavik Revisited: Steps Toward a World Free of Nuclear Weapons,* Hoover Institution and NTI, 2008, forthcoming; see especially the chapter by Raymond Jeanloz, "Comprehensive Nuclear-Test-Ban Treaty and U.S. Security."

[3] A counter-terrorism treaty, the International Convention on the Suppression of Acts of Nuclear Terrorism 2005, entered into force in 2007. India and Russia are Parties to the new Convention, which has been signed by 117 States; China, France, the UK and US have signed but not yet ratified it.

nuclear explosions, as well as the source of the nuclear material or the nuclear device. Some argue that the absence of nuclear testing and the diminishing numbers of nuclear weapons decrease the likelihood of terrorists obtaining nuclear weapons or materials. The prohibition of testing will make it more difficult for proliferators to develop warheads that might be mounted on missiles.[4] Because terrorism challenges the civilized norms contained in international law, a number of experts state that resolved commitment by the international community to such norms (including the CTBT) will contain radical terrorism.[5] Thus, it is time to take a fresh look at both the claimed merits and possible shortcomings of the CTBT.

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[4] Michael O'Hanlon, 'Resurrecting the Test-Ban Treaty,' *Survival,* February-March 2008, 126.

[5] Raymond Jeanloz, 'Comprehensive Nuclear-Test-Ban Treaty and U.S. Security,' in *Reykjavik Revisited*, op cit, 169 and J. Doyle, "Strategy for a Nuclear Age," *Nonproliferation Review*, 13, 2006, 1746-1766.

2. Status of The Treaty

2.1 Overview

After negotiations in the Conference on Disarmament in Geneva, the UN General Assembly adopted the Comprehensive Nuclear-Test-Ban Treaty (CTBT) on 10 September 1996. There were 158 votes in favour, with 3 against (Bhutan, India and Libya) and 5 abstentions (Cuba, Lebanon, Mauritius, Syria and Tanzania). On 24 September 1996, the CTBT was opened for signature. By mid-2008 it had been signed by 178 States, of which 144 had also ratified the Treaty. As mentioned previously, the CTBT cannot enter into force until each of the 44 States listed in Annex 2 of the Treaty have ratified. So far 35 have done so.[6]

The purpose of the Treaty can be found in the preamble, which recognizes that the cessation of all nuclear weapon test explosions, by constraining the development and improvement of nuclear weapons and ending the development of advanced new types of nuclear weapons, constitutes an effective measure of nuclear disarmament and non-proliferation. As US Ambassador John Holum stated: "The test ban's 'core' value is to avert an arms race…The CTBT will help impede the spread of nuclear weapons. But its great practical impact will also be … to end development of advanced new weapons and keep new military applications from emerging …In truth it is

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[6] For details on entry into force and other basic information, see www.ctbto.org.

and will remain possible to make simple nuclear weapons without nuclear explosive testing. So the CTBT's fundamental effect is less to preclude the acquisition of nuclear weapons as such, which the NPT addresses, than to constrain the advancement of nuclear weapon capabilities by any country."[7]

The basic provision of Article I of the CTBT is to prohibit and prevent any State Party from carrying out any nuclear weapon test explosion or any other nuclear explosion, and to prohibit and prevent any nuclear explosion at any place under its jurisdiction or control. States shall also not assist others in this field. The prohibition is supported by Article II, which provides for the establishment of a Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO) in Vienna. Its tasks include the setting up, by means of a Technical Secretariat, of an elaborate verification regime. This involves the planning, construction, operation and maintenance of 321 monitoring stations and 16 laboratories throughout the world that form an International Monitoring System (IMS), using four distinct technologies. The data from the stations are sent via a dedicated communication system, which includes satellite and other means, to the International Data Centre (IDC) in Vienna. The CTBT has detailed provisions for intrusive OSI after entry into force, which are in certain respects comparable to those in other arms control treaties, such as the Chemical Weapons Convention of 1993. Their purpose in the CTBT is to clarify whether the prohibition of nuclear weapon test explosions or any other nuclear explosion has been violated, and the Treaty specifies that it is up to the States Parties to make the final decision regarding whether a violation has occurred.[8]

2.2 The Preparatory Commission

As with some other treaties, such as the Chemical Weapons Convention, a PrepCom was established to make the necessary preparations before the entry into force (EIF) of the CTBT. The PrepCom is composed of all States Signatories, and a Provisional Technical Secretariat (PTS) was established to implement their decisions. The States Signatories meet usually two times a year for PrepCom meetings as well as for Working Group A, which considers financial and administrative issues, and Working Group B, which handles the setting up of the verification system. In the case of the CTBT the PrepCom was given rather unique powers since Article IV (1) of the Treaty stipulates that "At entry into force of this Treaty, the verification regime shall be

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[7] Ambassador John Holum, US Undersecretary of State for International Security and Arms Control, speech to the CD, January 1996.

[8] The Treaty prohibits testing, but not the *use,* of nuclear weapons in conflict.

capable of meeting the verification requirements of this Treaty." Thus the hardware of the verification regime, the IMS and IDC, needs to be installed in a sufficient manner before EIF of the Treaty. More than three fourths of the system has been installed and is operational, with substantial investment to support it. The system is expected to be 90 percent complete in another few years. The PrepCom also has the task of preparing operational manuals and developing training courses, as well as establishing administrative details such as staff regulations, financial regulations, etc. needed for the CTBTO to be formally set up after EIF. The PTS of the PrepCom is now a full-fledged secretariat that can smoothly transform into the Technical Secretariat of the CTBTO after EIF.

One of the essential tasks of the PrepCom is to conclude agreements with those States Signatories that have agreed to host monitoring stations for the purpose of the IMS. These are embodied in agreements between the PrepCom and each host State for the purpose of testing and provisionally operating the stations as well as providing data to the IDC. The PrepCom has concluded agreements with more than 90 percent of the States Signatories that host monitoring stations. There are often legal, financial and other difficulties associated with reaching agreement with host countries; frequently as well there are delays in obtaining telecommunications agreements with the appropriate ministry on the frequency to be assigned to a station. Further, each State Signatory has a National Authority that carries out liaison with the CTBTO as well as a National Data Center that is responsible for transmitting data from that country to the IDC in Vienna.

Other specific responsibilities of the PTS include receiving and processing in the IDC the data generated by the IMS monitoring stations; distributing the data to the members of the PrepCom; preparing daily bulletins with lists of seismic and other events; and preparing reports, recommendations and other documentation that are required of the CTBTO by the CTBT. All of these tasks are now far advanced. The PrepCom has also concluded co-operation agreements with the United Nations, the UN Development Programme and the World Meteorological Organization (WMO).

The PrepCom will prepare the first session of the Conference of the States Parties to the CTBT and remain in existence until the end of that Conference. The Conference will have to approve the various operational manuals for the verification technologies, the IDC and OSI, prepared by the PrepCom and needed for the full operation of the CTBT. It will also elect the first Executive Council (EC). Thus, once the CTBT has entered into force, the task of the PrepCom will come to an end, all its functions and assets being taken over by the CTBTO.

3. Recent studies related to the CTBT

Between 1996, when the Treaty was adopted in the United Nations General Assembly, and 2007, four important studies were conducted on implications of the Treaty: the Shalikashvili report titled ‘Findings and Recommendations Concerning the Comprehensive Nuclear Test Ban Treaty’, a study by the National Academy of Sciences ‘Technical issues Related to the Comprehensive Nuclear Test Ban Treaty’, a report by the Verification Research, Training and Information Centre (VERTIC) titled ‘Final Report of the Independent Commission on the Verifiability of the CTBT’, and the Jasons Report. The Jasons are an independent group of eminent scientists that advise the United States government on scientific and technical issues. Their studies have addressed the monitoring regime, verifiability and, in some cases, the effects of the Treaty on nuclear weapons stockpile safety and reliability.

3.1 The Shalikashvili Report[9]

Following the refusal of the U.S. Senate to give its consent to ratification of the CTBT in 1999, President Clinton appointed General (retired) John M. Shalikashvili, former Chairman of the Joint Chiefs of Staff, to be Special

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[9] General John M. Shalikashvili (ret), Report on the Findings and Recommendations Concerning the Comprehensive Nuclear Test Ban Treaty, 2001.

Advisor to the President and Secretary of State for the CTBT. He was asked to study the CTBT and recommend what measures could be taken to improve the prospects that the Treaty would be ratified by the United States. Shalikashvili consulted Senators, leading national security experts, representatives of NGOs, the three national weapons laboratories, officials of the CTBT Prepcom in Vienna and others. The resulting report was issued in January, 2001.

The Shalikashvili Report made four specific recommendations:

- Increase bipartisan and allied support for a carefully coordinated non-proliferation program; make a sustained effort to address senators' questions and concerns; continue the U.S. testing moratorium and support the build-up of the IMS;
- Enhance U.S. capabilities to detect and deter nuclear testing and other aspects of nuclear proliferation, including higher funding and priority to intelligence regarding the nuclear test activities and other aspects of nuclear weapon acquisition or development by other States;
- Improve the management of potential risks associated with the long-term reliability and safety of the U.S. nuclear deterrent; this would include higher priority to aspects of stockpile stewardship, a decision about the need for a large-scale plutonium pit manufacturing facility as soon as possible and strict discipline over changes to existing nuclear weapon designs;
- Address concerns about the CTBT's indefinite duration through a joint Executive-Legislative review of the Treaty's net value for national security to be held ten years after ratification and at regular intervals thereafter. If grave doubts remain about the Treaty's net value for U.S. national security, the President, in consultation with Congress, should be prepared to withdraw from the Treaty under the "supreme national interests" clause.

These recommendations were intended to address the arguments traditionally made in the U.S. against the CTBT. These could be summarized as follows:

- Need to develop new nuclear weapons
- Need to study nuclear effects
- Need to make and keep the nuclear weapon stockpile safe and reliable
- Need to maintain expertise in the weapons laboratories
- The CTBT cannot be effectively verified
- There is little non-proliferation benefit to be gained from a CTBT

The Report considered, and recommended against, several ideas designed to gain support for ratification. Among these were renegotiating the Treaty to provide a "sunset clause" requiring that it be renewed or abandoned after a certain period of time, allowing some low-yield nuclear explosions and making the Treaty's enforcement more explicit or more automatic. The Report also considered and rejected the idea of relying upon voluntary moratoria instead of a legally binding treaty.

In his net assessment, General Shalikashvili acknowledged that the Treaty entails some risks. However, he stressed that these risks are manageable and exist with or without the Treaty. Furthermore, the benefits of the Treaty clearly outweigh the risks. In summary, Shalikashvili stated, "I believe that it is very much in our national interest to secure these benefits through entry into force of the Test Ban Treaty. If this opportunity is lost, the United States' ability to lead an effective global campaign against nuclear proliferation will be severely damaged".

The Shalikashvili Report appears to have been essentially ignored by the Bush administration.

3.2 The U.S. National Academy of Sciences Report[10]

Following his report, Gen. Shalikashvili asked the U.S. National Academy of Sciences (NAS) to conduct a more detailed scientific study of CTBT issues. This report was concluded in 2002. The NAS was not asked for, nor did it provide, a net assessment of whether the CTBT is in the U.S. national interest. It did provide an authoritative scientific assessment of verification and stockpile safety and reliability.

On verification capabilities, the NAS concluded that, in the absence of special efforts at evasion, nuclear explosions with a yield of 1 kiloton[11] or more can be detected and identified with high confidence in all environments around the world. In some locations of high interest, this threshold is much lower. It was noted that, if deemed necessary, these capabilities could be further improved.

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[10] National Academy of Sciences (NAS), 2002, *Technical Issues Related to the Comprehensive Nuclear Test Ban Treaty,* National Academy Press, Washington, DC.

[11] 1,000 tons equivalent mass of TNT (trinitrotoluene) expresses a yield of a nuclear explosion. It corresponds to 4.18 TJ (terajoule) or 1 Tcalorie (10^{12}).

On the important subject of possible evasion techniques, the NAS concluded that the only evasion scenarios that need to be taken seriously at this time are cavity decoupling[12] and mine masking (hiding a nuclear explosion in a chemical explosion in a mine). Regarding decoupling, it was noted that the experimental base is very small and that the practical difficulties of achieving a high decoupling factor increase sharply with increasing yield. On the possible use of mine explosions, it was concluded that the nuclear yield could not exceed about 10% of the aggregate yield of the chemical explosion, and very large chemical explosions are rare and would draw suspicion (both of these possible evasion scenarios are discussed in more detail later in this paper). The NAS concluded that, assuming a fully functional IMS, an underground nuclear explosion cannot be confidently hidden if its yield is larger than 1 or 2 kt.

On the issue of confidence in the safety and reliability of the U.S. nuclear-weapon stockpile, the NAS concluded that the U.S. has the technical capability to maintain confidence in its existing stockpile under the CTBT, provided that adequate resources are made available to the Department of Energy. They identified a number of specific measures that would be most important to this goal.

3.3 The VERTIC Report[13]

In 2000, the Verification Research, Training and Information Centre (VERTIC), an international non-governmental organization based in London, set up an independent Commission, made up of experts from several countries, to study the verifiability of the CTBT. This was in response to criticisms of the verifiability of the CTBT, especially in the U.S. The Commission studied the expected capabilities of the IMS, the system of OSI and national technical means.

The Commission also examined various possible evasion scenarios. They identified what they considered the three most credible scenarios: decoupling, hiding a nuclear explosion in another event, and evading attribution. They dismissed the latter two, since they could find no credible examples. After studying decoupling, they concluded that it is unlikely that an emergent

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[12] Shock wave energy from an explosion can be reduced by detonating a device at the center of a deep underground cavity. An explosion set off in a sufficiently large underground cavity filled with air will generate seismic waves much smaller than those from the same size explosion of a device well-coupled to the material, such as hard rock.

[13] Verification Research, Training and Information Centre (VERTIC), Final Report of the Independent Commission on the Verifiability of the CTBT, 2000.

nuclear weapon state would have sufficient experience or resources to conduct a fully decoupled, completely contained clandestine nuclear explosion. They also judged that even the most sophisticated nuclear weapon states would have difficulty carrying out such an explosion, even at low yield.

The Commission's conclusions and recommendations were similar to those of the Shalikashvili Report and the NAS Report. In particular, they concluded that:

- When fully in place, the resources for verifying compliance 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 IMS stations are installed, more research is carried out and global communications systems expand;
- These global capabilities constitute a complex and constantly evolving verification gauntlet, which any potential violator would have to confront, and will serve as a powerful deterrent.

The Commission recommended that States should provide the necessary political, financial and technical support to the CTBT verification system, along with research to improve the scientific and technical underpinnings of global verification capabilities. It also encouraged the open exchange of data between the IMS and the global scientific community.

3.4 The Jasons Report[14]

In January, 2007 the Jasons issued a report on the lifetime of plutonium pits in the primaries of nuclear weapons - one of the most critical factors affecting confidence in the stockpile. The Jasons concluded that the primaries of most weapons types in the U.S. stockpile have credible lifetimes in excess of 100 years and that the intrinsic lifetime of plutonium (Pu) in the pits is greater than a century. Previously, it had been believed that aging might limit the credible lifetime of these components to perhaps 40 years. This report triggered a debate in the U.S. about the necessity of modernizing the stockpile of warheads with a Reliable Replacement Warhead program. The fact that the existing pits will last much longer than previously believed suggests that the possible need for testing is substantially reduced.

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[14] Reliable Replacement Warhead, Report, JSR-07-336^{E}, the MITRE Corporation, JASON Office, McLean September 2007. See two other JASONS reports relevant to this paper: Sidney Drell, *Subcritical Experiments*, 1997, Report JSR-97-300, and Sidney Drell et al, *Nuclear Testing*, Report JSR-95-320, 1995.

4. Verification of the CTBT

4.1 General comments

When a nuclear explosion occurs, considerable energy is released and physical products are generated. The energy interacts with the close environment and a very small fraction of it propagates over large distances as elastic waves through land, water and the atmosphere. As for an underground explosion, only a small percentage of the total energy is propagating outside the fractured zone. The physical products generated by a nuclear blast in the atmosphere could propagate at large distances through the atmosphere and/or spread through the seas. Also, the products can leak into the atmosphere even when the blast occurs underground or under water. Some radioactive products generated by a nuclear explosion are short lived, ranging from less than hours to months; others last much longer, in the order of years.

The CTBT verification regime – only fully applicable after entry into force - is designed to detect violations of the Treaty by monitoring for the presence of one or more phenomena associated with nuclear explosions in the atmosphere, on the surface of the earth, underground or underwater. These include atmospheric sound waves, seismic waves (waves propagating through the earth),[15] hydroacoustic waves (underwater sound waves), radionuclide

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[15] The waves are generated by the shock of the explosion but are transformed rapidly into elastic waves.

particulates (radioactive dust) and noble gases, electromagnetic waves and long-term disruption of the environment (craters, damage to vegetation). Moreover, before and after a test artefacts connected to the test may be present. In order to detect as many phenomena as possible and to cover all possible locations where nuclear weapons of varying yields could be tested, the verification regime of the Treaty has four elements: the IMS supported by the IDC, consultation and clarification, OSI and confidence-building measures.[16] As noted previously, OSIs are only possible after EIF.

Signals from the IMS stations are collected and sent via a global communications infrastructure (GCI) to the IDC, where they are analyzed. The results of the IDC analysis are distributed to the Member States (after entry into force to States Parties) through event bulletins that contain information about the detected event including, inter alia, specific depth, magnitude and location of each detected event. The detection of events from signals collected by the IMS could lead to the first step of the process that leads to consultation and clarification, or further investigations, such as the launch of an OSI. It is also possible that the trigger for further investigations would be raised by States Parties on the basis of information obtained by national technical means (sometimes referred to as national means and methods), including satellite information or other sources.[17] Confidence-building measures, such as calibration experiments on the seismic and other stations, would also be initiated. Mechanisms and procedures for conducting OSI must be in place by the time of EIF.

It is neither possible nor necessary to devise a system capable of detecting all nuclear explosions. Under the best of circumstances there will be a threshold below which detection of very low-yield explosions would require a system that would not be cost effective.[18] A great deal of discussion has taken place regarding the utility and detectability of very low-yield explosions to the development of a nuclear weapons arsenal. It has been argued that because a potential violator of the Treaty may not be sure of the verification capabilities of the system, he is likely to be deterred from conducting even low-yield tests for fear of being caught. A number of scientists have posited that the CTBT

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[16] Kalinowski, M. B. (2006): "Comprehensive Nuclear-Test-Ban Treaty Verification," in Avenhaus, R., Kyriakopoulos, N. Richard, M. Stein, G, (Ed.) (2006) *Verifying Treaty Compliance*, Springer, Berlin-Heidelberg, 135-152.

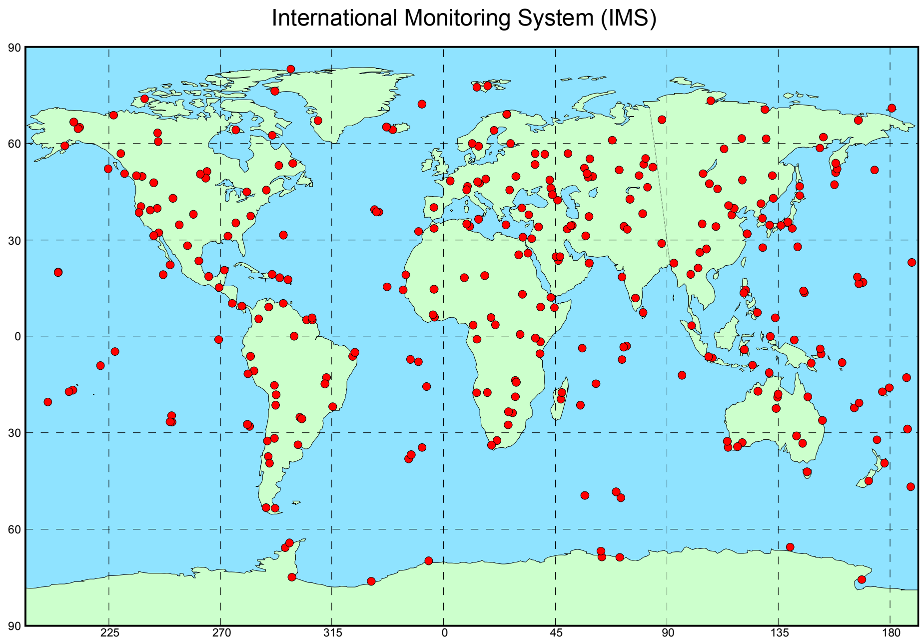
[17] Member States may also receive the raw data of the IMS if they so wish. They can analyse these independently, complemented with their own verification means.

[18] See A. Krass, *Verification: How Much is Enough?* Taylor and Francis, UK, and Philadelphia, Pennsylvania, 1985, USA.

can be monitored “with a sensitivity more than adequate for effective verification.”[19]

The problem of identifying the attacker, or “nuclear forensics” has puzzled scientists over the years, but attention has focused more sharply on it recently due to the concern over nuclear terrorism. The U.S. Department of Defense formed a national team to establish how to identify the attackers if the U.S. were to be struck with a nuclear bomb.[20] Data from the IMS stations could provide information relevant for attributing the source of the material used in a nuclear detonation. The nuclear States, under the IAEA or the CTBTO, could form an international team of nuclear forensics experts. The CTBTO has an established mission and an operational charter in some aspects of post-detonation nuclear forensics.[21] The relevant OSI provisions under the CTBT can not be used, however, until the Treaty enters into force.

4.2 The International Monitoring System (IMS)



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[19] Raymond Jeanloz, “Comprehensive Nuclear-Test-Ban Treaty and U.S. Security,” *op cit.*

[20] William J. Broad, “New Team Plans to Identify Nuclear Attackers,” *The New York Times,* February 2, 2006

[21] See Willliam Dunlop and Harold Smith, “Who Did It? Using International Forensics to Detect and Deter Nuclear Terrorism,” *Arms Control Today*, October 2006.

The seismic, hydroacoustic and infrasound networks are designed to detect and localise on a global scale underground, underwater, and atmospheric explosions, while the radionuclide network is to confirm the nuclear character of an explosion by collecting and analysing air samples. It should also give an indication of the location of a nuclear explosion through the use of atmospheric propagation models. When completed, the IMS will comprise 50 primary seismic stations, 120 auxiliary seismic stations, 11 hydroacoustic stations, 60 infrasound stations and 80 radionuclide stations, most of which will also be capable of monitoring for noble gases upon entry into force of the Treaty. The radionuclide stations will be supported by the 16 certified laboratories on contract to the organization for the analysis of samples from the stations. The four technologies are designed to work in synergy with each other in order to maximize their potential capabilities. [22]

The *seismic* network records seismic events such as earthquakes, volcanic eruptions and underground explosions, and sends the data to the IDC. The primary seismic stations send the data continuously and in real time, while the auxiliary stations send data only when requested by the IDC. It should be noted that the reason for making a distinction in the Treaty between primary and auxiliary stations was purely economic. When the Treaty was negotiated, it was more expensive than it is today to transmit data continuously from remote locations around the globe. More than half of the primary seismic stations are arrays of seismic detectors (9 to 25 elements depending on the array) with aperture of some kilometres, while the rest consist of three-component seismometers. The seismic arrays provide, in addition to event detection, directional information for locating events. The data from the auxiliary stations are used to refine the results from the primary stations and contribute to the discrimination between earthquakes and nuclear explosions. The seismic network detected and located from more than 10 seismic stations the 9 Oct. 2006 underground explosion in the DPRK. It also detected the Kursk Russian submarine explosion on 12 August 2000.

The *radionuclide* network consists of 80 radionuclide stations supported by 16 radionuclide laboratories; most of these stations will also be equipped to detect the presence of noble gases when the Treaty enters into force. The network detects radionuclide material (particulates and gases) released from atmospheric explosions and transported and dispersed by the winds, as well as from vented underground and underwater nuclear explosions under certain conditions. Among the four monitoring technologies, the radionuclide technology is the only one that could directly identify the nuclear character of an explosion. Radionuclide stations are capable of detecting within

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[22] For detailed information on the IMS see Ola Dahlman, Svein Mykkeltveit, Hein Haak, *Nuclear Test Ban- Converting Political Vision to Reality,* Springer, 2008.

approximately 14 days any nuclear explosions that vent radionuclides into the atmosphere. In spite of elaborate and expensive measures to prevent underground explosions from venting,[23] a significant percentage of tests by both the U.S. and the former Soviet Union did vent. Noble gas monitoring provides powerful additional detection and identification capability for underground explosions or for explosions taking place above ground under circumstances where local atmospheric conditions (such as rain) could lead to a significant reduction in airborne particulates.[24] Noble gases are likely to be released into the atmosphere from a nuclear explosion; of these, xenon isotopes are the most suitable for monitoring purposes. As they are chemically inert, xenon isotopes from an underground explosion cavity are more likely to leak than particulates. Noble gas observations at the station in Yellow Knife, Canada are consistent with a release at the time and location of the North Korean test (see paragraph 3.21).

For particulate detection, the station is an air sampler with a large blower capable of blowing 500 m3/hr to 1000 m3/hr through a paper filter that collects particulates on the order of 0.1 micrometer of diameter. After 24 hours, the filter is compacted in order to measure its radioactivity by a high resolution gamma detector. The gamma ray spectrum obtained shows the different radioactive isotopes and possibly the recent fission products that could come from a nuclear reactor or a nuclear explosion. Gamma ray spectroscopy makes it possible to distinguish between the two types of radioactive sources.

For the noble gases, detection is addressed by concentrating the gas before analysis. One method of concentration is to use activated charcoal in the atmospheric air flow. The gases trapped in the charcoal are subsequently released by heating the charcoal and measuring the radiation strength of the xenon isotopes.

The *hydroacoustic* network detects noise from sources in the ocean-such as small explosive sources, oceanic earthquakes, volcanic eruptions, ships and submarines, the fracture of iceshelves in the Antarctic as well as whale conversations-with exceptional sensitivity, due to the fact that acoustic waves

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[23] The greatest part of the radioactive material formed in a deep underground explosion condenses with vaporized rock and is incorporated in the vitrified material. Venting occurs when non-condensable gases escape from the geological confinement at the time of an explosion. Leakage results from the transport of radioactivity by ground water at any time after condensation of the vitrified material.

[24] F. Hourdin and J.P. Issartel, "Subsurface nuclear test monitoring through the CTBT xenon network," 2000, *Geophysical Research Letters* v. 27, no 15, pp 2245-2248.

travelling in water suffer much less attenuation than they do when travelling in the ground. They also have relatively slow propagation velocity that is not very sensitive to water temperature and salinity. Because they are so effective, far fewer hydroacoustic stations are needed compared to the seismic network. The network comprises only 11 stations (6 hydrophones or underwater microphones and 5 seismic stations called T-phase seismic stations) strategically located to cover most of the oceans. The hydroacoustic network is capable of locating small events at great distances with a good accuracy because acoustic waves propagate with relatively slow velocity, so errors on arrival time are converted into small distance errors. Velocity corrections versus temperature and salinity variations improve the location capability. Each hydroacoustic station consists of 3 hydrophones 150 m apart in order to provide azimuth information on the incident acoustic wave sweeping the station. The sensors are placed several tens of kilometres away from shore, generally at a depth of 600 m to 1200 m, in the SOFAR (SOund Fixing and Ranging) channel, which acts as a wave guide for the acoustic waves travelling in water. The data from the hydroacoustic network are also sent continuously and in real time to the IDC. They are often used in synergy with the seismic data to improve detection and location as well as characterization of the source. A T-phase station is a seismic station placed on seashores or islands. It detects hydroacoustic waves that are converted to seismic waves as they reach the shore. The T-phase stations are less sensitive than the hydrophones but easier to install and maintain. They are also much less expensive because the cost of the cable-and its installation-to connect the hydrophones to the shore facilities of the station is high. Nevertheless, the T-phase stations are capable of detecting an undersea explosion of several pounds of TNT at a distance of several thousand kilometres.

The *infrasound* network, comprising 60 stations, is a unique system both for its global monitoring capacity and its exceptional sensitivity, It detects very low frequency sound waves, produced by natural or man made events, propagating in the atmosphere. Each station is an antenna formed with acoustic sensors or microbarometers of high sensitivity located 1 km to 3 km apart. Infrasound had not been used much since the era of atmospheric testing. The negotiations in Geneva triggered a number of studies on infrasound mini-array technology (dealing with sensors, calibration reduced noise system, real time data processing, etc.). Initially designed with four sensors, the sensitivity of the infrasound stations has improved considerably since then in some sites, depending on climate and geography, by increasing the number of sensors to eight or more. As is the case with the primary seismic and hydroacoustic data, the infrasound data is sent continuously in real time to the IDC. Acoustic filters associated with each microbarometer reduce the ambient acoustic perturbations (noise) by factors in the order of 10 and enhance the ability of the infrasound stations to detect weak signals.[25]

The detection sensitivity of the infrasound network is also dependent on the atmospheric winds. Seasonal winds (mainly summer and winter, following East-West or West-East directions respectively) with velocities of several tens of m/s could potentially attenuate and filter propagating infrasound waves. Also, the propagation models need to take into account the large velocity variations in order to improve the location and reduce the uncertainty.

It should be emphasized that the four networks are designed to work as a unified, synergistic system rather than as independent monitoring systems. The detection and discrimination capabilities of the IMS are enhanced through the synergies among the four technologies. The integration of the IMS with OSI that will be possible once the Treaty has entered into force and, potential additional technologies such as remote sensing from space, would increase the confidence in the capability of the verification regime to detect nuclear explosions by an order of tens of tons. With further support from National Technical Means (NTM), which are permitted under the provisions of the Treaty, or other national programmes, the capability of detecting explosions could be enhanced.

The countries that negotiated the Treaty decided it would not be cost effective to include in the IMS devices for detecting electromagnetic pulse (EMP) and the optical flash generated by a nuclear explosion. However, systems to detect these phenomena are present in the national technical means of several countries. If the need arises and all States Parties agree, the Treaty provides (article IV, A, paragraph 11) for the possibility of enhancing the IMS to include monitoring for these and other relevant phenomena.

4.3 The International Data Centre

The IDC is a powerful information processing facility that includes expert analysts in the four monitoring technologies. Its role is to support effectively the verification activities of the States Parties by providing data from the four monitoring networks and products derived from them. The IDC collects, processes, analyses and archives the IMS data received through the GCI. In addition, the IDC may provide the raw data collected from the four monitoring networks as well as technical support in the form of analytical tools and services to States Parties that request them in order to help the

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[25] M. Hedlin *et al*, ‘Evaluation of rosette infrasound noise reducing spatial filters,’ *Journal of the Acoustical Society of America,* 114, 2003.

States Parties arrive at their own conclusions about compliance. The results of the IDC are made available to the States Parties through the GCI in the form of event bulletins. They provide information on the characteristics of the detected events, including magnitudes and locations. The data collected by the IMS are sent to and processed in real time by the IDC. A first automated bulletin is released within two hours of the arrival of raw data; subsequently two more automated event bulletins are produced. Analysts review the results of the automated procedures and the IDC issues a Reviewed Event Bulletin.

An important function associated with the production of event bulletins is the use of screening criteria to screen out benign causes of detected events.[26] For the seismic network, some of the criteria are: location and depth of events, comparison of surface wave magnitudes and body wave magnitudes, frequency content of signals, spectral ratios of phases, comparative measures to other events and groups of events, etc. For the hydroacoustic network the screening criteria are applied to the spectral characteristics of the signals such as wide band energy, mean center frequency and bandwidth, spectral ratios, frequency-dependant duration of signals, etc. The screening criteria for infrasound are spectral characteristics, peak amplitude and signal duration. For the radionuclide network, the objective of the screening process is to classify radioactivity measurements on the basis of number, type and relative amounts of nuclides present. Some of the screening parameters are: concentration of natural and man-made radionuclides, concentration of specific fission products and activation products outside normal observations, and ratios of one specific fission product to another.

In addition to the event bulletins issued for each of the four networks, the IDC will also provide Fused Event Bulletins. Initially, these bulletins provide cross-references in time and space for events detected by the four networks. With continuing advances in the field of data fusion, the synergies among all components of the monitoring system will allow the extraction of additional information to that provided independently by each of the four monitoring networks. In particular, it is believed that the supplemental information will enhance the capability of the verification system to detect, locate and characterize events below the threshold originally estimated from theoretical calculations when the Treaty was being negotiated. Due to financial and political constraints, the IDC is presently not in operational mode 24 hours a day 7 days a week.

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[26] Most seismic events result from natural phenomena. Many seismic events have characteristics, such as depth and frequency spectrum, that could not result from a man-made explosion.

4.4 Status of the four monitoring networks

As of June 2008, 80 percent of the IMS stations have been installed, 68 percent have been certified (fulfilling specifications), and 72 percent are transmitting data to the IDC. Of the planned 40 noble gas stations, 16 are operating on an experimental basis and have already demonstrated the significant contributions made by the radionuclide network to the verification of the CTBT. The development of mobile noble gas stations will significantly enhance the effectiveness of the OSI regime after EIF when they are brought to the inspection area to search for venting of a nuclear explosion. The radionuclide stations are always on alert in anticipation of the presence of radionuclides in the atmosphere.

It should be noted that decisions based on measurements are associated with uncertainties. These uncertainties are present, for example, in making assessments about whether or not a nuclear explosion has occurred, where the event has taken place and, in some scenarios, who is the originator. It is difficult to answer the question of whether or not a treaty is "verifiable" with a "yes" or a "no," because the answer must take into account the uncertainties associated with the information used to arrive at any conclusion. The four elements of the verification regime are designed to function in an integrated manner in order to minimize these uncertainties.

The system detected the seismic signals coming from the tests conducted by India and Pakistan in 1998, when the PTS was just being established. When the IMS was only 60 percent complete and the noble gas station only 25 percent complete,[27] the seismic network detected and located an underground explosion in the DPRK with a magnitude of the order of mb 4.0 corresponding to a yield of 1 kt in hard rock. The location error was less than 5 km. In the first opportunity for the radionuclide system to prove that it worked, approximately two weeks later the IMS station CAX16 at Yellowknife, Canada, recorded indications of the presence of xenon.[28] The seismic signals, in conjunction with the xenon data, confirmed the nuclear character of the explosion. Scientists believed that the detection of the DPRK event was a timely demonstration of the capabilities of the monitoring system to detect low yield nuclear explosions.

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[27] Tibor Toth, speech at the International Conference on Achieving a World Free of Nuclear Weapons, Oslo, Norway, 26-27 Feb. 2008.

[28] P. Saey, M. Bean, A. Becker, J. Coyne, R. D'Amours, L.-E. De Geer, R. Hogue, T.J. Stocki, R.K. Unger and G. Wotawa (2007a) A long measurement of radioxenon in Yellowknife, Canada in late October 2006," *Geophysical Research Letters*, 2007, v. 34, L20802, doi: 10.1029/2007GLO30611, no.10.

In building the verification system during the past ten years, the PTS has employed the latest technical and scientific developments both in-house and in cooperation with members of the PrepCom. Some examples include: regional calibration efforts of the seismic network, infrasound noise reduction at the infrasound stations, propagation models for both infrasound and radionuclide transport, and detection/localisation algorithms particularly for infrasound and hydroacoustic signals. A particularly useful example is the development of an infrasound processing system associated with each acoustic antenna for detecting and locating events in real time. The system processes the acoustic noise and detects the arrival of infrasound waves by computing propagation time differences using the cross correlations of signals between couples of sensors. Wave azimuths and apparent velocities are computed and the source location is obtained by simple multi azimuth intersections from couples of acoustic antennas. This methodology is now adopted for infrasound data at the IDC and by a number of National Data Centres.[29]

Another example of the benefits of collaborative research activities is the gaining of a better understanding of wind dynamics across seasons and their effects on the standard propagation models.[30] These activities include collaboration with the World Meteorological Organization (WMO) and occasional studies on the propagation of atmospheric waves caused by volcanic explosions.[31]

Thus, the scientific and technological improvements for signal detection and surveillance that have taken place since 1996, including the above-mentioned activities, have resulted in better detection and discrimination methodologies and more accurate models of the physical phenomena associated with the events of interest to the verification system.[32] As a result, the global verification regime is now in a better position than in 1996 to detect small-scale nuclear tests.

The verification system of the CTBT is unique because it collects and provides to all members of the PrepCom-and after EIF all States Parties-standardized data from sources around the world through a global communications system and an IDC. Although most analyses of world capabilities to detect nuclear explosions focus on this verification regime of

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[29] Y. Cansi, "An automatic Seismic Event processing for detection and location: the PMCC Method," *Geophysical Research Letters*, 1995, vol.22, p. 1021-1024.

[30] Le Pichon, A., et al, (2006), 'How can infrasound listen to high altitude winds?' *J. Geophys. Res.*, vol. 110, 2006.

[31] Drob, D. et al, (2003), 'Global morphology of infrasound propagation,' *J. Geophys. Res.*, vol. 108, 2003.

[32] M.B. Kalinowski, J. Feichter, M. Nikkinen, C. Schlosser, 'Environmental Sample Analysis,' in *Verifying Treaty Compliance,* op cit, p. 367-387.

the CTBT, it is important not to neglect the role of the national technical means of the States Parties both in detecting and deterring nuclear explosions. Although difficult to quantify, the benefits of national technical means for verification are quite substantial. An interesting example of the use of such tools is found in the North Korean test in October 2006. It has been reported that, in addition to the detection of radionuclides at the Yellowknife IMS station in Canada, U.S. aircraft flying close to North Korea also detected radionuclides. It is believed that counterparts of all four IMS technologies are found in the national technical means of some countries. Surveillance satellites also carry detectors for electromagnetic and optical waves emanating from nuclear explosions. In addition, satellites, both classified and commercial, constitute a powerful source of information, for example, in detecting preparations for a test, as well as its effects. In the case of an OSI, satellite information could be used to compare the inspection area before and after the event, including the observation of activities to hide the effects of an explosion before the inspection team arrives. The secrecy surrounding the capabilities of national technical means provides a strong deterrent effect. A potential violator of the Treaty preparing for a clandestine test would have to calculate the risk of detection not only by the IMS, but also by the intelligence services of various States. The uncertainty about the capabilities of national technical means lowers the confidence level in the probability of non-detection and increases the potential cost of violating the Treaty.

4.5 On-Site Inspections

The OSI regime is a vital part of the verification system. The potential of an OSI, which cannot be refused by a State Party, is the ultimate deterrent against a clandestine violation of the Treaty. The PTS has been developing the procedures, training process, equipment and operational manuals that will be used for an OSI once the Treaty is in force.

The CTBT mentions basically two rather different scenarios: an OSI to establish whether an event on the territory of a State Party is a nuclear explosion or not; and an OSI in the case of an identified nuclear explosion in a place outside national jurisdiction or control (for example the high seas) to collect information to help identify the perpetrator. Because of the sensitivities involved with an OSI on the territory of a State Party, nearly all OSI procedures mentioned in the Treaty concentrate on this scenario. Moreover, the Treaty stipulates that final decision as to whether or not the Treaty was violated rests with the States Parties, not the Technical Secretariat (TS).

An OSI can be triggered on the basis of information collected by the IMS, national technical means of one or more State Parties, or a combination of the two. For an OSI to commence, one or more State Parties need to submit a request to the 51-member Executive Council (EC) that will be created when the Treaty enters into force and the Director-General (DG) with information about the approximate location of the suspected event, the boundaries of the area to be inspected, the approximate time when the event occurred and all the data on which the request is based. In addition, the request must include the results of the consultation and clarification process, or an explanation of the reasons why the process was not followed. Within 96 hours of receipt of a request for an OSI, the EC would have to decide on the request. An affirmative decision requires 30 votes; there is no veto.

4.5.1 Planning and execution of on-site inspections

The Treaty and the Protocol include elaborate procedures for initiating and conducting OSI on the territory of a State Party. The procedures are designed to achieve a number of objectives. Requests for inspections should be based on probable cause and not be made frivolously. Inspections should commence as soon as possible following an approved request in order to ensure that the maximum possible amount of evidence is preserved at the suspect site. The timelines provided in the Treaty assure that the inspection would begin no later than nine days from the time of the request. The tools and procedures available to the inspection team should be sufficient to extract the maximum amount of information from the inspection area; at the same time, they should not extract irrelevant peripheral, but sensitive, information from the inspected State. The last constraint has the potential to cause conflict between the inspectors and the inspected party. A well-defined mechanism needs to be in place to resolve potential conflicts at the operational level in order to reduce the probability of moving them to the political arena. It is important to note that the inspected State Party has many rights to protect sensitive information not related to the Treaty, but that State must make it possible for the inspection team to do its job. If insufficient cooperation is provided, including insufficient access to (parts of) the inspection area, the team will report this to the DG and EC.

The inspection area is limited to no more than 1000 km2 and the linear distance in any direction may not exceed 50 km. The time interval for conducting an inspection is specified to be no more than 60 days, but this may be extended to a maximum of 130 days from the date of the approval of the inspection.

The DG selects the inspection team, consisting of no more than 40 members at the same time, from a list of approved inspectors. These will consist of some staff members of the TS as well as experts nominated by States Parties who will obtain advanced training in OSI activities. At its initial session, the Conference of State Parties will approve a list of equipment for use during

OSI. To be able to launch an OSI within a few days, the TS must make considerable preparations beforehand (selecting, maintaining and securing specialized equipment, training of inspectors, updating of the Operational Manual in view of new technologies etc.).

At the inspection site, some of the tasks to be performed by the inspection team during different phases of the inspection include: confirmation of the boundaries of the inspection area, visual observations, video and still photography, multi-spectral imaging, infrared measurements, measurements of radioactivity, environmental sampling and analysis of solids, liquids and gases, passive seismological monitoring for aftershocks, seismic surveys, magnetic and gravitational field mapping, ground penetrating radar and electrical field measurements to detect and locate underground cavities, and rubble zones as well as other anomalies or artefacts connected with a test, and finally when needed even drilling to obtain radioactive samples. Although normally samples are to be analyzed on site, they may be taken off site to approved laboratories, if necessary. OSI may also include low altitude aerial surveys involving optical and multi-spectral imaging, gamma ray spectroscopy and magnetic field mapping.

The panoply of tools available to an inspection team combined with the latitude to conduct investigations in the inspection area make it unlikely that a clandestine test would go undetected. It would not be possible for a perpetrator to erase all artefacts produced by the test and the preparations for it, even though a few days would elapse between the initial time when indicators of a suspect event would become known and the time of arrival of the inspection team at the suspect site. In some cases it might be difficult to detect such artefacts. Satellite surveillance would begin almost immediately after the first indicators would be detected and would record any effort to alter the physical characteristics of the terrain. Although some of the radionuclides have very short lives, others, such as argon and xenon gases, last weeks. The underground cavity itself will be highly radioactive and will register as such for at least decades. The team would normally place a local seismic network as quickly as possible to try to find aftershocks of the seismic event to narrow down its probable location, while taking measurements to detect possible seepage or venting of radioactive gases and flying over the area looking for visual effects of the event. Subsequently, it could use different techniques (infrared equipment, earth penetrating radar, magnetometers etc.) to find artefacts that would be connected with a test, such as boreholes and cables.

4.5.2 Status of the on-site inspection regime

In contrast to the IMS, which performs its monitoring function during the development stage and has demonstrated its capabilities in detecting the

North Korean test, the capabilities of the OSI regime are being tested in realistic scenarios that would be employed after the Treaty enters into force. Working Group B of the PrepCom and the PTS, in cooperation with relevant experts from a number of States, have carried out considerable work in developing the infrastructure needed to support the inspections.

The development of the Operational Manual for OSI, as required by the Treaty, is far advanced. Also, procedures for the selection and integrity of inspection equipment have been established, while special equipment has been tested and, where necessary, developed by several States or commercially (such as mobile noble gas detection equipment). Small and larger field tests and tabletop exercises, as well as specialized seminars, have been conducted and plans are under way to conduct in September-October 2008 a large-scale mock OSI, called Integrated Field Exercise 08 in Kazakhstan. The aim of these activities is to test various pieces of equipment and operational activities and to develop a curriculum for training the on-site inspectors.

4.5.3 Investigation of suspect events outside the territory of State Parties

A State could decide to conduct a nuclear test explosion in an area beyond the jurisdiction or control of any country, such as the vast, nearly empty, areas in the southern oceans. Such a scenario may be attractive for a country with a beginning secret nuclear weapon capability to test whether the device works. A test in the atmosphere or on the surface of the sea would be detected by all four of the IMS technologies as well as by the national technical means of one or more State Parties. The difficult task would be to identify the perpetrator.

The guidance given in paragraphs 105-108 of the Protocol of the Treaty on how to handle OSI in areas outside the jurisdiction or control of any State Party is not nearly as detailed as that involving inspections within the territory of a State Party. The procedures and tools being developed at present for OSI are geared toward land areas, although not explicitly stating so. Areas that fall outside of the jurisdiction of any State, such as the high seas or the atmosphere, would require ships and other equipment. NTM is likely to play a large role in such a scenario.

To initiate a request for an OSI outside the territory of a State Party, one or more State Parties would be needed. It would be easier to obtain permission for such an inspection compared to one for a site within the territory of a State. It would not be in the interest of any State Party to object, because an objection would automatically draw suspicion upon the objecting party. The problem is not in detecting the test or initiating an inspection; rather, the most difficult part would be to identify the perpetrator. By the time inspectors reach the site, whoever conducted the test would be long gone.

The CTBT verification regime is designed to detect, locate and classify events. It has no explicit mechanism for conducting investigations to identify unknown perpetrators; nevertheless, one is needed regardless who does the investigation. Collection and analysis of information about sea and air traffic in the vicinity of the test within a time window preceding and following the test would be an essential component of such investigation. Although collection of this type of information is not mentioned explicitly in the Treaty or the Protocol, a couple of options are available for doing so. One is to keep the investigation outside the Treaty domain and leave it up to interested States Parties to seek the perpetrator. Another is to consider the procedures for identifying unknown perpetrators an integral part of the procedures for conducting OSI and incorporate them in the OSI Operational Manual. A major advantage of the first option is that some States could bring to bear the extensive resources within their National Technical Means unconstrained by rules inherent in treaty verification regimes. However, the gain in information derived from the ability to operate in secret might be outweighed by the potential loss of credibility. Allegations based on secret information would be inherently suspect, because third parties would not be able to distinguish between allegations based on facts and those made with political motives. The alleged existence of weapons of mass destruction in Iraq in 2003 is a case in point. The second option of conducting the investigation within the framework of the CTBT has the advantage of international legitimacy. Its major weakness is potential reduction in effectiveness due to the constrained and cumbersome operation of the verification mechanisms within the CTBTO. A particularly weak point would be the ability of the Technical Secretariat to expand an investigation in progress in directions unforeseen by the operating rules agreed upon by the Conference of the State Parties on the basis of consensus. Nevertheless, the advantage of international legitimacy is a strong incentive for Working Group B to work on the development of such procedures within the Treaty framework.

Another potential legal problem is the constraint of 1000 km2 on the inspection area. By the time an inspection team arrives at the suspect site, air and sea currents could spread important evidence beyond the 1000 km2 area. For inspections over the high seas the inspection team should have the flexibility of collecting evidence from as large an area as necessary. Unlike land where physical artefacts from an explosion remain near the location of the test, the sea is not stationary. In addition, on the high seas no State would have a legitimate national security interest to put bounds on an investigation as long as the area under investigation would be outside the territory of any State.

The case of a nuclear explosion in an area beyond the jurisdiction or control of any State is sufficiently complex – both in the practical and the legal sense. As a first step, it would be advisable for the PrepCom to identify the issues arising from investigating explosions in such areas. For example, it would be advantageous to work together with the IAEA, which has considerable expertise in the field of nuclear forensics, as well as with some States Parties with logistical and analytical capacities. Due to the difference in goals and membership of the two organizations, however, it seemed until now politically somewhat difficult to arrange cooperation with the IAEA. A task force under the guidance of Working Group B could be a mechanism for exploring the issue, identifying potential problems and proposing solutions. By doing so, the CTBTO would be better prepared to handle such a case after entry into force, should the need arise.

4.6 Actual and potential verification capabilities of the IMS

When the CTBT was negotiated, the capability of the verification regime to detect nuclear explosions was assessed on the basis of the state of the art in sensing, communications and information technology at the time. When the Treaty was signed in 1996, the theoretical detection capability of the IMS was estimated at 1 kt worldwide with the technology available then. The locations of the primary stations were selected to provide more accurate information for known test sites such as Lop Nor, Nevada Test Site, Novaya Zemlya and Semipalatinsk. After the IMS began to be deployed and monitoring data were being collected and analyzed, the actual detection threshold has been shown to be much lower than the original estimates. In most of the northern hemisphere land mass, explosions in hard rock in the order of 0.1 kt can be detected and identified as explosions; in some locations such as the known test sites, the threshold may be as low as 0.01 kt. The threshold for detection of underwater explosions is lower than 0.001 kt, while that for atmospheric explosions by the infrasound network is in the order of 1.0 kt worldwide and 0.5 kt in the northern hemisphere. Even smaller explosions would be revealed by the detection of radionuclides, though this is difficult to quantify. The case of evasion scenarios is treated in the next Section. Some sources state that the IMS can detect explosions down to yields of about 0.1-0.5 kt worldwide and that it can identify the event as an explosion rather than an earthquake, or an implosion (e.g. mine collapse), as well as the time and location of the event.[33]

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[33] 'Comprehensive Nuclear-Test-Ban Treaty and U.S. Security,' op.cit. 158 and P.G. Richards, "Forensic Seismology and CTBT Verification," *CTBTO Spectrum 9*, 2007, 1, 6, 19.

Since 1996, technological advances in sensing, communications and data processing allow for the collection, storage and processing of significantly larger amounts of data in much shorter times. The technology used in the current IMS is much improved from that which was available in 1996. Advances have also been made in detection and discrimination algorithms. Thus, the combination of technology and analytical techniques not only has improved the initial estimates of the detection thresholds of the IMS, but it has the potential of decreasing further in time. Using current or evolving technology, the verification capabilities of the existing IMS can be improved significantly with minimal cost.

Not all of the earth's surface needs to be covered equally. There are regions where the morphology of the terrain makes it very difficult, if not impossible, to prepare for and conduct tests. The simplest way to improve the current detection capabilities of the IMS would be to increase the number of monitoring stations in order to decrease the distance between potential test sites and IMS stations. The most cost effective way to increase the number of monitoring stations used for detecting events would be to supplement the primary seismic network with the stations of the auxiliary network, which would increase the number of seismic stations supplying continuous data from 50 to 170. Because of the high cost involved with sending data when the Treaty was negotiated in 1996, auxiliary data is made available only upon request. The cost of sending auxiliary data on a continuous basis now would be minimal, although some countries object to doing so. Both primary and auxiliary IMS stations fulfil the same technical and operational requirements and are, thus, capable of detecting seismic signals with similar levels of accuracy. The designation of a station as auxiliary refers to the manner in which the signals are collected and the manner in which they are used by the IDC to generate event bulletins. The capability of the GCI to collect auxiliary data in the same manner as that for the primary stations already exists and is used to transmit the data to the tsunami warning centres around the world. In effect, the auxiliary station data are available for use by the IDC with minor changes in the way they are transmitted.

In addition to the expansion of the number of seismic stations that would be used in the detection and initial localisation of events from the present 37 to 170, improvements could be achieved in a number of other areas. Expansion of the database to accumulate signals from all non-nuclear events over longer periods of time would allow the use of more sophisticated correlation techniques that would improve the capability of the IDC to do better event screening. An increase in the amount of data collected through confidence-building measures would improve event discrimination. Increase in storage and speed would facilitate development of new methodologies and algorithms for the extraction of additional information from the signals collected by the IMS stations. The best evaluation of propagation times between source and stations generally can be achieved by calibration tests, using well located chemical explosions. This in turn would lead to more effective fusion of the data from the four types of monitoring stations. Detection of signals from chemical explosions in known locations allows the stations to establish a reference point for the propagation of signals from a known source to those stations.

Another area in which current technology can help in the discrimination between nuclear test and other seismic events is in the treatment of the signals from the sensing elements. The current sampling rate for the seismic sensors is 40 samples/second resulting in an information bandwidth of 16 Hz.[34] An increase in the sampling rate would broaden the information bandwidth and allow for improved discrimination between nuclear and chemical explosions. Currently, commercially available seismometers have information bandwidths in the order of 100 Hz. The ability to distinguish chemical from nuclear explosions would practically eliminate any possibility of hiding small nuclear explosions under chemical ones.

As mentioned, the Treaty States that the auxiliary network shall provide data to the IDC "upon request" and data "from the auxiliary stations may at any time be requested by the IDC" (Protocol, paragraph 8). Nevertheless, following the tsunami in the Indian Ocean, it was decided that in order to monitor earthquakes that may produce tsunamis, a number of auxiliary stations could send their data to the PrepCom 24 hours a day on a test basis. Since November 2007 international tsunami centres are able to access this data. It has been argued that the IDC should also be allowed to use continuous data from the auxiliary seismic network for further analysis of events.

4.7 Verification Under Evasion Scenarios

Although the detection of low-yield underground explosions in the order of tens of tons is within the monitoring capabilities of existing technologies, concerns have been raised that detection of explosions of much higher magnitude could be avoided through various evasion scenarios. These fall into two major categories: a) masking or hiding a nuclear explosion under another event; and b) decoupling the mechanical effects of the explosion from the surrounding environment.

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[34] Herz is a frequency unit, the number of repetitions of one periodic signal per time unit. The inverse of frequency is the period expressed in time unit, the second.

Potential masking scenarios considered in the past involved exploding a nuclear device at the onset of an earthquake or using chemical explosions to disguise an underground nuclear test. The first is highly unlikely. To prepare for such a test, an evader would need to be able to predict the location and timing of an earthquake, a practical impossibility. Even if such a task could be accomplished, regional seismic networks in conjunction with the increased capability provided by current technology would be able to discriminate between the two events. Similarly, it would be difficult to hide nuclear test signals under signals from nearby chemical explosions. To minimize the probability of detection, the chemical explosion would need to have a magnitude much greater than the nuclear one. However, routine industrial uses of chemical explosions such as in mining and construction have relatively low yields, in the order of 0.3-0.5 kt, limiting the potential yield of a hidden nuclear test to the order of tens, or at worst, hundreds of tons. A large chemical explosion would automatically draw suspicions and give reasonable cause for initiating a challenge inspection. Furthermore, one of the confidence-building measures of the CTBT verification regime is the "notification of any chemical explosion using 300 tons or greater of TNT-equivalent blasting material detonated as a single explosion." Although such notifications are voluntary, the TS would accumulate over time enough information to be able to characterize large chemical explosions that could help the States Parties discriminate between nuclear and chemical ones.

The second scenario, decoupling the mechanical effects of the explosion from the surrounding environment, may look more realistic than the first one. It consists of testing in a large underground cavity. A nuclear explosion set off in a sufficiently large cavity emits seismic waves much smaller than those from the same size explosion detonated in a conventional test. The ratio of the respective amplitudes of the emitted seismic waves is called the decoupling factor. It increases with the size of the cavity and could, theoretically, reach 100.

In the past, some experiments involving decoupling conducted in salt structures, selected for their stability, have reached decoupling ratios ranging from 15 to 70. These cavities were formed either by previous large-scale nuclear explosions or in salt mines. The decoupling ratio of 70 was obtained with a small nuclear explosion (< 0.5 kt); with a larger explosion (~10 kt) the ratio was only 15. It was observed that the seismic waves generated from the blast suffered much greater attenuation at low frequencies (in the vicinity of 1 Hz) than at higher frequencies (15 Hz - 30 Hz). The higher frequency components would be detected at regional distances by the closest IMS seismic stations. For 1 kt to be decoupled, there is a need for a cavity with a radius of the order of 30 m (to fully decouple a 5 kt explosion in salt, a spherical cavity with a diameter of at least 86 m would be required).[35]

To achieve a decoupling ratio high enough to hide a nuclear explosion in the order of kilotons, a large man-made spherical cavity would have to be excavated. It would not be easy to find natural cavities with spherical shapes. Natural cavities have irregular shapes resulting in very small decoupling ratios. An evader seeking to construct a cavity large enough to hide an explosion in the order of kilotons would have to excavate and transport more than 100,000 m3 of material. In addition to the daunting technical challenges facing such a task, earth surface activities would be extensive enough over a substantial time interval to make them detectable by remote sensing satellites.[36]

Even if the construction of an underground cavity went undetected, it would be difficult, if not impossible, to hide a clandestine explosion. Some radioactive particulates and noble gases might escape through fissures in the surrounding earth mass and would be detected by the radionuclide network. Thus, the evasion scenario involving decoupling is much less realistic than it appears in theory, at least for yields of 0.1 kt or higher.

In summary, after EIF the CTBT verification regime-functioning as an integrated system consisting of the IMS, consultation and clarification, OSI and confidence-building measures-is capable of detecting nuclear explosions down to a fraction of 1 kt with a very high level of confidence. The various evasion scenarios have sufficient weaknesses to decrease the confidence of a potential evader that a clandestine test would remain undetected. The combination of improved detection technologies and increasingly powerful data processing and analysis techniques will decrease even further the ability of potential evaders to conduct even small scale tests undetected.[37]

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[35] W. Leith, ‘Geological and Engineering Constraints on the Feasibility of Clandestine Nuclear Testing by Decoupling in Large Underground Cavities,’ Open File Report 01-28, 2001 US Geological Survey, Department of Interior.

[36] L.R. Sykes, ‘Dealing with decoupled Nuclear Explosions Under a Comprehensive Test Ban Treaty, in E.S. Husebye, ed., Monitoring a Test Ban Treaty, NATO ASI Series E. 1995, v.302, pp. 247-293, Kulwer, Amsterdam and B. Jasani, Civil Reconnaissance Satellites: Opportunities and Challenges, in *Verifying Treaty Compliance,* op cit, pp. 323-334.

[37] ‘Seismic Verification of Nuclear Testing Treaties,’ Office of technology Assessment, Congress of the United States, May 1998. See also footnote 9.

5. Reliability of existing nuclear weapons stockpiles

The policy of the United States is to maintain a credible nuclear weapon capability into the indefinite future. Presumably, the other Nuclear-Weapon States (NWS) have similar policies. The current US approach is to rely upon theoretical models and legacy test data, test non-nuclear components, use hydrodynamic (subcritical) tests and remanufacture the existing nuclear weapons under the Stockpile Stewardship Program (SSP) of the Department of Energy (DOE), as required. An alternative approach, called in the U.S. Reliable Replacement Warhead (RRW), envisions the development of new weapons to replace the existing ones. Both approaches include testing that is allowed under the CTBT, i.e. without conducting a nuclear explosion. In order to avoid the aging problem, some scientists have recommended that the key elements of nuclear weapons could be re- built to original specifications every 20-50 years.

One of the arguments made by opponents of the CTBT in the U.S. is that uncertainties regarding the long-term reliability of the U.S. nuclear weapon stockpile make a permanent cessation of testing unwise. The argument is made that U.S. nuclear weapons were designed close to "performance cliffs" during the Cold War in order to maximize performance. They were not designed for longevity and thus are especially susceptible to problems due to the degradation of nuclear and other components over time. Although, in principle, all components of a nuclear weapon could be replaced, certain materials and manufacturing processes are no longer available, due to environmental and other factors. It is believed that France already has warheads with attributes similar to the RRW. It is not clear whether similar concerns apply to other NWS.

The proposed solution is to produce a RRW (actually a series of warheads over time) of more conservative design. The stated goal would be a one-for-one replacement of existing warheads, and would not involve a new role or new military capabilities - for example, higher yield. Improved security features could also be incorporated into the new design, making the weapon more resistant to unauthorized use - for example, by terrorists.

Because of the conservative design, proponents of the RRW argue that it could be certified and maintained without testing. Senior U.S. officials have stated that the RRW would dramatically reduce the possibility that the United States would ever be faced with a need to conduct a nuclear test in order to diagnose or remedy a reliability problem. This implies that having the RRW would make the Treaty more acceptable to the U.S. by overcoming one of the major objections made against it. The reverse linkage has also been made by opponents of the CTBT, who argue that retaining the current stockpile without the RRW would increase the likelihood that renewed testing would be needed in the future, making ratification of the CTBT unwise. Thus some officials have suggested the possibility of a compromise in the U.S., whereby proceeding with the RRW and ratifying the CTBT would be a "package" deal.

Opponents of the RRW argue that it could lead to further undesirable competition in nuclear weapons and perhaps additional nuclear proliferation. They also argue that the RRW is not necessary. They point out that all non-nuclear components can be fully tested and that, as far as the aging of nuclear components is concerned, the 2007 Jasons Study discussed above concluded that plutonium pits will last much longer than expected. In particular, it said, "Most primary types have credible minimum lifetimes in excess of 100 years as regards aging of plutonium; those with assessed minimum lifetimes of 100 years or less have clear mitigation paths that are proposed and/or being implemented..." Opponents of the RRW also note that there is no guarantee that the RRW would not itself require testing in order to be certified for the stockpile. The U.S. Congress has been somewhat sceptical of the need for the RRW and funding for the program is uncertain. Some believe that a CTBT-RRW package might increase support for both.

It should be noted that development and deployment of a new warhead is not prohibited by the CTBT, so long as no nuclear explosions are conducted. However, objections could be raised by some non-nuclear weapon States that the development and deployment of new types of nuclear warheads would be inconsistent with the spirit of both the CTBT and NPT.

6. Relationship between the CTBT and Non-Proliferation

The Nuclear Non-Proliferation Treaty (NPT) is called the cornerstone of the non-proliferation regime. It entered into force in 1970 and now has the largest number of States Parties among arms control treaties, 190. Its three pillars are non-proliferation, nuclear disarmament and peaceful applications of nuclear energy. The nuclear-weapon States (NWS) are obliged in Article VI of the NPT to pursue good faith negotiations on measures relating to nuclear disarmament. In return, the non-nuclear-weapon States (NNWS) agreed not to develop or acquire nuclear weapons.

The CTBT is seen as a central element of the commitment embodied in Article VI on nuclear disarmament, and the non-nuclear NPT member States have raised the issue of a nuclear test ban at every NPT Review Conference, in the UN and elsewhere. In the view of the NNWS, the NWS have not fulfilled their obligations under article VI, and the CTBT is a long-overdue commitment of the NWS under that article. Further, absent the fulfillment of obligations article VI, they see the NPT as discriminatory because it creates a class of "haves" and "have-nots" regarding possession of nuclear weapons. From their perspective, they agreed to indefinitely extend the NPT in 1995 largely on the basis of the renewed commitment by the major nuclear weapons powers to conclude the CTBT and pursue other Article VI objectives.

At the 2000 Review Conference of the NPT, States Parties agreed to a set of 13 steps for the "systematic and progressive efforts to implement Article VI of the Treaty on the Non-Proliferation of Nuclear Weapons." One of the steps was the signing and ratification of the CTBT. These steps were the criteria by which some assert that Article VI compliance analysis must be undertaken. The 2000 NPT Review Conference unanimously reaffirmed the "importance and urgency of signatures and ratifications, without delay and without conditions to achieve the early entry into force of the Comprehensive Nuclear Test Ban Treaty." Thus, the CTBT is seen to be inextricably linked to the NPT.

The preamble of the CTBT notes that "constraining the development and qualitative improvement of nuclear weapons and ending the development of advanced new types of nuclear weapons, constitutes an effective measure of nuclear disarmament and non-proliferation." Some believe that indefinite delay of the CTBT's entry into force could undermine adherence to other arms control agreements. While some States reject the CTBT, other States that have foregone the option of developing nuclear weapons might decide to renege on their obligations under the NPT. Some see the withdrawal of North Korea from the NPT in 2003 in this light and ponder if others might follow suit.

In addition, the tremendous demand for energy has sparked renewed interest in building nuclear reactors to help fulfill this demand, as well as relevant fuel cycle services such as uranium enrichment and/or reprocessing of spent fuel. This may increase the potential for proliferation. A combination of factors such as questions about compliance with the IAEA safeguards, especially recently by North Korea and Iran, the deal between India and the U.S., the perceived lack of commitment to the NPT Article VI and other unstable factors in the international security situation have led to a great amount of malaise regarding the vulnerability of the NPT regime. Some non-nuclear weapon States have also developed suspicions regarding the fact that the Bush administration shortened the timeline for test preparation from the present 24-36 months to 18 months and has advocated the RRW and plans for modernization of weapons

If both the NPT and the CTBT were to unravel, it would certainly be more difficult for the international community to pursue non-proliferation or disarmament. Further, if the CTBT does not enter into force, the NNWS may feel a heightened sense of betrayal. Some may decide that since, in their view, the nuclear-weapon States are unwilling to fulfil their obligations under Article VI, they should not be asked to refrain from exercising their full rights under Article IV to develop their nuclear energy programs. This could lead to one or more States withdrawing from the NPT and possibly developing their own nuclear weapons.

7. Benefits of Entry Into Force (EIF)

7.1 Full operation of IMS/IDC and the possibility of On-Site Inspections

In addition to the political arguments put forth in Section 5 above, there are other important benefits to be gained by EIF. As mentioned previously, the IMS is working more or less as it was intended, but the PrepCom does not have the money, and some countries do not want, to have the IDC operate around the clock.

Various Member States of the PrepCom will not agree to incur such expenses, put the system into full operation and provide all their possibly sensitive data until the Treaty enters into force. These countries, such as China, do not want other States to have all the advantages of the IMS without commitment to the Treaty itself.[38] Thus, the IMS/IDC will in all probability only become fully operational after EIF. Some have surmised that if EIF is

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[38] In this connection, a number of States are delinquent in paying their dues. The USA is not paying that part of its financial contribution of the PrepCom connected with the further development of the OSI regime as well as costs connected to stimulate the EIF of the Treaty. However, it pays for the IMS/IDC, which provides data to PrepCom Members. A number of other States that should contribute substantially less proportionally to the budget are also overdue in their payments.

postponed for a long time to come, the system could fall apart as States lose interest and decrease their funding.

There are other important provisions of the CTBT that are essential for its effectiveness, yet which cannot be put into even practical effect before the CTBT has entered into force. Although the IMS can sometimes identify a nuclear explosion, often only an OSI can establish if one has really taken place, for example after a suspicious seismic event in the territory of a State. Paragraph 35 of Article IV of the Treaty makes it clear that the 'sole' purpose of an OSI is to clarify whether a nuclear explosion has been carried out, and to gather any facts which might help in identifying any possible violator. To launch an OSI, a Party must first present a request for it to the EC of the CTBTO. The EC cannot exist until the CTBT has entered into force. Yet, when the IMS has detected an event, an OSI may be the only way to find and verify whether there has been a nuclear explosion or not. For this important purpose, there is no substitute for an OSI.

Under the current circumstances, the inability to conduct an OSI means that the UN Security Council is also much less able to agree to imposing sanctions or other measures on a State or a non-State entity (such as a terrorist organization) if, for example a seismic event takes place which may have been a nuclear explosion. To do so, the Council needs convincing evidence, and for this an OSI may be needed.

Since 1996, the threat of terrorism has grown considerably. The knowledge how to make a nuclear explosive device proliferates. As more and more States develop peaceful nuclear capabilities, including sensitive technologies, there is a greater chance in the long run that terrorists will be able to obtain fissile materials to be used in a nuclear explosive. In the short run, highly enriched uranium may be diverted from research reactors and/or obtained (with plutonium) from the black market. It would be much easier to use radioactive material with a conventional explosive, probably not killing many people but effective in creating havoc and making certain areas uninhabitable. Complete nuclear weapons could also fall in the hands of terrorists in a number of countries. The risks of nuclear terrorism have been perceived for some time. Already in 1979, the Convention on the Physical Protection of Nuclear Material[39] was adopted, and amended in 2005 to include also nuclear facilities. IAEA guidelines on this same matter are even older and followed by most States. And, in 2007 the International Convention for the Suppression of Acts of Nuclear Terrorism 2005[40] entered into force, establishing strict rules and guidelines for implementing penal law against individuals involved

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[39] United Nations Treaty Series, UNTS 44004.

[40] United Nations General Assembly Resolution, A/RES/59/290.

in illegal nuclear activities. If the CTBT does not enter into force, the chance of nuclear proliferation is likely to increase, and more countries building bombs provides more possibility for terrorists to get hold of them.

7.2 Scientific, Civil and Environmental Benefits of the CTBT

The civil and scientific use of the data and products from IMS/IDC sources for verification purposes constitute a unique resource which can contribute to humanitarian and environmental purposes and to a better understanding of the geosphere in general.[41] This is true for tsunamis, earthquakes, volcanic ash hazards, radioactive pollution, etc., as shall be seen below. The four monitoring networks, spread evenly over the earth with standardized equipment and procedures, most of it on-line, forms a very powerful and unique tool for civil use and scientific research. Although this is not the purpose of the IMS/IDC - which is designed to find nuclear explosions - it is a most important spin-off. It would be wise to use this costly system where possible. Such applications are already being implemented and these civil and scientific uses of the IMS/IDC will improve considerably after EIF when all stations foreseen in the Treaty are installed and working on line together with the IDC 24 hours a day seven days a week. Civil use and research would be strongly facilitated by allowing the unrestricted access to IMS data and IDC products but unfortunately there is some opposition among members of the PrepCom to allowing such unrestricted access.

The PrepCom has agreed that the PTS should give continuous access to seismic data (both from primary and auxiliary stations) as well as hydroacoustic data on a real time basis to international tsunami monitoring organizations, and this is now being done. The importance of this contribution has already been demonstrated in the case of recent large tsunamigenic earthquakes in the Indian and Pacific Ocean. A number of International Tsunami Monitoring Centres are presently integrating, within their alert system, data provided by the PTS. Following the tsunami disaster of 26 December 2004, the PrepCom decided to explore the potential value of IMS data for tsunami warning purposes and provided the opportunity for international tsunami warning organizations to assess the technical value of real time IMS data. These organizations formed a clear consensus as to the enhanced tsunami warning capabilities that would result from improvements in timeliness and availability of IMS data compared to other sources. They also pointed out the additional benefits from having access to monitoring

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[41] Experts' Meeting on Civil and Scientific Applications of CTBT Verification Technologies, Budapest, 2-3 September 2006, PTS of the PrepCom for the CTBT.

stations in new locations. It was also observed that in some cases data from IMS auxiliary seismic stations would be essential for tsunami warning if they were available in real time and continuously.

Interestingly, it was observed that processed data from both seismic arrays and hydroacoustic triplets could be used to map in real time the rupture propagation during the very large earthquake of 26 December 2004 west of Sumatra. Analysis given very rapidly on the size of the earthquake could indicate the tsunamigenic character of the source. From a pure seismological point of view, the description of the rupture propagation is also an interesting result.

In other ways, scientific cooperation with the International Seismic Centre (ISC) has significantly contributed to the knowledge of earthquakes. In seismology, the Reviewed Event Bulletin (REB), a comprehensive list of epicentre locations, including phase arrival times and amplitudes at IMS stations revised by analysts, provided by the PTS to the ISC since 2000, has significantly contributed to accurate evaluations of earthquake magnitudes. This may have a positive impact on seismic hazard assessments in some areas of the globe. The ISC also provides the IDC with access to the collection of data from 2000 stations worldwide, making the collaboration between the PTS and ISC of clear mutual benefit. Furthermore, the increased access to waveforms and phase readings made possible by the IMS network will certainly help to improve the three-dimensional tomographies of the globe computed by national and international scientific institutions, allowing a better understanding of Earth’s internal structure.

The synergy between the different verification technologies has also improved the understanding of the geosphere behaviour to large natural phenomena such as strong earthquakes. As an example, a combination of IMS seismic and infrasound data pointed out the solid earth response and subsequent atmospheric response to large shallow earthquakes (Southwest China 2003; Peru 2005).

In infrasound technology, the sensitive IMS infrasound arrays and the adapted processing software developed at the IDC and different NDC’s have provided a unique tool which detects, locates and characterizes natural atmospheric phenomena on a global scale, and so could refine atmospheric transport models for the benefice of the verification system performances. The infrasound network provides also new data on other phenomena (such as meteorites falling into the atmosphere).

With regard to volcano monitoring, there is a need expressed by the International Civil Aviation Organization (ICAO) to improve the rapid warning facilities on the ash being spewed in the air by volcanoes (so called ash panaches alert systems). It is recognized that infrasound signals propagated from active volcanoes and detected by IMS infrasound stations might contribute to improve the efficiency of these predictions, important to warn aircraft. There is a clear need of further scientific work in this field.

With more than 60% of the IMS stations now in operation and transmitting their data in real time to the IDC, the IDC is already now providing National Data Centres (NDCs) with timely, high quality and reliable data and products. As a result various NDCs have conducted extensive research, sometime in collaboration with the PTS, to improve the characterization and understanding of various sources and propagation phenomena. These scientific developments could contribute to the optimization of the verification system and also be beneficial to civil and scientific applications. When the IMS/IDC is fully operational after Entry Into Force of the Treaty, these benefits will certainly increase while some political barriers against the use of IMS/IDC data for civil and scientific purposes already now may disappear.

The IMS radionuclide network also provides a new level of sensitivity and coverage through the worldwide, quasi continuous low level data of natural or artificial radioisotopes. For example, natural radioisotopes originating from the crust and from upper atmospheric layers may provide clues on the vertical mixing and interaction of air masses on a global scale, of possible interest to global warming investigations.[42] Continuous radionuclide monitoring at very low detection thresholds will allow detection and tracking of accidental releases. This will help emergency preparedness efforts in detection, modelling and decision support by providing predicted deposition rates. The centrally stored daily filters of all the stations will in time provide unique data on the worldwide distribution, and changes thereof, of certain pollutants, pollens etc.

The hydroacoustic network detects break-offs of the Antarctic shelf, important for the study on global warming. Submarine volcanoes, earthquakes and underwater explosions are also identified and located, contributing to a better understanding of hydroacoustic wave propagation and to the network calibration.

Although the verification system is not yet fully complete and the issue of access to IMS data and IDC products for civil and scientific purposes has not

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[42] H. Kromp-Kolb, "The importance of IMS data for Global Climate Change Research," *Spectrum CTBTO Newsletter,* no 10, p. 22-23, July 2007.

yet been finalized,[43] impressive developments in scientific research are taking place and are likely to increase as collaboration between IDC and NDCs grows. This collaboration could be expanded to the scientific society, and to contribute to human welfare and safety through cooperation programmes with other international organizations.

Much of the research done by national and international scientific institutes using the IMS/IDC will increase the knowledge about the detected phenomena, which in itself will improve the analysis of data for the purposes of the CTBT. Thus there is a mutual benefit from cooperation between the CTBTO and civil and scientific society. Because the data from the different IMS networks are analysed at the same time, the combination of data often gives more information than the individual networks.

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[43] One MOU has been agreed between the WMO and the PTS for meteorology data; another one is between the WMO and the PTS on an experiment of transport simulation; an agreement with ISC for seismic products and an agreement with tsunami centres illustrate the current collaboration by the PTS on these topics.

8. Suggestions pending the entry into force of the CTBT

8.1 Provisional Application (PA) of the Treaty

Since a large number of States has ratified the CTBT, while entry into force (EIF) has been delayed because a number of essential States has not ratified, the idea has been put forward to start applying the Treaty on a provisional basis. In this way, Signatory States would show that the Treaty works and is sufficiently verifiable, which may help to convince non-ratifiers to ratify the Treaty.

The legal basis for PA is to be found in Article 25 of the Vienna Convention on the Law of Treaties 1969:

> 'A treaty or a part of a treaty is applied provisionally pending its entry into force if:
>
> (a) the treaty itself so provides; or
> (b) the negotiating States have in some other manner so agreed.'

There are numerous precedents of the PA of different types of treaties. The General Agreement on Tariffs and Trade (GATT) operated provisionally, and quite successfully, for several decades and never entered into force (and later led to the more successful World Trade Organization). In the context of arms control, PA was sometimes applied for considerable periods in the case of the multilateral Treaty on the Conventional Forces in Europe (CFE) restricting conventional arms in Europe. Indeed, PA would seem to be a way to start agreed activities, on a voluntary basis, quickly without waiting for ratification. The question is: would PA of the CTBT also be attractive and, if so, possible without excessive complications?

One could argue that, through the considerable powers given to the PrepCom – in particular to set up most of the verification system of the CTBT – quite a substantial part of the Treaty is already provisionally applied. This is true in particular for the IMS/IDC. However, in the strict formal sense, IMS/IDC cannot be used for verification of the Treaty until it has entered into force. And OSI cannot be organized without EIF.

Although in theory Article 25 of the Vienna Convention does not exclude Signatories agreeing on the further PA of the CTBT for them, how could they do this in practice? The IMS/IDC and other existing assets belong to the PrepCom, to be handed over to the CTBTO after EIF. However, the PrepCom also consists of Signatories that are non-ratifiers, like the USA, China and others, paying their substantial contribution to the system. It would seem impossible to transfer any assets of the PrepCom to a smaller group of States without the approval of the non-ratifiers in the PrepCom, and it seems unlikely that they would give that approval (or stop their contribution in money and availability of IMS stations on their territory). Thus, it can be excluded that ratifiers could "take over" the organization.

What other element could be part of PA? Signatories could, for example, agree to accept OSI before EIF. But who is going to implement such a complex operation? Not the PrepCom, since it does not have the powers to do so, as explained earlier in this paper. Thus, one would have to set up a kind of parallel organization which could in theory do an OSI, a very costly operation. Moreover, one can imagine that some important States, such as Russia, are not going to accept voluntary OSI as long as other relevant States like the USA, China and others are not in the same boat. Also here, only EIF can bring a satisfactory solution

Further PA of this particular Treaty seems complicated without real benefits. Instead, States that wish to support the Treaty could pay their contributions in full and in time; create a voluntary fund to finance a 24 hours/7 days a week IDC operation; assist in setting up the remaining IMS stations (also in developing countries); participate actively in the further development of the OSI Operational Manual (only a small number of countries have been involved in this complex negotiation); further develop new OSI equipment; and use the highest level contacts with the States concerned to raise the issue of CTBT ratification.

8.2 Safeguards

In order to guard against collapse of the Treaty, or in the event of some event jeopardizing the supreme interests of a State Party which it views as requiring withdrawal and the carrying out of nuclear testing, certain safeguards might be required. Among these might be:

- Maintaining a readiness to test
- Maintaining the safety and reliability of an existing nuclear weapon stockpile
- Maintaining a cadre of scientists and engineers with expertise in nuclear weapons
- Maintaining an intelligence capability to provide assurance that other states are not carrying out nuclear explosions.

In the U.S. some safeguards were proposed to the Senate during the failed CTBT ratification hearings in 1999. These included safeguards put forward by the U.S. administration in 1995 regarding a science based stockpile stewardship program. Additional safeguards were proposed in the Shalikashvili Report discussed above. For example, the Report urged enhanced surveillance and monitoring activities, a dedicated infrastructure revitalization fund, strict discipline over changes to existing nuclear weapon designs and the establishment of a high-level external advisory mechanism. The Report also urged an intensive review of the Treaty's net value for U.S. national security at ten-year intervals, together with a willingness to withdraw under the "supreme national interests" clause, if there are grave doubts on this score.

Countries could develop safeguards along the lines mentioned above.

9. Conclusions and recommendations

In the 12 years since the CTBT was opened for signature, a number of significant developments have taken place, which justify a new look at the Treaty. As of mid-2008, 178 countries have signed the Treaty, of which 144 have completed ratification. Of the 44 countries whose ratification is required for EIF, 35 have done so. Since it seems clear that at least some of the holdouts are waiting for the United States, it could play a leading role in this process if it would complete its own ratification. Many have argued that the U.S. could play a decisive role in persuading the others to ratify.

The NPT and the CTBT are generally seen as the cornerstone of the worldwide efforts to prevent the further proliferation of nuclear weapons. The Treaty recognizes that "the cessation of all nuclear test explosions, by constraining the development and improvement of nuclear weapons and ending the development of advanced new types of nuclear weapons, constitutes an effective measure of nuclear disarmament and non-proliferation." When the Non-Proliferation Treaty (NPT) was extended indefinitely in 1995, the Nuclear Weapon States committed themselves to work seriously on nuclear disarmament measures, including completing a CTBT by 1996. In fact, negotiations were completed by this deadline, but the expected entry into force did not follow. At the 2000 NPT Review Conference, the NPT Parties unanimously expressed the urgency of the entry into force of the CTBT as one of 13 steps towards the future.

A number of negative developments have occurred since 1996, in addition to the failure to achieve EIF. India and Pakistan have tested nuclear weapons, North Korea has conducted a nuclear explosion and there are concerns that Iran may be seeking nuclear weapons. Indefinite delay of the CTBT's EIF could undermine adherence to other arms control agreements and weaken the NPT. India stated at the United Nations General Assembly in 1998 that it would not "stand in the way" of the Treaty, but in June 2008 Prime Minister Mammohan Singh said that India will not sign it.

On the positive side, the NWS continue to observe a moratorium on nuclear explosions. Significant progress is being made in reducing the deployed nuclear weapons of the United States, Russia, Britain and France, as well as in securing and eliminating WMD in the former Soviet Union. The IMS is 80 percent complete. The IDC is functioning successfully. Work is proceeding on preparing for OSI, including increasingly realistic and elaborate tabletop and field exercises. It is also clear that the scientific, environmental and civil benefits of the CTBT verification system will be substantial, especially after EIF.

Several high-level US and international studies have been conducted on the possible need for testing nuclear weapons, as well as on the potential of the extensive verification system of the CTBT-key points in the reasons for the 1999 rejection of the treaty by the U.S. Senate. The scientific and political conclusions of these studies support the conclusion that ratification of the CTBT serves the US and other countries better than rejection. A number of senior officials, including Henry Kissinger, George Shultz, William Perry and Sam Nunn, supported by many other senior politicians and experts recommended ratification of the CTBT, 'taking advantage of recent technical advances and working to secure ratification by other key States.'[44] In addition, an independent scientific study has been launched to determine the capability of the verification system.

In several aspects, the capabilities of the verification system have proven to be better than foreseen in 1996, due to advances in science and technology. The CTBT verification regime, functioning as an integrated system, consisting of the four worldwide monitoring networks (IMS) and the analytical tools of its data centre (IDC), consultation and clarification, OSI, confidence-building measures and NTM, is capable of detecting and identifying nuclear explosions down to a fraction of 1 kt with a high level of confidence. Various

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[44] George P. Shultz, William J. Perry, Henry A. Kissinger and Sam Nunn, "A World Free of Nuclear Weapons," *Wall Street Journal*, Jan. 4, 2007. The same authors in "Toward a Nuclear-Free World," *Wall Street Journal,* January 15, 2008.

evasion scenarios, in particular decoupling and mine masking, could remain of concern. These scenarios, however, have sufficient weaknesses that it would be difficult for a potential evader to have confidence that a clandestine test, even using these deceptions, would remain undetected. In addition, there will be considerable synergy between the IMS and non-IIMS data from NTM and various existing national networks (in particular seismic). Much of the synergy will be built through National Data Centers that are developing and improving data processing for the different technologies on a cooperative basis. The combination of improved detection technologies and increasingly powerful data processing and analysis techniques will decrease even further the ability of potential evaders to conduct even small-scale tests undetected, and thus deter such a violation.

Of course, the integrated verification system can only work fully after EIF. For example, the system of OSI, which may sometimes be an essential component in establishing without doubt whether a nuclear explosion has taken place, as well as the identity of the perpetrator, can only be used after EIF.

In this report, proposals are made to improve the verification system. Ideas have also been suggested that might help some States surmount their domestic or security obstacles to ratifying the CTBT. The arrival of a new U.S. administration in 2009, the approach of the NPT Review Conference in 2010 and renewed concerns regarding nuclear proliferation and nuclear terrorism all point to the opportunity for, and urgency of, bringing into force the ‘longest-sought, hardest-fough’ arms control and non-proliferation agreement.

About the authors

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About The International Group on Global Security (IGGS)

The IGGS is an informal group of experts in the field of arms control and disarmament, including experts on international law, technical experts – especially on verification issues – and diplomats, or combinations thereof. In addition to the authors listed on the first page of this report, the IGGS includes Dr. Ralph Alewine (USA), Dr. Ola Dahlman (Sweden) and Dr. André Poucet (Belgium).

The Group has published three reports:

1. 'Generic Aspects of Arms Control Treaties: Does One Size Fit All? Lessons for Future Agreements on Global Security' European Commission, Joint Research Centre, Non-Proliferation and Nuclear Safeguards Unit, Ispra, Italy, report EUR 21077 EN, 2004.
2. 'Container Security, a Proposal for a Comprehensive Code of Conduct' Center for Technology and National Security Policy, National Defense University, Washington, January 2005, www.ndu.edu/ctnsp/publications.html
3. 'Assessing Compliance with Arms Control Treaties," Geneva Centre for Security Policy GCSP and Centre d'études de sécurité internationale et de maîtrise des armaments CESIM, September 2007, www.gcsp.ch

These reports can be found on the websites listed above as well as CESIM, www.cesim.fr.