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CTBTO preparatory commission for the comprehensive nuclear-test-ban treaty organization
PREPARATORY COMMISSION

14

CTBTO SPECTRUM

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OUR LONGSTANDING SUPPORT FOR THE CTBT

The Comprehensive Nuclear-Test-Ban Treaty (CTBT) bans all nuclear explosions on Earth.

It opened for signature on 24 September 1996 in New York.

As of April 2010, 182 countries had signed the Treaty and 151 had ratified it. Of the 44 nuclear capable States which must ratify the CTBT for it to enter into force, the so-called Annex 2 countries, 35 have done so to date while nine have yet to ratify: China, the Democratic People's Republic of Korea, Egypt, India, Indonesia, Iran, Israel, Pakistan and the United States.

The Preparatory Commission for the Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO) consists of the States Signatories and the Provisional Technical Secretariat. The main tasks of the CTBTO are to promote signatures and ratifications and to establish a global verification regime capable of detecting nuclear explosions underground, underwater and in the atmosphere.

The regime must be operational when the Treaty enters into force. It will consist of 337 monitoring facilities supported by an International Data Centre and on-site inspection measures.

COVER IMAGE:
The concrete dome is on Runit Island (part of Enewetak Atoll, Marshall Islands). It covers the nine metre deep, 107 metre wide crater created by the 1958 "Cactus" nuclear test. Under the dome lie 84,927 cubic metres of radioactive soil and debris from Bikini and Rongelap Atolls. [Gettyimages]

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EDITORIAL
TIBOR TÓTH
EXECUTIVE SECRETARY

A phenomenon occurs when more people ride bicycles or walk a city's streets: there are fewer accidents involving them, which leads to the hypothesis that there is safety in numbers. The proposition is well served by the Comprehensive Nuclear-Test-Ban Treaty (CTBT).

Until 1996 when it opened for signature there had been over 2,000 nuclear tests conducted. Since then there have been a handful, all by newcomers and all condemned by the UN Security Council.

The numbers speak for themselves: 182 States have signed the CTBT and 151 have ratified it. The Treaty is approaching universality. It is a matterof fact. There are few international treaties and legal agreements that enjoy such a commitment of support.

It remains of utmost importance that each and every one of the nine outstanding States takes steps to ratify the Treaty so that it can enter into force and consigns the nuclear testing era to the dustbin of history. That is truly my hope.

Nevertheless, this waypoint we've reached has been the consequence of every single signature, every single ratification by States over the past ten years, commitments entered into even in times of the most politically inclement weather. Bold, singular commitment is still required to stay the course by ratifying and signatory States alike.

Without a CTBT firmly in place, it will ultimately not be possible to move forward on other non-proliferation and disarmament measures. In May the Nuclear Non-Proliferation Treaty (NPT) Review Conference, an event held every five years, opens in New York. It gives the NPT's 189 Member States another opportunity to repeat afresh, and it needs to be part of the final outcome, the commitment they made in 2000 to bring the CTBT into early force.

The Treaty's virtue is that the whole is more than the sum of its parts. To maintain the CTBT and have it flourish demands broad political support sustained by active participation.

Translated, this means engaging as many stakeholders as possible, stakeholders who have to be provided with the means to participate on an equal footing in implementing the Treaty as well as benefiting from its civil and scientific applications.

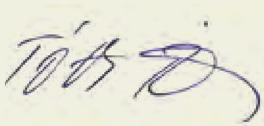
More than any other international arms control treaty, the CTBT relies on a unique and comprehensive verification regime driven by science and technology. The ability of many countries to participate in it is limited by its advanced technical nature. This is why we have embarked on a new initiative offering Member States the means to further develop the capabilities to have a more active role. The initiative will expand on the capacity building activities that already exist.

We are restructuring training activities, consolidating further courses and workshops, and increasing our focus on improved distance learning opportunities. In addition, we will expand our existing networks and seek open, flexible and tailor-made cooperation arrangements with potential partners from all parts of the world.

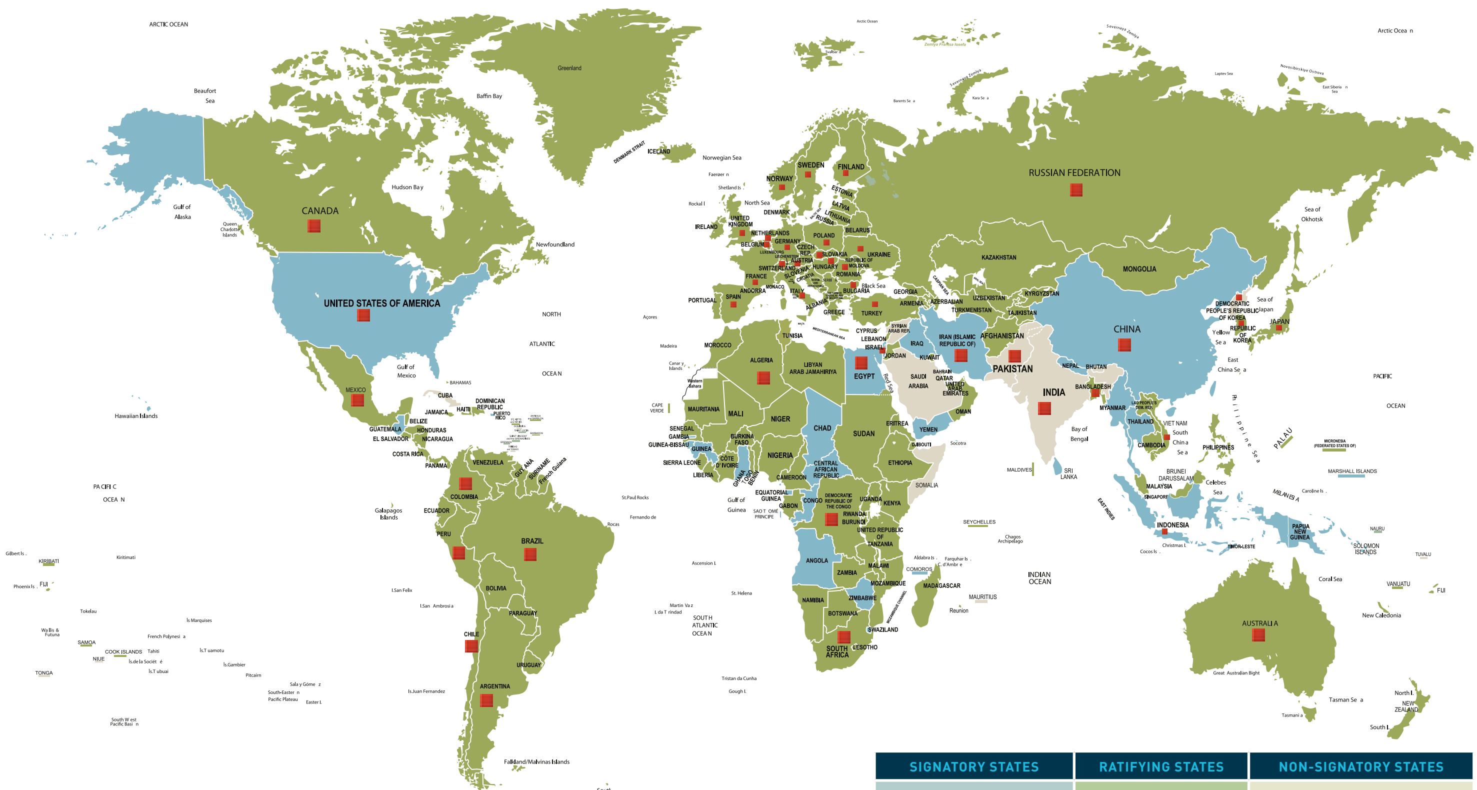
The Preparatory Commission for the Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO) – and I dare to say other non-proliferation and disarmament bodies – need a deeper pool from which to draw the experts they require to sustain the credibility of their verification arrangements.

The articles in this issue of Spectrum reflect the wealth of topics related to the CTBT and its verification regime. The President of the Marshall Islands and the Foreign Minister of Kazakhstan both touch upon the devastating history of nuclear testing and how their countries have benefited from the CTBT. The Foreign Ministers of Australia and Mexico respectively explain their countries' strong commitment to a CTBT in force. The U.S. chief negotiator of the CTBT, Stephen Ledogar, expands on a number of key issues from the Treaty negotiations, which continue to be relevant for today's debate. On the verification side, themes span from how hydroacoustic data can be used to monitor whales and how developing countries benefit from capacity building activities, to recent developments in data mining and on-site inspection techniques.

Let me end by paying tribute to my dear friend and colleague Boris Kvok, director of the On-Site Inspection (OSI) Division from 2004-2010, who passed away in February. Boris was a beloved colleague, leading his division from a conceptual to a more practical approach. He will be greatly missed as a professional as well as a human being, by everyone at the CTBTO and in the wider non-proliferation and disarmament community of which Boris was an active member.



STATUS OF SIGNATURES AND RATIFICATIONS
AS OF 6 APRIL 2010



	SIGNATORY STATES	RATIFYING STATES	NON-SIGNATORY STATES
TOTAL STATES: 195	182	151	13
ANNEX 2 STATES: 44	41	35	3

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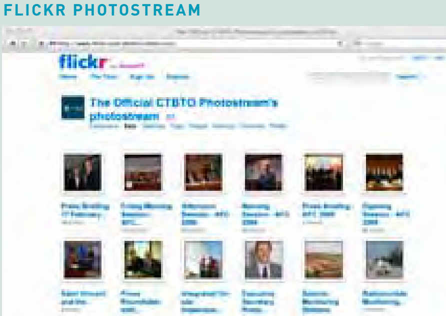

TWITTER FEEDS

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QUOTES

...we must encourage the rapid signing and ratification of the Comprehensive Nuclear-Test-Ban Treaty, which would finally allow for it to go into effect. This is an extremely important task.

Dmitry Medvedev

PRESIDENT OF RUSSIA,
UN SECURITY COUNCIL,
NEW YORK, 24 SEPTEMBER 2009

[We are] committed to ratification of the Comprehensive Nuclear-Test-Ban Treaty as soon as possible, and **will work together** for the early entry into force of the CTBT.

Barack Obama
Hu Jintao

PRESIDENTS OF THE UNITED STATES AND CHINA,
BEIJING, 17 NOVEMBER 2009

A decade ago, we led this effort to negotiate this treaty in order to keep emerging nuclear states from perfecting their arsenals and to prevent our rivals from pursuing ever more advanced weapons. We are confident that all reasonable concerns raised about the treaty back then – concerns about verification and the reliability of our own arsenal – have now been addressed. **The test ban treaty is as important as ever.**

Joe Biden

U.S. VICE PRESIDENT,
WASHINGTON DC,
18 FEBRUARY 2010

It is difficult to overstate the importance of the Comprehensive Nuclear-Test-Ban Treaty as a **crucial building block for both non-proliferation and disarmament**. It sets, in effect, a qualitative cap on the capacity of both existing weapons possessors and potential new ones to develop new nuclear weapons.

THE INTERNATIONAL COMMISSION ON NUCLEAR NON-PROLIFERATION AND DISARMAMENT REPORT,
NOVEMBER 2009

We hold the firm view that the qualitative development of all nuclear weapons must stop, and therefore seek universal adherence to the CTBT, first and foremost by all Nuclear Weapons States. **That would make an excellent first step towards a world of zero nuclear weapons.**

Marty Natalegawa

FOREIGN MINISTER OF INDONESIA
SINCE OCTOBER 2009,
CTBT ENTRY INTO FORCE CONFERENCE,
NEW YORK, 24 SEPTEMBER 2009.

THE MARSHALL ISLANDS

»... no nation, and no people, should ever again be faced with a burden such as ours. And there is really only one way to assure that – through full global acceptance and ratification of this Treaty.«

It is time for the CTBT to come into force

INTERVIEW WITH
PRESIDENT JURELANG ZEDKAIA
OF THE MARSHALL ISLANDS

The Marshall Islands have witnessed firsthand the immediate and long-term effects of nuclear weapon testing on human health, the ecosystem and the environment. Speaking at the Conference on Facilitating the Entry into Force of the Comprehensive Nuclear-Test-Ban Treaty (CTBT) in September 2009, John Silk, the Foreign Minister of the Marshall Islands, poignantly described the effects of the U.S. testing programme: "The use and testing of nuclear weapons has created a burden, a legacy of impacts which have lasted generations, legacies on our land and our health handed down from mother to daughter, and father to son."
Could you elaborate on this statement?

Although the nuclear tests ended in 1958, their lasting consequences continue to be one of our most important struggles. Firstly, the health impacts on our population continue to be passed down through generations, and are very much a contemporary issue.
Secondly, while some remediation has occurred, some of our local communities continue to remain in exile as we seek to ensure full scientific understanding. For the Marshallese, our land is closely tied to our very identity and culture.
Thirdly, we have yet to receive adequate and full compensation for our losses.
Fourthly, we are faced with addressing the storage facility on Runit island *(see cover)* for some of the radioactive material. This storage facility is on a low-lying island, surrounded by oceans and vulnerable to climate change impacts. The scientific understanding of human and environmental exposure to nuclear material has been, unfortunately, a moving target; some of our communities resettled in their traditional homeland decades after testing ended, and had to be evacuated again when the science was revised. There is still, to this day, some dispute over the safe levels of exposure, and so the risks posed by testing may remain. In September, Minister Silk acknowledged the important actions already taken by the United States to address these impacts, and discussions are underway with the U.S. Congress


Majuro and Arno Atolls,
Marshall Islands

on some of these remaining issues. But ultimately, the deep scars on our nation caused by nuclear testing can never be erased, no matter how many years pass.

How do you think the damage caused by the nuclear testing programme in the Marshall Islands between 1946 and 1958 has helped raise awareness about the perils of these weapons of mass destruction?

We cannot undo the past, but the world must never again repeat such mistakes. It is important to note that these nuclear tests were also conducted by the United States with the explicit authorization of the United Nations (in Trusteeship resolution 1082 in 1954, and resolution 1493, adopted in 1956). During the time of testing, there was considerable attention both from the international community, and scientists and public citizens within the United States.

We have continued over the years to remind the international community of the lessons which should have been learned then, and which must be learned now. We were one of the key nations speaking before the International Court of Justice, during its consideration of the use of nuclear weapons in 1995.

»The CTBT defines a truly comprehensive and globally structured platform for preventing nuclear testing. It builds a global consensus and strong momentum for both immediate efforts to reduce arsenals and the long-term goal of a nuclear-weapon-free world.«

The CTBT not only prevents the development of new nuclear weapons and the improvement of existing nuclear weapon designs but also helps prevent human suffering and environmental damage caused by nuclear testing.

Although the Treaty is approaching universal adherence, with 182 signatures and 151 ratifications to date, three of the Pacific Island States – Niue, Tonga and Tuvalu – have still not signed the CTBT. How do you think these non-signatory States can be persuaded to sign the Treaty?

Of course, we cannot speak for our Pacific neighbours on specific policy issues. From our own experience as a small and recently independent nation, we are often overwhelmed by the number of international treaties and their ratification or implementation obligations. We have one of the highest "treaty per capita" ratios in the world. While the CTBT is a clear global priority, many other treaties also have very important goals, and it can be difficult to know which to address first, since we cannot do all at once when resources are limited.

Based on the experience of the Marshall Islands, how do you think the Preparatory Commission for the Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO) can help those countries that have decided to sign or ratify the Treaty in terms of legal or administrative assistance?

A range of actions or options could be possible. From the Marshall Islands' unique perspective, sometimes more general strategies have to be further refined or closely tailored to address national circumstances. In addition, the CTBTO can continue to assist in technical areas where national expertise has not been fully developed – in our experience, the most effective assistance strategies covering capacity building are those which are sustained over a longer period of time.

The Republic of the Marshall Islands was amongst the first 71 countries to sign the CTBT when it opened for signature on 24 September 1996. It ratified the Treaty on 28 October 2009. Why did the Marshall Islands decide to ratify the Treaty at this particular point in time?

Increased international attention to nuclear testing, including the upcoming Nuclear Non-Proliferation Treaty Review Conference this May, provides a compelling reason to again focus global attention on a nuclear-weapon-free world. The issue of nuclear testing and weapons was recently listed by UN Secretary-General Ban Ki-moon as one of the UN General Assembly's top work goals for this year.

What impact do you think ratification by the Marshall Islands might have on other countries that have not yet done so?

The Republic of the Marshall Islands has a strong moral voice on this issue; we are very unique in terms of the impacts on our people and culture. One of the best ways the international community can respond to us is by showing their firm and legal commitment to halt future testing. This is particularly true for nations which possess nuclear stockpiles.

»I deeply regret that such a Treaty, and such a global consensus, did not exist when testing occurred in the Marshall Islands.«

It should be unquestionable that no nation, and no people, should ever again be faced with a burden such as ours. And there is really only one way to assure that – through full global acceptance and ratification of this Treaty.

In addition to the political benefits, membership of the CTBTO offers a number of potential civil and scientific applications of its monitoring data, which could contribute to sustainable development and human welfare. These include tsunami warning, research on ocean processes and marine life; climate change research; volcanic eruption monitoring for aviation safety; and studies on the Earth's structure. How important are some of these potential uses of CTBT data for the Marshall Islands?

Given the impacts suffered by our nation, we have a rightful and highly symbolic role to play as a global beacon by gathering monitoring data. We should be among the first to warn the world. The more comprehensive benefits from environmental monitoring are, for us, equally important. Being a small island nation, we also have one of the most expansive, pristine and diverse ocean territories in the world, and our survival, and our food security, depend closely on the health of our coastal resources – which are increasingly threatened by climate change impacts.

We hope to work closely with the CTBTO to bolster our monitoring capacity, and to become an important international voice on understanding our environment.

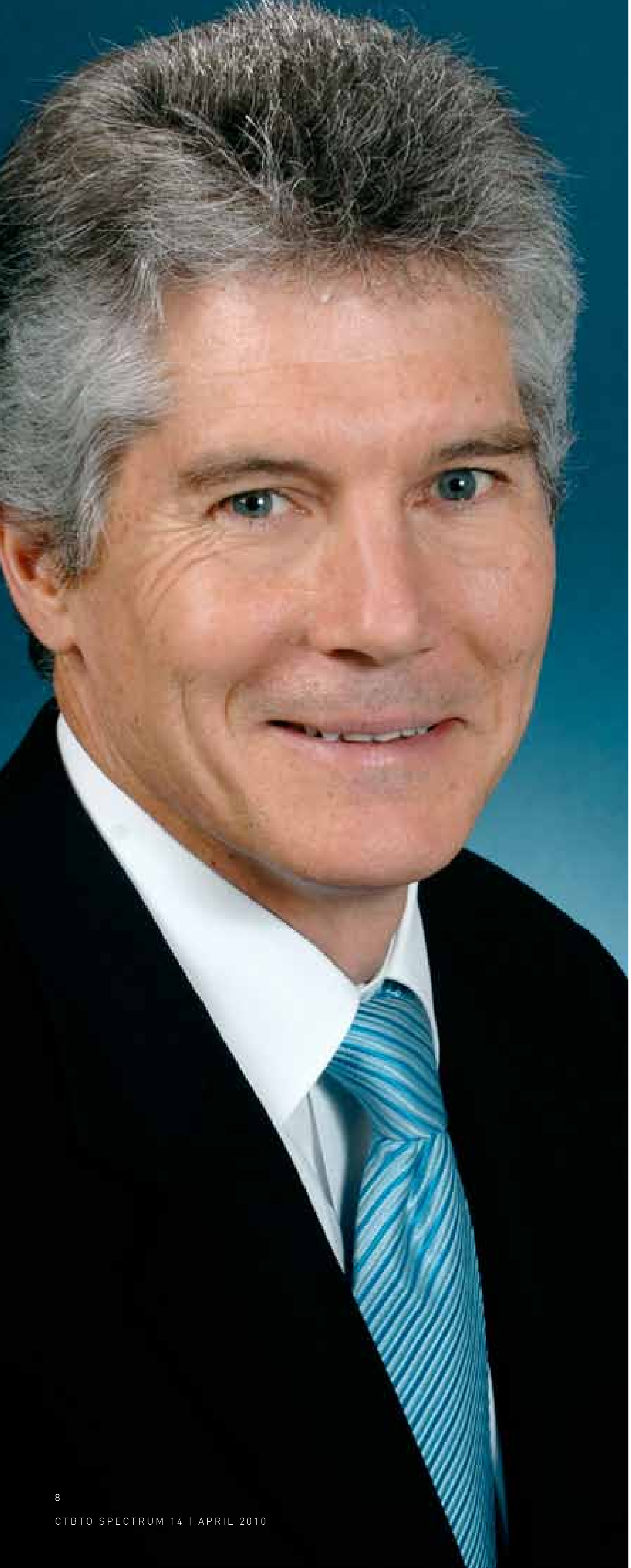
How significant do you consider the CTBT to be for international efforts to reduce nuclear arsenals, and for the long-term goal of a nuclear-weapon-free world?

The CTBT defines a truly comprehensive and globally structured platform for preventing nuclear testing. It builds a global consensus and strong momentum for both immediate efforts to reduce arsenals and the long-term goal of a nuclear-weapon-free world. The Treaty platform means that the global community sees not only political commitment, but also multilateral assurance, to prevent the harmful use of such weapons.

I deeply regret that such a Treaty, and such a global consensus, did not exist when testing occurred in the Marshall Islands.

BIOGRAPHICAL NOTE

PRESIDENT IROIJ JURELANG ZEDKAIA was elected as the fifth President of Republic of the Marshall Islands in October 2009. Mr Zedkaia first became engaged in local politics in 1991 as a representative of the people of Majuro Atoll, which is the location of the capital of the Marshall Islands. He was elected Vice Speaker of Parliament in 1997. Between 2000 and 2007 he served again as a Member of Parliament for Majuro Atoll and in 2008 became the Speaker of Parliament.



AUSTRALIA

Helping to achieve a world without nuclear weapons

BY STEPHEN SMITH, MINISTER FOR FOREIGN AFFAIRS OF AUSTRALIA

The entry into force of the Comprehensive Nuclear-Test-Ban Treaty (CTBT) is a long-standing non-proliferation and disarmament priority for Australia. It is a crucial building block towards achieving the goal of a nuclear-weapon-free world. Australia is proud to have played an instrumental role in the development of the CTBT, and to be at the forefront of efforts to promote its entry into force.

WHY THE CTBT MATTERS

The CTBT, once brought into effect, will play a key role in the global non-proliferation and disarmament regime. As noted by the recent International Commission on Nuclear Non-proliferation and Disarmament (ICNND) report, *Eliminating Nuclear Threats*, the CTBT "sets, in effect, a qualitative cap on the capacity of the existing nuclear weapons possessors and potential new ones to develop new nuclear weapons." In the five decades before the CTBT's conclusion in 1996, over 2,000 nuclear tests were conducted. There have been only a handful of tests since then, most recently those by North Korea in 2006 and 2009, with a number of those States that have not yet ratified the Treaty observing an informal moratorium on testing.

Such an important measure for international peace and security should not depend, however, on informal and voluntary observance. It needs to be reinforced by the legally binding effect and authority of the CTBT coming into force, and the complete implementation of its verification system. Australia believes entry into force of the CTBT would also reinforce and complement the Nuclear Non-Proliferation Treaty (NPT), one of the key pillars of global stability and security. We support strongly the negotiation and conclusion of a fissile material cut-off treaty that would, as the ICNND report notes, set 'a quantitative cap' on the development of new nuclear weapons.

AUSTRALIA'S CONTRIBUTION

Australia played an active and influential role in the negotiation of the CTBT in the Conference on Disarmament (CD) from 1994 to 1996. When adoption of the Treaty was blocked in the CD, Australia led international action to take it to the United Nations in New York, where it was adopted by an overwhelming majority. Australia signed the CTBT on 24 September 1996 and ratified the Treaty on 9 July 1998. The strong international support for the CTBT is demonstrated by its 182 signatures and 151 ratifications. But to achieve universal application of the CTBT, it is vital to get over the line with ratification by the remaining nine Annex 2 States required to bring the Treaty into force.

Australia has warmly welcomed President Obama's commitment that the United States will move forward with ratification and work with others to bring the Treaty into force. Ratification by the United States would be a catalyst for others to act. But the responsibility to act rests not only with the United States. Other Annex 2 States also need to ratify.

Since the conclusion of the CTBT, Australia has vigorously promoted the Treaty's entry into force. Australia initiated the "Friends of the CTBT" Foreign Ministers' Meeting in 2002, in cooperation with Japan and the Netherlands. In 2008, I was pleased to Chair a meeting of around 80 foreign ministers at the UN in New York, which reaffirmed the crucial importance of the CTBT and its entry into force.

»I recently discussed with the CTBTO Executive Secretary, Tibor Tóth, how Australia can continue to encourage other nations in our region to sign and ratify the Treaty.«

For more than a decade, Australia, Mexico and New Zealand have sponsored a UN General Assembly (UNGA) resolution calling for the entry into force of the CTBT. In 2009, a breakthrough was achieved when, for the first time in nine years, all five permanent members of the Security Council voted for the resolution.

Australia has also led efforts in the Conference on Facilitating the Entry into Force of the CTBT – the so-called Article XIV conference – and from 2005 to 2007 served as coordinator of international efforts to promote this objective. Australia will continue to promote the critical importance of the CTBT to our neighbours in the Asia Pacific region. Australia has supported the CTBT through regional outreach programmes to promote ratification, most recently in workshops in Indonesia in November 2008 and in Palau in May 2009. I recently discussed with the Preparatory Commission for the Comprehensive Nuclear-Test-Ban Treaty Organization's (CTBTO) Executive Secretary, Tibor Tóth, how Australia can continue to encourage other nations in our region to sign and ratify the Treaty.

AUSTRALIA'S ROLE IN THE CTBT'S VERIFICATION SYSTEM

The establishment of the CTBT's verification system – including the International Monitoring System (IMS) – will be a challenging task.

Photo: Todd Vincent

CTBTO OPERATION CENTRE
Australia's Foreign Minister Stephen Smith [left] and Tibor Tóth, CTBTO Executive Secretary [right] at the CTBTO headquarters in Vienna, 17 February 2010.

Infrasound station IS05
Hobart, Australia

»… We regard the CTBT as one of the most fundamental steps the global community can take to reach the ultimate objective of the abolition of nuclear weapons.«

The CTBTO is to be congratulated for its efforts to date. But much work remains to be done, and it is important that States provide the necessary financial, technical and political support to the CTBTO. The IMS is a sensitive and highly reliable network of over 300 monitoring facilities. Australia will host 21 of these facilities, the third largest number in any country, after the United States and Russia.

Seventeen of Australia's facilities have already been installed, certified to CTBT standards and are sending data to the International Data Centre (IDC) in Vienna. Plans to install the remaining facilities are in hand. An Australian expert is chairing work to develop procedures for on-site inspections. In May 2010, Australia will host a workshop for regional countries to discuss the work of National Data Centres (NDC) under the CTBT. The workshop will aim both to promote the establishment of NDC capacity in Australia's region, and to help relevant States to complete ratification processes.

The benefits of the CTBTO's IMS are not limited to the detection of possible nuclear tests. Much of the data gathered can have valuable civil and scientific applications. The reliability, global coverage and near real-time function of the IMS makes its data useful for disaster alert. On 12 September 2008, Australia signed an arrangement with the CTBTO under which data from IMS stations can be used by the Australian Tsunami Warning System. As I noted in a meeting with Executive Secretary Tóth on 17 February 2010, we regard the CTBT as one of the most fundamental steps the global community can take to reach the ultimate objective of the abolition of nuclear weapons.

I urge all States yet to sign and ratify the CTBT to do so at the earliest opportunity.

BIOGRAPHICAL NOTE

STEPHEN SMITH
was sworn in as Australia's Minister for Foreign Affairs in December 2007. Prior to this appointment, Mr. Smith held a range of key shadow ministerial positions, including in the portfolios of Education and Training, Industry, Infrastructure and Industrial Relations, Health, Trade, Communications and Resources and Energy. From 1991 to 1992, he was Special Adviser to the Prime Minister and Senior Adviser to the Deputy Prime Minister and Treasurer.

Thirteen years of cooperation with the CTBTO

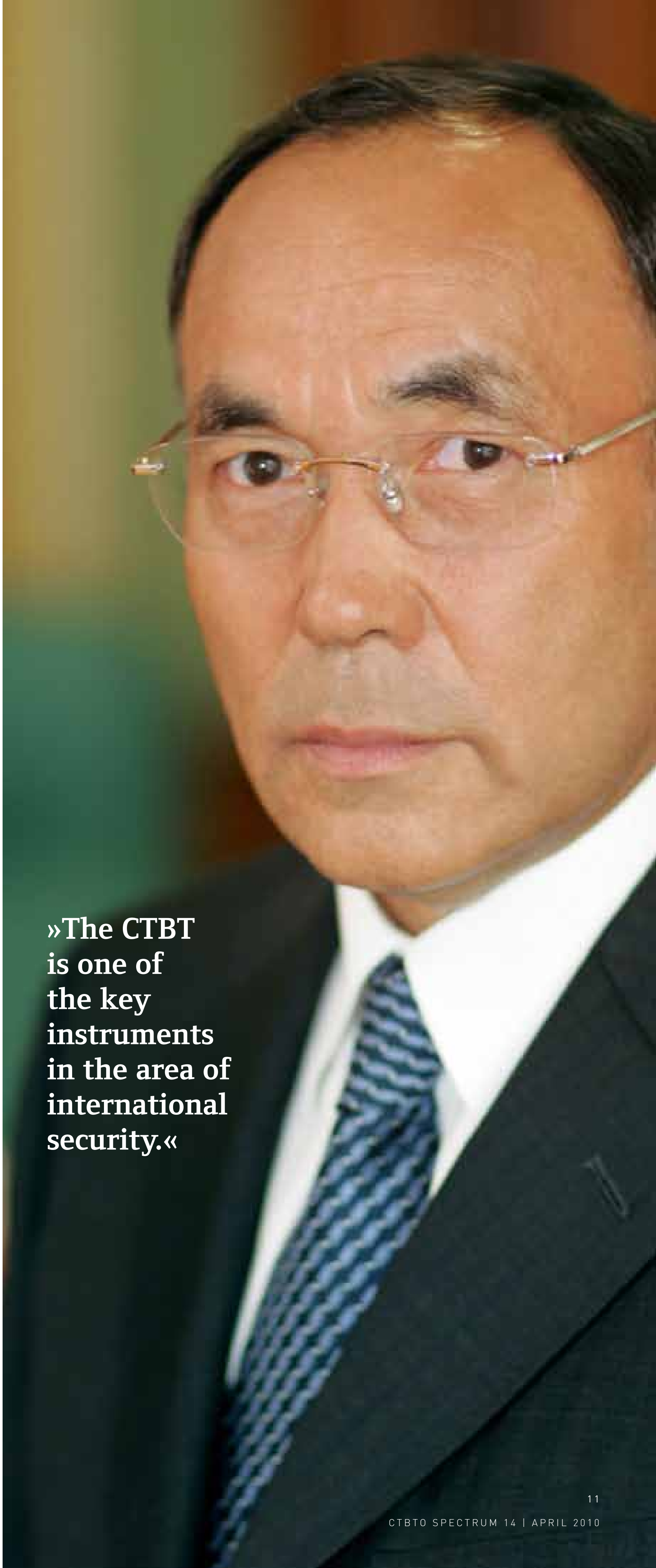
BY KANAT SAUDABAYEV, MINISTER OF FOREIGN AFFAIRS OF KAZAKHSTAN

It can definitely be said that during the 13 years of its existence, the Comprehensive Nuclear-Test-Ban Treaty (CTBT) has brought palpable benefits. This means, in particular, the closure of nuclear test sites. Kazakhstan signed the Treaty in 1996, only a few days after it had been opened for signature, and has remained one of its most steadfast supporters ever since. There is a background to Kazakhstan's firm devotion to CTBT, which explains why our country could not and cannot act in any other way.

KAZAKHSTAN'S COMMITMENT TO A NUCLEAR-WEAPON-FREE WORLD

On 29 August 1991, President Nursultan Nazarbayev of Kazakhstan issued a decree closing the Semipalatinsk nuclear testing site, the second largest in the world. The Soviet Union carried out over 450 nuclear weapons tests at the site between 1949 and 1989, affecting over 1.5 million people.

This decision was followed by the voluntary renunciation of the fourth largest nuclear missile arsenal in the world, which Kazakhstan inherited from the Soviet Union. Since independence, Kazakhstan has also eliminated the infrastructure of the old test site and is actively and systematically



»The CTBT is one of the key instruments in the area of international security.«

Photo: Kirsten Haupt

SEMIPALATINSK, KAZAKHSTAN

The former Soviet Union nuclear test site is pockmarked with craters, remnants of over 450 nuclear weapons tests that were carried out between 1949 and 1989.

promoting the principles and ideals of nuclear disarmament and seeking to rid the world of the nuclear threat. Over the last year, Kazakhstan has further demonstrated its commitment to nuclear non-proliferation. In March 2009, Kazakhstan and the countries of Central Asia made a crucial contribution to the implementation of the Nuclear Non-Proliferation Treaty (NPT) and the CTBT when the Treaty on a Nuclear-Weapon-Free Zone in Central Asia entered into force. The special feature of this zone is that it lies between two major nuclear powers. The zone could play a significant practical role in preventing the uncontrolled proliferation of nuclear materials and combating nuclear terrorism.

In April 2009, President Nazarbayev announced Kazakhstan's readiness to consider the possibility of the deployment on our territory of an international nuclear fuel bank, controlled by the International Atomic Energy Agency (IAEA), the establishment of which could be a decisive step towards strengthening the non-proliferation regime.

Most recently in December 2009, the United Nations General Assembly adopted a resolution proclaiming 29 August the International Day against Nuclear Tests, which was an initiative of Kazakhstan. The date has a deep symbolic significance. It was on that day in 1949 that the first nuclear weapons test was carried out at the Semipalatinsk site and also on that day in 1991 that the site was closed down forever. Our hope is that on this day, activities will take place all over the world to remind the international community of the terrible consequences of nuclear testing and calling on it not to allow any resumption of nuclear tests in the future.

POLITICAL AND TECHNICAL SUPPORT FOR THE CTBT

Since it opened for signature, the CTBT has enjoyed strong support, both politically and practically, from Kazakhstan, which considers it one of the key instruments in the area of international security. We confirm the value of participation in the Treaty and are ready to provide assistance to other countries with those basic aspects of the work of the Preparatory Commission for the Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO), from which we ourselves have gained invaluable experience.

»Together, we must persuade the nine countries that have either not signed at all or have not ratified the Treaty, and without whose participation it is not fully effective, to do so.«

Five monitoring stations, certified in accordance with all the CTBTO's technical requirements, have been established in the territory of Kazakhstan, and are operational under the International Monitoring System (IMS). Data are transmitted directly to the International Data Centre and to the newly established Kazakhstan National Data Centre. Moreover, in support of the Treaty and under an agreement with the United States, two seismic arrays have been set up in western and southern Kazakhstan. An additional eight stations have been restored and modernized and are now operational, including the unique large-aperture seismic array in Borovoe, central Kazakhstan.

The monitoring system set up in Kazakhstan in support of the CTBT made a significant contribution in identifying and assessing the nuclear tests carried out by the Democratic People's Republic of Korea in 2006 and 2009, as well as for both regional and long-range natural and man-made events.

In cooperation with the CTBTO, four field experiments for on-site inspections have also been carried out in Kazakhstan: in 1999, 2002, 2005 and 2008. Kazakhstan made the territory of the Semipalatinsk nuclear test site available for this purpose since it has retained numerous special features from its history of nuclear tests, which have contributed to the success of the exercises.

LARGEST ON-SITE INSPECTION EXERCISE EVER CONDUCTED BY THE CTBTO

Of particular importance was the large-scale Integrated Field Exercise 2008 - IFE08 - conducted at the Semipalatinsk nuclear test site in 2008. IFE08 was a huge logistical undertaking involving the transportation of 200 participants, including 47 inspectors and almost 50 tonnes of equipment, from Vienna to Kazakhstan. It produced unprecedented results. For the international community, it was a unique opportunity to try out, on a multilateral basis, most of the main elements of the inspection system within a short space of time, under real conditions. Kazakhstan also gained considerable experience, which will be used in conducting further field exercises and resolving problems relating to the assessment of the safety of the Semipalatinsk site.

The implementation of CTBTO projects provides an opportunity to use the infrastructure of the former Semipalatinsk nuclear test site to promote international peace and security. The Semipalatinsk site is becoming increasingly popular with observers from various countries since it offers them the opportunity to participate in or attend experiments and programmes carried out at the site. It is our hope that this cooperation with the CTBTO will continue through the development of a methodology for on-site inspections and research into inspection equipment. The CTBTO can and must improve the effectiveness of its operations still further.

We have helped promote the Treaty through five international conferences entitled "Monitoring of nuclear tests and their consequences". These conferences, which have taken place in central Kazakhstan, have been instrumental in providing scientists and specialists from various countries and international organizations with the opportunity to further the interests of the CTBT by discussing, on an operational and systematic basis, current technical and scientific problems relating to the monitoring of nuclear tests.

PROMOTING CTBT UNIVERSALITY

We, for our part, are also prepared to work intensively to promote the Treaty's entry into force as quickly as possible. A key issue for the viability of the IMS is to make the Treaty truly universal. Together, we must persuade the nine countries that have either not signed at all or have not ratified the Treaty, and without whose participation it is not fully effective, to do so. Against that background, the endeavours of the President of the United States of America, Barack Obama, to give new impetus to the process and submit the Treaty to the Senate for ratification provide a good example for others. We hope that this step will meet with success in the near future.

Kazakhstan is a strong proponent of initiatives designed to rid the world of nuclear weapons and in June 2009, President Nazarbayev spoke out in favour of drawing up a new universal treaty on general horizontal and vertical non-proliferation of nuclear weapons involving both nuclear and non-nuclear States.

We welcome the global summit on nuclear security to be held in Washington in April 2010. We hope that participating countries like Kazakhstan will have the opportunity to discuss many questions on the international agenda on non-proliferation and take practical steps towards our common goal – the creation of a world free from nuclear weapons.

This year, Kazakhstan is chairing the Organization for Security and Co-operation in Europe (OSCE). In that capacity, too, we are determined to do everything in our power to ensure the practical implementation of the commitments made by the OSCE on the non-proliferation of weapons of mass destruction, set out in the Ministerial Declaration on Non-Proliferation adopted in Athens in 2009.

As a country that has itself suffered the horrors of nuclear tests, closed the world's second biggest nuclear test site and voluntarily renounced the world's fourth largest nuclear arsenal, Kazakhstan has the full moral right to seek more decisive action on disarmament and a fundamental strengthening of the non-proliferation regime. And it is our belief that the most effective action would be the speedy entry into force of the Comprehensive Nuclear-Test-Ban Treaty.

BIOGRAPHICAL NOTE

KANAT SAUDABAYEV
began his career as a diplomat in 1991, prior to which he had a long career in the fields of government and the arts. Between 1992 and 2007, he served as Ambassador of the Republic of Kazakhstan to Turkey, the UK, and the USA, respectively. In May 2007, Mr. Saudabayev was appointed Secretary of State of the Republic of Kazakhstan, and in September 2009 also became the Minister of Foreign Affairs of the Republic of Kazakhstan.

SEISMIC STATION PS23:
Makanchi, Kazakhstan.

MEXICO

Our longstanding support for the CTBT

BY PATRICIA ESPINOSA CANTELLANO
SECRETARY OF FOREIGN RELATIONS OF MEXICO

After the nuclear annihilation of Hiroshima and Nagasaki on 6 and 9 August 1945 respectively, the world was confronted with the need for a new code of ethics for humanity. The atomic bombs dropped on Japan in 1945 demonstrated the horrific cruelty and devastating effect of nuclear power when it is used for such destructive purposes. Regrettably, the subsequent Cold War and the conflict between the superpowers meant that nuclear power continued to be used for weapons rather than for peaceful applications.

CUBAN MISSILE CRISIS AND THE THREAT OF NUCLEAR WAR

The Cold War was a period in history during which world powers struggled for military superiority and political influence, pushing humankind to the brink of extinction. In this sense, Mexico's longstanding commitment to non-proliferation and nuclear disarmament comes as no accident. The Cuban Missile Crisis of 1962 at the height of the Cold War occurred very close to our shores, making us realize that the threat of non-peaceful uses of nuclear power had no borders, legal limits or moral justification.

NUCLEAR-WEAPON-FREE ZONE ESTABLISHED IN LATIN AMERICA

The promotion of a treaty establishing Latin America as a nuclear-weapon-free zone was, in fact, the by-product of the Cuban Missile Crisis. The main purpose of the Treaty of Tlatelolco, which entered into force in April 1969, is to shield the region and its people from a deliberate nuclear attack. Despite this "safeguard", my country acknowledged that it was not enough. A nuclear confrontation anywhere will definitely have devastating repercussions worldwide.

MEXICO'S LONGSTANDING SUPPORT FOR THE CTBT

In 1993, when the Ad Hoc Committee of the Conference on Disarmament on the Prohibition of Nuclear Tests decided to continue its work with the mandate to negotiate a Comprehensive Nuclear-Test-Ban Treaty (CTBT), Mexico was one of its main proponents. In 1994, Ambassador Miguel Marin Bosh of Mexico presided over the work of the committee. Ambassador Antonio de Icaza was subsequently appointed "Friend of the Chair" during the CTBT negotiations to define the formula for the Treaty's entry into force.

Finally in 1996, after two years of intense negotiations, the CTBT was adopted and opened for signature in September of that year. Mexico was one of the 71 States which signed the Treaty on 24 September 1996, subsequently

HYDROACOUSTIC STATION: *HA06 is located on Isla Socorro which is a 132 km² volcanic island in the Revillagigedo Islands, off Mexico's western coast. HA06 covers large parts of the North Pacific Ocean.*

ratifying on 5 October 1999. The main objective of the Treaty is to ensure the total and worldwide prohibition of all nuclear tests, be it civil, military or any other kind. The CTBT bans testing in all types of environments, with no limitation on duration.

In order to ensure compliance with the Treaty, provisions have been made for the establishment of a verification regime. This includes an international monitoring system capable of detecting nuclear explosions anywhere on the planet, as well as providing for on-site inspections once the Treaty enters into force.

The International Monitoring System (IMS) has already proven its capability of detecting nuclear tests while also demonstrating the benefits of using its network of stations for civil applications in the case of disaster mitigation, such as early tsunami warnings.

CTBT HELPS ENSURE SURVIVAL OF HUMANITY

Unfortunately, the CTBT has not entered into force, partly due to its non-compatibility with the military interests of a few countries. Nonetheless, it represents a milestone in the efforts of humankind to advance towards peace and international security and, above all, to ensure the survival of humanity through the elimination of nuclear tests. The CTBT also helps to prevent the design, development, or modernization of nuclear weapons. Mexico regrets that several States have not yet signed or ratified the Treaty, which is why my country stresses the vital importance and urgency of signature and ratification, without delay and without conditions, to achieve the earliest entry into force of the CTBT. It also calls upon all States to support it and promote the development and operation of the IMS and, pending entry into force, to maintain a moratorium on nuclear tests.

PROMOTING THE TREATY'S ENTRY INTO FORCE

As a testimony of the importance Mexico attaches to the Treaty, my country, together with Australia and New Zealand, presents a resolution proposal aimed at promoting the Treaty's entry into force every year at the United Nations General Assembly First Commission. Since 2002, Mexico has also participated actively in the ministerial meetings to promote the Treaty's entry into force that take place on the margins of the United Nations General Assembly sessions during the years in which Conferences to Facilitate the Entry into Force of the CTBT (Article XIV conferences) are not held. Mexico has also participated in every Article XIV conference since 1999. Various activities have been carried out at the regional level to promote the Treaty, including a seminar organized by Mexico and Canada for the Caribbean region in October 2006. The event allowed participants to exchange experiences regarding

RADIONUCLIDE STATION
RN44, which has recently been constructed at Guerrero Negro, Mexico.

»The IMS has already proven its capability of detecting nuclear tests while also demonstrating the benefits of using its network of stations for civil applications in the case of disaster mitigation, such as early tsunami warnings.«

the Treaty's signature and ratification process, the operation of the National Data Centres in the region and the installation of the IMS stations.

Mexico also participated in the CTBT Workshop on Cooperation which took place in the Bahamas in November 2007, and in the Regional Ministerial Meeting to promote the CTBT, which was held in Costa Rica in September 2008. Both activities aimed at promoting signatures and ratifications of the Treaty. Given that only four Latin American States still have to sign or ratify[1], it proves that political will can help ensure the universality of this instrument.

MEXICO HOSTS FIVE IMS STATIONS

Likewise, my country contributes to the IMS through the installation and certification of monitoring stations, which are foreseen in the Treaty. Three seismic and one hydroacoustic station are now fully operational and sending data in real time to the International Data Centre of the Preparatory Commission for the Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO) in Vienna.

We expect the radionuclide station located in Guerrero Negro to be certified shortly so that it can also start transmitting data to Vienna. Furthermore, Mexico and the CTBTO will soon sign a Facility Agreement for the stations in Mexico's territory.

SIGNIFICANCE OF PRESIDENT OBAMA'S PRAGUE SPEECH

The reappearance of nuclear disarmament on the international agenda is now being observed again after several years of discouragement and frustration. Mexico hopes that, given the current situation, the States included in Annex 2 of the CTBT, which have not yet ratified and must do so before it can enter into force, will reflect on their positions and ratify it as soon as possible.

It is against this backdrop that President Barack Obama's speech delivered in Prague in April 2009 is particularly significant and keeps alive the hopes of the CTBT's early entry into force by affirming that his administration will pursue "immediate and aggressive" ratification of the Treaty by the U.S. Senate.

As a non-nuclear weapon State, we have the right to demand that those States listed in Annex 2 which have not yet ratified the Treaty drop their objections, since the right of the majority of the international community to ensure peace and international security through disarmament cannot be ignored |by only a few.

Ratification by the Annex 2 States represents a solid political sign of strict adhesion to disarmament on the part of the nuclear community.

BIOGRAPHICAL NOTE

PATRICIA ESPINOSA CANTELLANO is a career diplomat who was appointed Secretary of Foreign Relations of Mexico in 2006. From 2002 to 2006 she served as Mexico's Ambassador to Austria and Permanent Representative to the International Organizations in Vienna and from 2001 to 2002 as Mexico's Ambassador to Germany. In 2005, while in Vienna, Ms. Espinosa served as Chair of the CTBTO's subsidiary body that deals with budgetary and administrative matters.

[1] *Editor's Note:*
The only countries in the region that have not yet signed the Treaty are Cuba and Dominica, while Guatemala and Trinidad and Tobago have yet to ratify.

INTERVIEW

Ambassador Stephen Ledogar

talks to Annika Thunborg, Head of Public Information at the CTBTO

New York, November 2009

FRIDAY, MARCH 8, 1996:
U.S. Ambassador to the Conference on Disarmament, Stephen Ledogar, talking about the CTBT to the press at the Palais des Nations, Geneva, Switzerland. (AP Photo/Beatrix Stampfli)

You have had a very distinguished career in the U.S. military and Foreign Service and you were also a chief negotiator of a number of key arms control treaties including the Comprehensive Nuclear-Test-Ban Treaty (CTBT).

It is now 13 years since those negotiations were completed. What is your view of the Treaty today?

I am disappointed that the Treaty hasn't entered into force yet. One of the conditions for the CTBT being signed was a complete moratorium on all testing on the part of all countries participating in the negotiations. Unfortunately, many of those who participated in the negotiations in 1996 figured that since mutual moratoria were already in place, we didn't need to focus on the test-ban anymore but should move on to the next item. They didn't recognize the important advantage that we would have had in terms of stability and additional security if the obligations that are now being honoured were part of international law, as they will be when the Treaty enters into force.

I am also very disappointed with the entry into force paragraph, which was one of the last items we dealt with during the negotiations. The basic problem was that, on the one hand, you had the five confessed nuclear powers – China, France, Russia, the United Kingdom and the United States – who were identified as such in the Nuclear Non-Proliferation Treaty (NPT) and were also the five permanent members of the UN Security Council (P5). And then there were the neutral and non-aligned countries who were particularly concerned that India, Israel, Pakistan, and North Korea should not be named as ones that were essential to the agreement. They were afraid that this would reward them for bad behaviour on other obligations. But we had to find some sort of collective that would say which countries were essential to the Treaty. This problem was exacerbated by the time pressures of trying to get everything finished for the UN General Assembly in New York where the Treaty was to be adopted. The solution that we came up with, while it was approved and signed, doesn't work very well. It is, as you know, a list of countries known as the Annex 2 States, that, as of a certain date, had a particular kind of nuclear reactor for research and development. They must all ratify the CTBT before it can enter into force.

Do you think it would have been possible to have created a different entry into force clause?

It's really a shame that there was such time pressure. Things might have been different if we'd realized that the entry into force requirement was an invitation to certain countries to take the whole Treaty hostage.

One possibility would have been to stipulate, as we did in the Chemical Weapons Convention (CWC), that the CTBT would enter into force once the 65th Member State had deposited its instruments of ratification. The five nuclear weapon States would all need to ratify because the Treaty wouldn't work without their participation.

What about the three de facto nuclear weapon possessors: India, Israel and Pakistan?

You would need to exert heavy political pressure on them but I think they would fall in line with the five nuclear weapon States.

You have defended other provisions of the Treaty on several occasions. In particular, you have said that the verification regime, to a large extent, reflected the U.S. position and the final result resembled what the U.S. would have wanted.

Yes, I think the United States had an important influence, particularly on certain issues. We had a lot of experience in bilateral negotiations in designing verification programmes with the Soviet Union. There was the SALT, the START and the ABM treaty.

A lot of people didn't appreciate that the P5 were holding confidential meetings outside the Conference on Disarmament negotiations. During the last few months of the negotiations, the P5 worked almost full-time on the question of what we would be permitted to do once the Treaty had been signed. Obviously, we were not destroying our

»With the CTBT now firmly back on the U.S. political agenda, the implications of ratification are greater than ever. Approval by the Senate will act as a catalyst for remaining Annex 2 States such as China and Indonesia to ratify, as well as providing the United States with greater leverage over countries of concern.«

stockpiles so we agreed that we would be able to keep them safe and secure and make sure they remained reliable and so forth, right down to the issue of testing the weapons. We finally reached the border line and could not agree on very low-yield tests.

Back in the 1950s in the time of Eisenhower, the United States wanted a moratorium. But we also wanted to continue certain programmes because we were in the process of developing new generations of nuclear weapons for Cold War purposes. The internal U.S. threshold was worked down to no more than four pounds of TNT equivalent yield: that's about the size of a hand grenade. After a short chain reaction, the bomb just fizzles out because you don't have enough electrons to start the multiplication of a chain reaction. Later on during the negotiations, we tried to sell that to the other four permanent members of the UN Security Council but because they were not as sophisticated or as experienced as we were in the very low-yield experiments, they argued that they needed a higher threshold in order to gain any useful data. As far as I remember, the Soviet Union wanted a threshold of 10 tons and the highest threshold request was France, which wanted a limit of 300 tons, probably because they had an on-going testing programme at Mururoa.

We probably wasted six months over the threshold question until August 1995, when President Clinton announced that the United States was revising its position: from then on, the United States went for a "zero" yield. And finally, the French and Chinese stopped testing. The trouble was that the word "zero" had already appeared in the rolling text and the Australian draft proposal, which was the "zero" text and actually, it is the scope of the paragraph of the Australian text which is in the Treaty today.

»I think the CTBT should stand on its own and that should be done as soon as possible.«

Why was it problematic to use the word "zero"?

Because the Russians said that while the United States were pushing for a "zero" threshold, they really meant four pounds. So the Russians were absolutely adamant they would never use the word "zero". They took it out of the text. Instead, Article 1 of the Treaty prohibits each State Party from carrying out any nuclear weapon test explosion or any other nuclear explosion.

The U.S. administration at that time realized that we'd be better off with a comprehensive ban on nuclear testing and it was on that basis that we deployed the new initiative to go to "zero". Actually, it was easy enough because we were just agreeing with the majority who wanted a simple, definable threshold, and things moved very rapidly from then on.

Some of the critics of the Treaty argue that because there is no definition, this is open to interpretation.

That's wrong. During my testimony in favour of ratification before the Senate Foreign Relations Committee in 1999, I explained that the CTBT, as its name suggests, imposes a comprehensive ban on all nuclear explosions, of any size, in any place. Some critics of the Treaty sought to cast doubt on whether Russia, during the negotiation and signing of the Treaty, committed itself under treaty law to a truly comprehensive prohibition of any nuclear explosion, including an explosion/experiment/event of even the slightest nuclear yield. The chief Russian negotiator, Grigory Berdennikov, is even on record as saying that the Russians did not like the word "zero" and that they had embraced a treaty with no threshold whatsoever. And the fact is that the Russians, as well as the other four nuclear weapon States, did commit themselves to the Treaty text. This is substantiated by the record of the negotiations at almost any level of technicality (and national security classification). It is also substantiated by the public record of statements by high level Russian officials as their position on the question of thresholds evolved and fell into line with the consensus that emerged.

Whether any of the five are cheating or not is a different question. And the question is, is it militarily significant? The 2002 National Academy of Sciences report on *Technical Issues Related to the Comprehensive Nuclear Test Ban Treaty* concluded: "Very little of the benefit of a scrupulously observed CTBT regime would be lost in the case of clandestine testing within the considerable constraints imposed by the available monitoring capabilities. Those countries that are best able to successfully conduct such clandestine testing already possess advanced nuclear weapons of a number of types and could add little, with additional testing, to the threats they already pose or can pose to the United States. Countries of lesser nuclear test experience and design sophistication would be unable to conceal tests in the numbers and yields required to master nuclear weapons more advanced than the ones they could develop and deploy without any testing at all."

With the proper expenditure of time, money, intellect and so forth, you can design a verification programme that gives you a high probability of being able to detect any militarily significant cheating. I think that the Preparatory Commission for the Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO) has perfected its verification regime to a large extent. As it becomes more and more precise and the build-up

AP Photo/Donald Stampfli.

718TH PLENARY SESSION OF THE CONFERENCE ON DISARMAMENT, GENEVA, SWITZERLAND, 1995:
from left to right: Michael Weston, British Ambassador to the Conference on Disarmament (CD), Wolfgang Hoffmann, German Ambassador to the CD, and Stephen Ledogar, US Ambassador to the CD

BIOGRAPHICAL NOTE

STEPHEN LEDOGAR worked for the U.S. Foreign Service from 1959 to 1997. He served as Deputy Chief of Mission to NATO from 1981 to 1987 and as Head of the U.S. Delegation to the Conference on Disarmament from 1990 to 1997. He was also the chief negotiator of a number of key arms control treaties including the CTBT. Under Presidents Reagan, Bush and Clinton, Ambassador Ledogar headed U.S. delegations in Vienna and Geneva. Since retiring, he has worked as a consultant to the U.S. Department of State on national security matters.

of the Treaty's International Monitoring System (IMS) approaches completion, it certainly becomes very hard to evade detection by carrying out a clandestine nuclear test. The interplay of the CTBT's four major verification capabilities has a synergy of sorts so you can enhance your capabilities to the threshold which is militarily significant.

I'd also like to reiterate my position on nuclear deterrence, which I believe to be consistent with the CTBT. Through a vigorous programme of what is euphemistically called "stockpile stewardship", you can maintain the reliability and safety of your nuclear stockpile for as far into the future as you can see.

Another argument used by opponents of the Treaty is that a country can refuse an on-site inspection. In your 1999 statement, you argued the opposite: that a country cannot refuse an on-site inspection.

Yes. If I recall, an on-site inspection (OSI) needs to be approved by at least 30 of the 51-member Executive Council. An OSI goes ahead unless you mount a coalition of a certain size to veto it within a certain period of time. In most circumstances, it would be difficult if there was evidence that a State Party had reason to be concerned.

During your testimony speech you talked about the consequences if the United States didn't ratify the Treaty in 1999. All those things actually happened.

That's right. I said there would be jubilation among our foes and despair among our friends. Restraints would loosen on those States with nuclear aspirations and our allies would feel deserted and betrayed. That the NPT regime would be endangered, and that the world would have to brace itself for more Indian and Pakistani tests. And China would not ratify the Treaty.

With the CTBT now firmly back on the U.S. political agenda, the implications of ratification are greater than ever. Approval by the Senate will act as a catalyst for remaining Annex 2 States such as China and Indonesia to ratify as well as providing the United States with greater leverage over countries of concern.

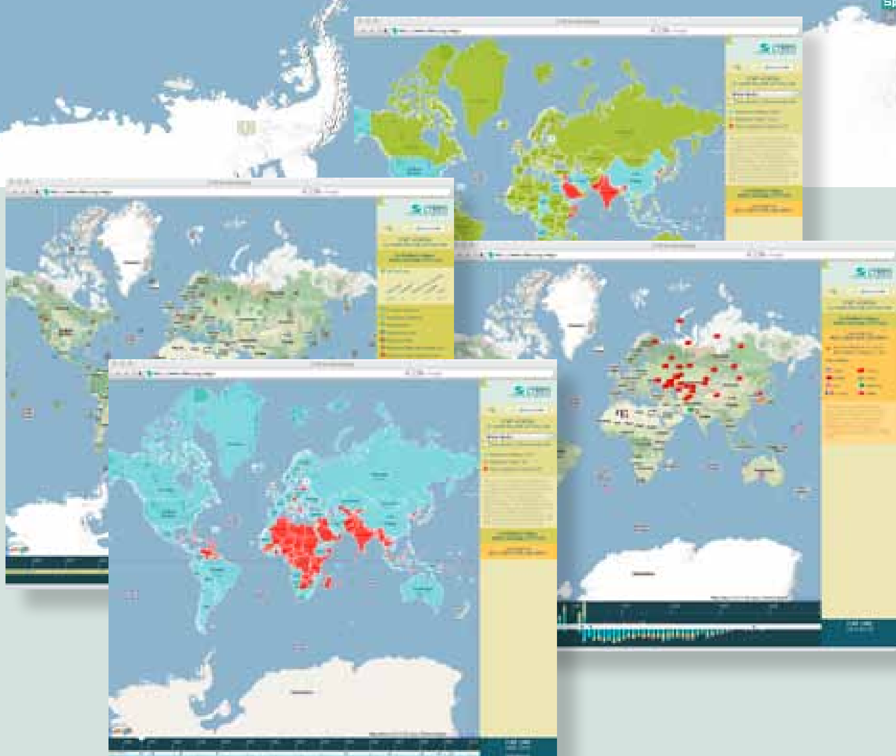
Just a final question: How can we move towards a nuclear-weapon-free world and what role can the CTBT play in helping to achieve that goal?

I'm much more in favour of working towards further reductions in nuclear weapons stockpiles than I was when we were in the middle of the Cold War, which is probably understandable. I think we should do some serious work with the Russian Federation about bringing our own stockpiles down from their current levels. That's what we're seeing right now. But you run into problems. It's very expensive to take apart and dispose of nuclear weapons. Quite frankly, I don't think that we're going to get to zero nuclear weapons in the world in my lifetime but I think that people should continue working towards that goal. I think the CTBT should stand on its own and that should be done as soon as possible.

STATUS OF CERTIFIED IMS FACILITIES
AS OF 6 APRIL 2010

CERTIFIED	TESTING**	UNDER CONSTRUCTION	PLANNED	TOTAL
255	22	27	33	337

- Primary Seismic
- Auxiliary Seismic
- Infrasound
- Hydroacoustic
- Radionuclide
- Radionuclide with Noble Gas *
- Radionuclide Laboratories



NEW GOOGLE MAP FEATURES

A number of new interactive features have recently been added to all the world maps on our website, including:

TIMELINES on different historical aspects of the CTBT and the build-up of its global monitoring system.

MILESTONE EVENTS in the history of nuclear testing.

...and much more!

VISIT ONLINE:
www.ctbto.org/map

IN MEMORY OF

Boris Kvok

Director of the On-Site Inspection Division

Mr. Boris Kvok, Director of the On-Site Inspection (OSI) Division of the Preparatory Commission for the Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO), passed away unexpectedly on 12 February 2010. His untimely departure is deeply felt in his division, the organization as a whole, and in the international non-proliferation and disarmament community of which Mr. Kvok was an active member.

Mr. Kvok was born in 1954. As a Russian diplomat, he was posted to Pakistan (1978-1983), to Australia (1987-1990), and later to Geneva at the Permanent Mission of the Russian Federation to the Conference on Disarmament (1993-1997). He also carried out the function of Deputy Permanent Representative of the Russian Federation to the International Organizations in Vienna (2001-2004), before joining the CTBTO as the Director of the On-Site Inspection Division in August 2004.

His background as a diplomat, and in particular his deep expertise in disarmament issues, enabled him quickly to focus on the strategic questions pertaining to the further development of the OSI regime. Under his leadership, one could note a paradigm shift from a technical and scientific perspective to a holistic and strategic approach. He was able to blend the technical elements of the OSI regime with a diplomatic component.

Mr. Kvok worked tirelessly on highlighting the importance of an operationally ready OSI component as a crucial pillar of the verification regime of the Comprehensive Nuclear-Test-Ban Treaty. During his time as a Director of the OSI Division, the CTBTO successfully carried out a number of exercises and activities, among them the 2008 Integrated Field Exercise for on-site inspections in Kazakhstan. Mr. Kvok's skillful leadership was crucial in conducting this exercise, which was a milestone in moving forward. His vision was clearly focused on reaching OSI readiness at entry into force of the Treaty – this was his main quest.

Being a highly valued professional and respected boss, Mr. Kvok also never forgot to bring in the personal touch to all his interactions. Boris was a beloved gentleman and a true friend who was highly admired by all in his division and within the entire organization. Boris was an extremely popular colleague, leading his division from a conceptual to a more practical approach. His endeavours and zeal for reaching OSI readiness and thus contributing to nuclear disarmament and eventually to a safer world will not be forgotten, but will serve us as a motivation to continue the work he has done so well.

We are confident that as much as Mr. Kvok is remembered for his important work at the CTBTO, he will also be remembered for the endearing friendship and support that he offered to so many people, inside the profession and far beyond it. Mr. Kvok was simply a wonderful human being, a man who had a deep and open curiosity about everything and everyone he met everywhere in the world.

Main lessons from the Integrated Field Exercise 2008

BY JOHN R. WALKER

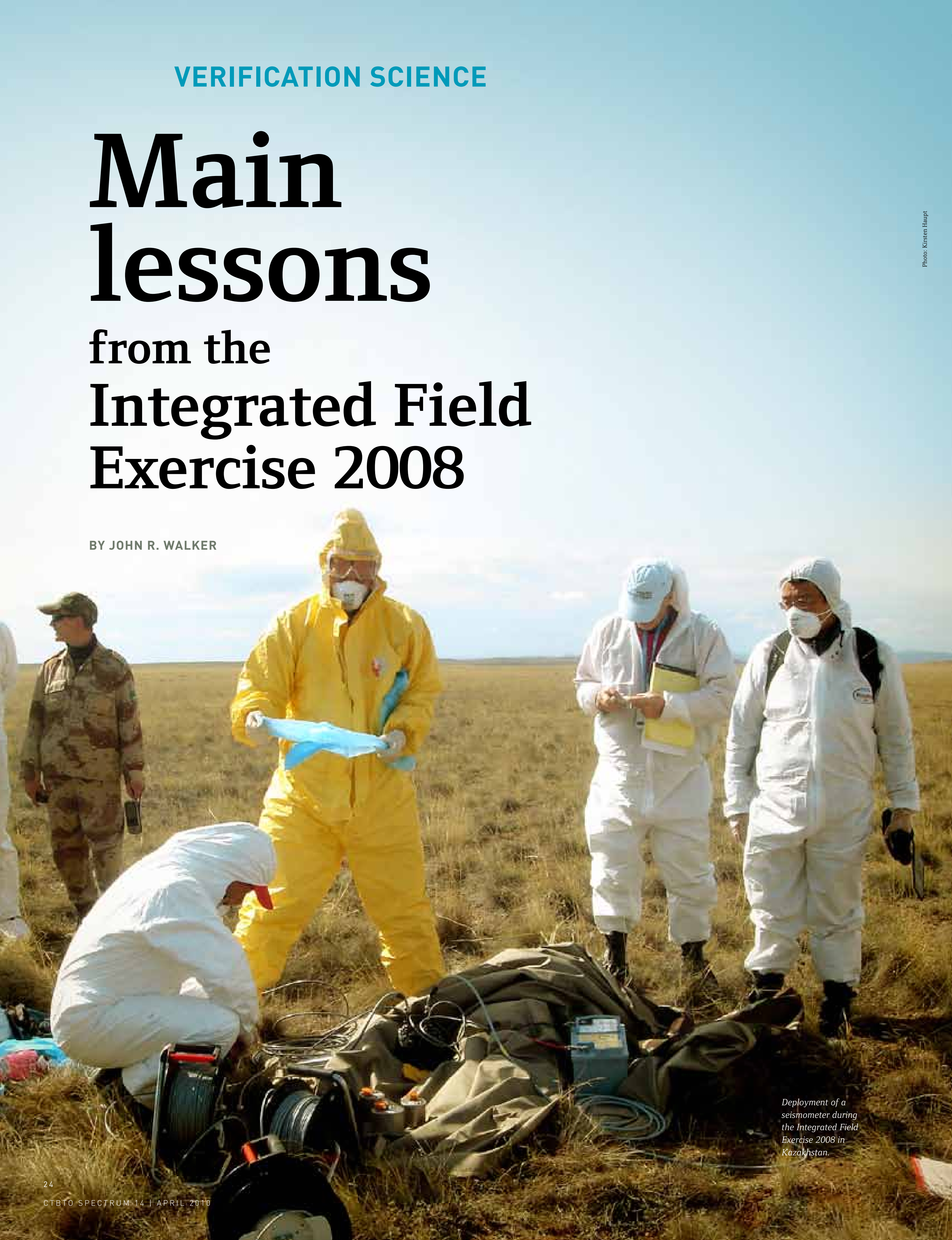


Photo: Kirsten Haupt

Deployment of a seismometer during the Integrated Field Exercise 2008 in Kazakhstan.

»A credible OSI capability will be a key component of the CTBT's verification regime once the Treaty has entered into force, and will serve as a deterrent to cheating. «

In spring 1962, as the newly established Eighteen Nation Disarmament Committee started work, President John Kennedy wrote to his friend and colleague Harold Macmillan, then British Prime Minister and a staunch advocate of a Comprehensive Nuclear-Test-Ban Treaty (CTBT). One of the main problems facing the negotiators was how to deal with large numbers of uncertain seismic events that would be detected by the then envisaged monitoring system. Kennedy told Macmillan:
"No matter how we arrange to detect seismic events that might or might not be nuclear explosions, the only way we can always verify the proposition that a given event is not a nuclear explosion is by on the spot inspection."

Forty-eight years later that statement remains as valid as it was in 1962. Although the early years of CTBT negotiations in the late 1950s and early 1960s witnessed a considerable amount of experimental work on seismological and other means of detecting nuclear explosions, nothing equivalent was done for on-site inspections. For this we had to wait until the establishment of the Preparatory Commission for the Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO) in 1996, which has since conducted a large number of field exercises. These have yielded practical insights into how to plan, mount and conduct an effective on-site inspection (OSI). The Integrated Field Exercise 2008 (IFE08), carried out at the former Soviet nuclear test site at Semipalatinsk, Kazakhstan, was by far the most ambitious and largest CTBT OSI ever conducted. It involved nearly 50 tonnes of equipment and around 200 personnel and generated a vast quantity of information. This article highlights the main lessons, future priorities and action being taken by the CTBTO's OSI Division to implement them.

THE ROLE OF AN OSI

A credible OSI capability will be a key component of the CTBT's verification regime once the Treaty has entered into force, and will serve as a deterrent to cheating. We need to build up a cadre of well-trained and motivated inspectors with the right balance of experience and expertise across a diverse range of scientific and other disciplines. We need robust and reliable equipment that is fit for purpose. And finally, we need logistical support to enable inspectors to be deployed quickly, along with their equipment, to potentially remote and climatically hostile locations.

Inspectors may use several techniques, such as visual observation and gamma radiation detection for detecting residual radioactive contamination, which is needed to help inspectors narrow down the search area. Overall it is the effective and sustained integration of these techniques that is critical for a successful inspection. The IFE08 therefore sought to test how key OSI techniques could be implemented in an integrated manner. In CTBT OSIs, it is the synergy of these techniques that provide the system's strength; if they are applied disjointedly with no attempt to integrate the information gathered, then an inspection's utility is limited. In addition, its prospects of establishing whether the suspect event in question was a nuclear explosion conducted in breach of the Treaty's Article I , which bans all nuclear test explosions and any other nuclear explosion, correspondingly diminishes.

Photo: Kirsten Haupt

NOBLE GAS SAMPLING:
Testing noble gas sampling equipment during the Noble Gas Field Operation Test, Slovakia, October 2009.

TESTING NOBLE GAS DETECTION PROCEDURES

Inspectors drilling a hole to extract air from the ground to be examined for traces of the radioactive noble gas, Argon.

Photo: Kirsten Haupt

IFE08: SOME MAIN POINTS

IFE08 provided some 880 lessons covering a wide range of issues – from matters such as planning and scenarios for future exercises; radiation monitoring; the Seismic Aftershocks Monitoring System; overflights; negotiating and leadership; equipment specifications; design and operation of the Field Information Management System (FIMS) – the computer system used by inspectors to hold, process and present inspection data gathered in the field; size and composition of an inspected State Party's escort team; geophysical surveys; sampling strategies; design and operation of the radionuclide laboratory; logistical support; documentation; health and safety; and media handling. In the subsequent review and evaluation process, we found that in some areas good progress had been made, but in other areas much more is required to bring capabilities up to a higher standard. The Seismic Aftershock Monitoring System worked well and provided valuable data for the inspectors – this is one of the key techniques employed by inspectors in the early stages of an OSI. Deployment of the seismometers and the subsequent data processing all performed satisfactorily.

One of the problems in many arms control verification exercises is realistically simulating features and signatures that would be indicative of non-compliance – especially in a CTBT OSI exercise; or sufficiently anomalous to attract inspectors' attention. A key lesson from IFE08 for the design of future comparable exercises is the need to develop more plausible and technically credible "artificialities". Some of those created for IFE08, although providing a useful prop for testing some of the Treaty's inspection provisions, could have been better developed.

As the Duke of Wellington remarked later in life on his first campaign, "At least I learned what not to do, and that is always a valuable lesson." The whole point of exercises is to establish what remains to be done and where weaknesses lie so that they might be overcome. The CTBTO's OSI Division has an Action Plan in place to implement these lessons and to move forward the level of operational readiness. Pressing ahead with this Action Plan is now a key priority for the CTBTO.

OSI OPERATIONAL MANUAL

The CTBTO's OSI Operational Manual, when finalized, will contain detailed guidance for the future CTBTO, inspectors and an inspected State Party on the preparations for, planning and conduct of an inspection. One of IFE08's main objectives was to test a version of the Operational Manual specifically prepared for the exercise. This was to facilitate further elaboration of the draft OSI Operational Manual to be adopted by the first Conference of States Parties after entry into force of the Treaty. IFE08 showed that much of the Test Manual worked reasonably

THE FINAL STAGE OF IFE08
John Walker [right] during the discussions of the final reporting document at IFE08.

Photo: Kirsten Haupt

well, but that more work is required on some issues, such as definitions of what constitutes the initial overflight.

FUTURE WORK

IFE08 did not address all aspects of the OSI regime. Some techniques (multispectral imaging, radioactive xenon sampling and analysis, active seismometry, gravimetry – a technique that measures relative variations in the Earth's gravitational field – and drilling) and issues (off-site sample analysis and requesting State observer) were excluded. This was largely for financial reasons and because some capabilities have not yet been fully developed for OSI purposes. Insufficient time, too, was available for a fuller testing of the geophysical techniques such as magnetometry and resistivity (an intrinsic property of a material which resists the flow of an electrical current within the material). A priority area for further development is field radioactive xenon sampling and analysis. Identification of radioactive xenon is a strong indicator that a nuclear explosion has taken place.

Further progress was made here after the Noble Gas Field Operation Test in Slovakia in October 2009.

Work is also needed on multispectral imaging so that it might be included in the next large scale exercise. More thought is necessary on the characterization of underground nuclear explosion signatures to assist further operationalization of some OSI techniques

The International Scientific Studies conference in Vienna in June 2009 – a series of independent scientific studies and assessments to address the readiness and capability of the CTBT to detect nuclear explosions worldwide – included a large number of poster presentations on the technologies behind the OSI techniques discussed here. It is clear that there has been significant progress in recent years, which will need to be taken into account as the CTBTO completes its work on building an OSI capability.

OSI READINESS

A key step is to develop a sense of what constitutes an OSI operational capability for the future CTBTO after the Treaty's entry into force. In this context it is reasonable to note that IFE08 itself represented, for all its limitations, a sort of basic capability, albeit one where much more work is needed to improve the performance of an inspection team.

Even here we should not forget that during IFE08, a surrogate inspection team did work professionally and managed to apply many of the OSI techniques specified in the Treaty in an inspection area of 1,000 km^2 in weather and working conditions that at times were harsh.

This was a success in itself and one which bodes well for future work and future such large scale field exercises.

BIOGRAPHICAL NOTE

JOHN WALKER
has worked in the Arms Control and Disarmament Research Unit at the Foreign and Commonwealth Office, UK, since March 1985. He covers CTBT on-site inspection (OSI) issues as well as the Chemical Weapons Convention and the Biological and Toxin Weapons Convention. Dr Walker headed the surrogate inspected State Party team in the Integrated Field Exercise 2008. He has participated in some 60 OSI exercises at numerous nuclear, chemical, biological and defence facilities since 1989.

Reading the waves:

How the CTBTO strengthens its monitoring system with knowledge

BY KIRSTIE GREGORICH HANSEN

Each day Esmeralda Banganan scrutinizes hundreds of waveforms that come in from around the world. She's part of a team of 20 top notch analysts who work at the International Data Centre (IDC) at the Vienna headquarters of the Preparatory Commission for the Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO). Where the average person sees squiggles on a page, Esmeralda sees volcano rumblings or a mine blast from 10,000 km away, as she applies filters to screen out such "noise" and look for telltale signs of nuclear explosions.

Since its inception, the CTBTO has helped thousands of people to develop skills like Esmeralda's – by training staff working at National Data Centres (NDC) across the globe to better understand and monitor their data and, as importantly, to interpret the analyzed information that flows back to them from Vienna. In short, to put meaning to those squiggles, and give NDC staff the expertise to decide if a detected event was a nuclear explosion.

"We want to reach a stage where even countries that don't have monitoring stations are able to receive and understand what Comprehensive Nuclear-Test-Ban Treaty (CTBT) data is all about," Lassina Zerbo the Director of the IDC said.

"It is important for the legitimacy of the Treaty that it is not only the big players that decide whether we are dealing with a nuclear explosion or not. It is important when the Treaty has entered into force that countries that are not nuclear powers know if someone is breaching the Treaty and conducting a nuclear test explosion.

Instead of having one country saying 'I have the proof', we want all countries to have the knowledge to be able to affirm if it was, or was not, a nuclear test," Zerbo said.

One popular support tool in the CTBTO's educational kit is the 'NDC-in-a box', a special software package to help users receive and analyze data. The CTBTO is helping its Member States to use and install the software worldwide.

A WELL-OILED VERIFICATION REGIME

It is said that ‘capacity building' is the essential lubricant of international development. That is certainly the case for keeping the CTBT's monitoring system running smoothly. When complete it will comprise 321 monitoring stations and 16 laboratories, many of them built in remote locations – from tiny islands, to blazing deserts or forested Alps. Those working on the ground need to be equipped with the skills to maintain the stations. The more stations transmitting data to Vienna on a daily basis, the stronger and wider the detection net to catch any signals of a nuclear explosion. The CTBTO helps to train station operators for exactly that purpose. In January 2010 for example, a course took place in Paris, training radionuclide station operators to perform the repairs necessary during the operation of a SPALAX Noble Gas Detector System, designed to pick up radioactivity in the air.

PREPARING FOR THE FUTURE

The targeted training the CTBTO provides is not just about the here and now. It's helping Member States to prepare for the future, the day the Treaty will enter into force. Each year future inspection teams are groomed in preparation for on-site inspections by taking part in on-site technical workshops and training activities.

INFORMATION EXCHANGE

Achieving entry into force and universalization of the Treaty is a key driving force at the CTBTO. Around 25 workshops with the dual aim of increasing the number of signatures and ratifications and achieving the build-up of the verification regime have taken place since 1996, when the Treaty opened for signature. Part of their aim is to encourage States to share and learn from each other's experiences in establishing and operating the stations.

"To try to get more developing countries buying into the Treaty, we need to give them something that interests them," Zerbo said. That has involved a restructuring of the workshops to include ways that the CTBT data can also be used for civil and scientific applications.

Photo: Todd Vincent

LEAD WAVEFORM ANALYST
Member of the Monitoring and Data Analysis team Ezekiel Jonathan analyzes data recieved from IMS stations around the world

The possibilities of establishing tsunami early warning systems for the African and Caribbean regions for example, were discussed at workshops in Namibia, the Dominican Republic and Mexico in 2009.

Other possibilities include assistance for natural disaster mitigation, like volcanic eruptions or earthquake monitoring, or even environmental monitoring to study isotopes of radionuclides that could affect the population's health.

FAST FACTS
CTBTO's Capacity Building Activities

WHO CAN BENEFIT?

- Monitoring station operators
- National Data Centre operators
- Inspection teams in preparation for on-site inspections

WHAT'S PROVIDED?

- Technical support
- Hands on training and workshops
- Hardware, software, including the 'NDC-in-a box' to receive and help analyze data.
- Workshops to promote the universalization of the Treaty and the build-up of the verification regime.
- Ongoing training via e-learning

WHAT WAS THE IMPACT IN 2009?

- Over 400 participants involved in 20 plus workshops and training activities.
- One hundred NDC staff trained through development workshops and advanced capacity building training programmes.
- Nine capacity building systems (computer hardware and equipment) delivered to NDCs.
- Ten scientists, mainly from developing countries trained for three months at the IDC in how to utilize data from Vienna. In turn they provide the CTBTO with an international pool of analysts.
- Three training activities for surrogate inspectors and diplomats to prepare for on-site inspections as well as one technical workshop, one field exercise and two field operational tests.

USING THE WEB FOR E-LEARNING

The learning doesn't stop when the workshops and hands-on-training cease. Through e-learning, the CTBTO provides Member States with 24-hour access to internet based lectures and tutorials covering a wide range of verification-related topics. The project was initiated with European Union funding. Comprehensive e-learning modules are made available in each of the six official United Nations languages.

For more information on upcoming training opportunities visit: www.ctbto.org

BIOGRAPHICAL NOTE

KIRSTIE GREGORICH HANSEN
worked as a journalist before joining the International Atomic Energy Agency (IAEA) in 2002. She worked in the press office and news and information section at the IAEA for seven and a half years. She joined the CTBTO Public Information team in February 2010.

Putting down its digital feet

A CTBTO project offers Member States the keys to better use its knowledge

BY PETER RICKWOOD

INFRASOUND STATION IS32
Training at the infrasound station in Nairobi, Kenya

An automated global monitoring system upholds the Comprehensive Nuclear-Test-Ban Treaty (CTBT) by verifying the absence of nuclear explosions. As the Preparatory Commission for the Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO) expands its monitoring system, it is assisting more people develop the skills to make better use of the information it provides.

In the South Pacific islands of Samoa, Siosinamele Lui is seeking ways to complement the digital output of the CTBTO's International Monitoring System (IMS) with the Lali drum, a large traditional instrument made from the trunk of a tree.

TSUNAMI WREAKS HAVOC ON SAMOAN ISLANDS

The Samoan islands lie less than 200 km north of the Tonga Trench, a subduction zone where the Pacific and Australian plates collide and create one of the deepest undersea canyons on Earth. In September 2009, 143 Samoans died when a tsunami created by a powerful earthquake roared ashore.

The Lali's loud drumming is among the warning signals employed by Samoa, together with the pealing of church bells, radio and television alerts, and text messaging to warn of impending danger from the sea.

Samoa hosts one IMS auxiliary seismic monitoring facility, which transmits data to the CTBTO's International Data Centre (IDC) in Vienna. But the islands don't possess the capability to make use of the data it provides, said Lui, a technical officer in the Meteorology Division of the Samoan Ministry of Natural Resources and Environment and responsible for CTBT data communications and equipment maintenance for Samoa.

SAMOA TO MAKE BETTER USE OF CTBT MONITORING DATA

That's about to change and a pillar of the Samoan response will be to make use of IMS data. Under the terms of the CTBT, the 182 countries that have signed it have access to all the data provided by its four monitoring technologies – seismic, hydroacoustic, infrasound and radionuclide.

However, another Treaty requirement is that although the Vienna-based organization provides reviews of the 10 gigabytes of information that currently flow into its headquarters by satellite from over 250 monitoring facilities every day, it is up to its Member States to pass the final judgement.

NINE COUNTRIES REPRESENTED IN TECHNICAL PROJECT

Last year Lui was invited to represent Samoa at a technical meeting at the CTBTO's Vienna headquarters as part of a project. The project was launched in early 2007 to enable experts from developing countries to attend technical meetings organized by the CTBTO.

Open to CTBTO Member States, nine technical experts now participate from Ethiopia, Kenya, Mexico, Mongolia, the Philippines, Samoa, Sri Lanka, Tunisia and Turkmenistan. Funding is provided by contributions from 19 countries and the Organization of the Petroleum Exporting Countries (OPEC) Fund for International Development.

Meeting with three of the project's technical experts. from left to right Norbert Opiyo-Akech, Siosinamele Lui, Peter Rickwood, Xyoli Pérez-Campos

Photo: Pablo Mehlhorn

PROJECT OFFERS NUMEROUS BENEFITS

Participants gain important professional knowledge about the CTBTO's verification work by attending the meetings, e.g. they learn about the benefits of IDC data and products, including their application for broader civil and scientific purposes. The experts' home countries are thus able to make better use of the verification data and products. Participants and CTBTO technical staff are able to exchange views on a range of technical matters, including specific issues related to IMS stations and National Data Centres (NDCs). The experts' input to its technical meetings is invaluable for the CTBTO and can assist with plans for national implementation of the Treaty.

Lui returned in February 2010 to a second meeting at the CTBTO, when she spoke to *Spectrum*. "It is really opening my eyes," she said. "We didn't know we could get this support – products and programmes, It feeds into [the development of] our own internal structure."

"We had no knowledge about how to set up an NDC," said Lui. "We were sending data to Vienna but we didn't have direct access to our own data. We didn't get it automatically."

GREATER INVOLVEMENT AT THE TECHNICAL LEVEL

Among other technical experts taking part in the project is Xyoli Pérez-Campos, from Mexico, which hosts three auxiliary seismic stations, a hydroacoustic station and a radionuclide station. Pérez-Campos is a researcher for the Seismology Department at the Geophysics Institute of the National Autonomous University of Mexico.

"When I started coming here (in 2008) the relationship started to change. [Previously] my institution didn't know how to approach the CTBTO."

Without the technical expertise, said Pérez-Campos, Mexico "hadn't paid much attention to technical aspects of the CTBTO – we received documents and just looked at them and didn't know their context, the history. Now we comment on them, we are getting more involved in what is going on here [at the CTBTO's headquarters]."

There's also been a strengthening of regional ties as a consequence of her involvement, she said. "I hold meetings with Latin American Missions in Vienna and inform them about what is going on, from the point of view of technical expertise – what I think is important and what is not." As well, technical experts now have a direct line to Vienna, she added.

As point of contact with the CTBTO for Kenya, which hosts one IMS seismic and one infrasound station, Norbert Opiyo Akech said he had remained outside of technical discussions before joining the project. But that changed in 2007 when Opiyo-Akech, a geologist and then Dean of the Faculty of Science at the University of Nairobi and manager of the IMS stations in Kenya, joined the CTBTO's working group concerned with verification issues through the project. In 2008 he was appointed a Task Leader for issues related to NDCs.

REGIONAL WORKSHOP TO BE HOSTED IN KENYA

As a result of his participation in the project, Kenya is now more proactive and more fully involved in CTBTO activities. In May, an NDC evaluation workshop is to be held in Nairobi, Kenya, bringing together emerging NDCs from the region as well as including training activities and demonstrations from NDC operators in Italy, Germany and Austria.

Opiyo-Akech is also a reliable source of information to whom the public turns in a crisis. When Nairobi was affected by tremors associated with the Oldonyo Lengai volcanic activities in northern Tanzania in July 2007, he was woken up at four in the morning and later explained the event on national television in Kenya.

BIOGRAPHICAL NOTE

PETER RICKWOOD
worked for most of his career as a journalist before joining the International Atomic Energy Agency (IAEA) as a press officer in 2001 where he worked for eight years. He has been working in the Public Information section of the CTBTO since October 2009.

Machine learning

for Comprehensive Nuclear-Test-Ban Treaty monitoring

BY STUART RUSSELL, SHEILA VAIDYA AND RONAN LE BRAS

The Comprehensive Nuclear-Test-Ban Treaty (CTBT) is gaining renewed attention in light of growing worldwide interest in mitigating the risks of nuclear weapons proliferation and testing. Since the Preparatory Commission for the Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO) installed the first suite of sensors of the International Monitoring System (IMS) in the late 1990s, the IMS network has progressed steadily, providing valuable support for event diagnostics. This progress was highlighted at the International Scientific Studies (ISS) conference in Vienna in June 2009, where scientists and experts in the CTBT verification technologies met with policy makers to assess the current status of the CTBT's verification system.

In this article, we introduce a few concepts in machine learning and assess techniques that could provide both incremental and comprehensive value for event detection by increasing the accuracy of the final data product. The techniques could also be applied to refining on-site inspection (OSI) conclusions, and potentially reducing the cost of future network operations.

MACHINE LEARNING TECHNIQUES CAN HELP IMPROVE ACCURACY OF IDC'S FINAL OUTPUT

The IMS includes waveform physical sensor stations (seismic, hydroacoustic, and infrasound) connected by a worldwide communications network to a centralized processing system in the International Data Centre (IDC) in Vienna. The IDC operates continuously and in real time, performing station processing (analysis and reduction of raw seismic sensor data to detect and classify signal arrivals at each station) and network processing (association of signals from different stations that have come from the same event). Fully automated processing of the signals to produce a reliable catalogue of event reports is currently beyond the state-of-the-art, so the IDC analysts must post-process the output from the automated system to generate higher quality event bulletins for further distribution. Errors in automated processing include false detections and missed detections caused by station noise; incorrect classification of arrivals; and incorrect associations. Thus, opportunities exist at all levels of the IDC pipeline to apply techniques from machine learning to improve the accuracy of the final output.

We begin by explaining the basic ideas of machine learning, with special emphasis on data-driven and model-driven methods. We clarify how these methods may be applied to improve the performance of various parts of the IDC processing pipeline. Multiple teams at the ISS conference presented preliminary results that demonstrated improvements in phase classification as well as the rejection of spurious associations via some of these methods. Please see **www.ctbto.org/specials/the-international-scientific-studies-project-iss/** for more information.

The second section of the paper proposes a more radical revision of the IDC data processing approach using a model-driven Bayesian methodology[1]. This approach has several potential advantages, including globally optimal association sets, proper handling of non-detections as evidence, improved low-amplitude signal detection and noise rejection, continually self-calibrating sensor models, and optimal fusion of multiple sensor modalities.

We conclude that incorporating machine learning methods into the IDC framework could indeed improve the detection and localization of low-magnitude events, provide more confidence in the final output, and reduce the load on human analysts. The principal obstacles to rapid instantiation of machine learning methods within an operational context, however, are the availability of raw data for testing during algorithm development and the difficulty of evaluating and benchmarking the impact of local

[1] Bayes' theorem is a formal way of including prior knowledge in assessments of probability. It shows that evidence has a strong confirming effect if it was unlikely before being observed.

improvements on the overall system. We outline a programmatic construct for overcoming these hurdles by proposing to coordinate and drive data-related research and development initiatives through a virtual Data Exploitation Centre (vDEC), under the auspices of the CTBTO, for the evolution and evaluation of next generation data processing methods for CTBT verification.

BASIC CONCEPTS OF MACHINE LEARNING

The field of machine learning covers all computational methods for improving performance based on experience. The range of methods and settings is too vast to be sketched here in completeness, but there is a small set of key questions that must be answered when choosing a learning method:

- Which component of the overall system must be improved?
- How is that component represented – e.g. a weighted linear function, a complicated decision tree, or an impenetrable chunk of machine code?
- What existing data are relevant to that component?
- Do the data include the "right answers" – i.e. correct outputs for the component given the inputs?
- What knowledge is already available to constrain the design of the component?

This article examines just two families of methods. The first, supervised data-driven learning, is appropriate for cases where data are plentiful and correct outputs are available, but little is known about the correct design of the component(s). The second, Bayesian model-driven learning, is effective in situations when significant prior knowledge is available; it does not require advance knowledge of the correct outputs for each component.

SUPERVISED DATA-DRIVEN LEARNING

The key idea here is many hundreds of years old: find a hypothesis that maximizes some combination of simplicity and explanation of the data. For example, suppose we want to classify detected seismic signals as **»P waves or S waves«** [see Glossary on p.35]. An unknown function f determines the true classification given the signal. In the supervised setting, we assume that we have a correctly labelled set of data – perhaps obtained from the final **»Reviewed Event Bulletin (REB)«** [see Glossary on p.35] or other authoritative source. The goal of learning is then to find a hypothesis h that is close to f in a precise sense: given a sufficient training set of examples, h should agree with f on the classification of almost all members of a previously unseen test set of unlabelled signals. The framework of machine learning provides guarantees on the possibility of finding such an h and predicts the amount of data necessary to find it.

This seemingly simple task encompasses a large range of activities, roughly characterized by the nature of the inputs, outputs, and the family of hypotheses considered. Supervised machine learning methods are readily applicable to IDC data sets for assisting the final diagnosis. Such methods were illustrated at the ISS conference last June. Several posters showed the value of incorporating off-the-shelf learning and classification methods to improve the accuracy of phase identification in station processing and to detect spurious events formed during network

POSTERIOR DENSITY *(summing over depth and time)*

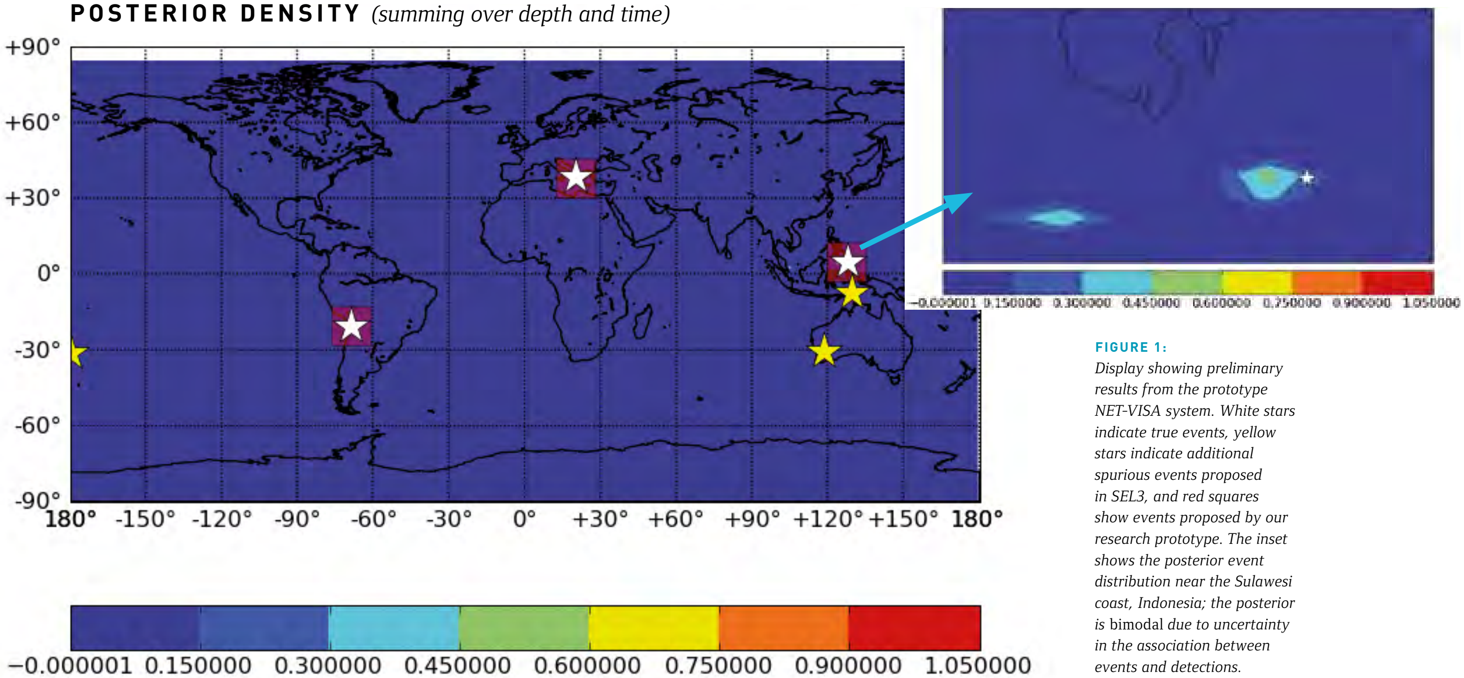


FIGURE 1:
Display showing preliminary results from the prototype NET-VISA system. White stars indicate true events, yellow stars indicate additional spurious events proposed in SEL3, and red squares show events proposed by our research prototype. The inset shows the posterior event distribution near the Sulawesi coast, Indonesia; the posterior is bimodal due to uncertainty in the association between events and detections.

processing. Examples of the benefits from data fusion were plentiful, and design concepts were presented for improving seismic database query processing, borrowing ideas from the Web-search environment. Underscoring the importance of machine learning, the Best Poster award at the conference went to a team that trained neural networks to identify false events in the **»SEL1 bulletin«** [see Glossary].

However, none of these supervised learning methods, as currently conceived, are likely to overcome the fundamental limitations of bottom-up, localized processing of signals and detections. Seismic data analysis on a global scale cannot be decomposed into independent local decisions about detections and associations; the ambiguities inherent in the data are best resolved by a comprehensive analysis of the kind offered by integrated probabilistic inference methods.

Moreover, such methods can easily integrate the best Earth models as well as detailed models of sensor artifacts and failures, and missing data. Such an approach is discussed in the following sections.

BAYESIAN MODEL-DRIVEN LEARNING

When there is substantial prior knowledge available – for example, that of seismic phases and signal propagation – this knowledge can improve prediction accuracy and reduce the amount of data needed for learning. Bayesian methods are well-suited to this context.

In general, Bayesian inference yields a posterior probability distribution over a set of hypotheses given some evidence. In the CTBT setting, a hypothesis might be a collection of seismic events (natural or man-made) occurring over space and time; the evidence is provided by the sensor data. The inference process is based on a model with two components: The **»prior probability distribution«** [see Glossary] over hypotheses; for the CTBT problem, this would include the natural seismicity distribution on Earth. The conditional probability distribution for the evidence given each possible hypothesis; in our case, this part of the model describes how signals propagate through the Earth and how they are detected by sensors, as well as the ways in which noise signals arise. In seismology, this is often called the forward model.

Bayes' rule simply multiplies these two components together to give the posterior probability distribution over the set of hypotheses, given the available evidence. Because there are infinitely many possible hypotheses (each a set of seismic events), the calculations involved are nontrivial and require efficient inversion of the forward model.

As a side effect of the inference process, the Bayesian approach generates information that can be used to continuously adapt the model to better explain the data. This adaptation requires no **»ground truth«** [see Glossary] (unlike supervised learning methods) and hence provides a technical foundation for continuous self-calibration and sensor diagnostics.

VERTICALLY INTEGRATED SEISMIC ANALYSIS

While the current IDC data analysis pipeline is functioning effectively, we believe that its overall serial nature imposes unnecessary limitations on system performance that can be largely overcome by a vertically integrated probabilistic approach. Recent advances in modelling capabilities and in general-purpose inference algorithms such as »Markov Chain Monte Carlo (MCMC)« [see Glossary] suggest that it is in fact possible to address problems as complex as seismo-acoustic event detection via a completely integrated, model-based probabilistic system derived from first principles. A research prototype system (Network Vertically Integrated Seismic Analysis – NET-VISA – for CTBT verification) is currently under development with the goals of testing it within the IDC domain.

Once data samples – currently, just the IDC arrival detections but eventually the full waveforms – are supplied to the system, MCMC probabilistically infers a posterior distribution over possible event locations, times, and magnitudes. In essence, MCMC efficiently samples over hypothetical worlds to obtain estimates that converge to the true posterior given the evidence. The fact that MCMC computes posterior probabilities – the best possible answers given the data – takes the algorithm itself off the table; to get better answers, one must either improve the model or add more sensors.

One important benefit of the vertically integrated approach is that signals need not be analyzed at each station in isolation. Suppose that a hypothetical event has been formed from detections at three other stations, such that the event's location, time, and magnitude imply an arrival at a fourth station in a given time window. If a signal is present – even well below the usual signal-to-noise-ratio threshold – it can be picked out and associated with the event. On the other hand, if no signal is present, the event may be disconfirmed by the (absence of) evidence. The smaller the window, the more pronounced this effect will be. Thus, a strong, and thus far unexploited, interaction exists between the accuracy of the travel time model and the ability to pick out signals from noise at a particular station.

The NET-VISA research prototype has been tested on a small two-hour segment of parametric data from the IDC (i.e. above-threshold P-wave detections, rather than raw waveforms). The segment includes three events that generated three or more arrivals, and the prototype recovers all three perfectly. In comparison, the IDC **»SEL3 bulletin«** [see Glossary] includes three additional events which are not well supported by the evidence (see FIG. 1). On a more comprehensive test with a week's worth of data comprising nearly thousand events, NET-VISA showed significant gains in detection sensitivity compared to SEL3, particularly at lower magnitudes.

VIRTUAL DATA EXPLOITATION CENTRE

Based upon the information above, we believe that the CTBTO could benefit greatly from a strategic thrust focused on improving techniques for processing IMS and on-site inspection (OSI) data sets, taking into consideration the state-of-the-art in machine learning, the advances in data structures and query techniques, and the shaping of sensor data for more accurate exploitation and inference. The long-term goal of such an effort should be to assist the CTBTO analyst in making more robust and expedient decisions, aided by a historical perspective, in the face of rapidly growing multi-sensory information and the importance of more accurate and timely event characterization. To facilitate such an endeavour, a valuable next step will be the creation of a virtual Data Exploitation Centre (vDEC) hosted by the IDC, which will connect international experts (academic, government, and commercial) in different disciplines with the IDC/OSI framework, to assess, develop and implement upgrades to the current data processing infrastructure for event detection and localization. vDEC's charter will be to advance the state-of-the-art in data processing in coordination with the operational arm of the IDC so as to provide a smooth transition from research into the production environment.

THE WAY FORWARD

We have summarized applications of machine learning to CTBT verification, including near-term improvements to components of the current IDC pipeline, as well as a more substantial architectural overhaul based on vertically integrated probabilistic models that connect underlying seismic events to measured signals. Such models could improve seismic phase classification, identify spurious associations through global optimization, characterize station drift/noise, use the absence of detections to disconfirm hypotheses, perform time-localized »sub-threshold« signal detections, combine multiple inputs, and cumulatively, lower the threshold for event detection and localization. Taken a step further, continuous sensor self-calibration could lead to better sensor design and layout and potentially mitigate the cost of future network operations.

To coordinate and guide machine learning and data exploitation methods development in support of Treaty verification, we recommend a focus centre (vDEC) under the CTBTO umbrella, which will leverage multidisciplinary expertise to incubate, test and evolve next generation data solutions for IDC/OSI missions.

GLOSSARY

GROUND TRUTH:
Seismoacoustic sources whose location, depth and origin time, (together with their uncertainties), are known to high precision, either from non-seismic evidence, or using exceptionally good coverage of seismometers close to the event.

MARKOV CHAIN MONTE CARLO (MCMC):
is a technique for generating random samples from a specified probability distribution by simulating a Markov chain. A Markov chain is a mathematical model for a probabilistic system whereby the next state of the system depends only on the current state and not on the previous states.

P (PRIMARY) WAVES AND S (SHEAR OR SECONDARY) WAVES:
P waves are compressional and analogous to a sound wave in air or water. They can pass through any kind of material. S waves move perpendicular to the direction of the waves' propagation and can only exist in the solid Earth.

PRIOR PROBABILITY DISTRIBUTION:
*reflects the probabilities one assigns to a set of hypotheses before seeing any evidence; the *posterior* probability distribution reflects the revisions to the prior in the light of specific evidence.*

REVIEWED EVENT BULLETIN (REB):
A bulletin listing events and signal measurements at each station that detected an event, derived from waveform data that have been reviewed by a human analyst.

STANDARD EVENT LIST (SEL):
A bulletin listing events based on the processing of waveform data. The first Standard Event List, SEL1, includes seismic and hydroacoustic data. Based on SEL1, additional seismic data may be requested from auxiliary seismic stations. Results listed in SEL2 also include the processing of auxiliary seismic and infrasound data. The third list, SEL3, adds processing of data arriving late from all monitoring stations.

BIOGRAPHICAL NOTES

STUART RUSSELL
joined the University of California, Berkeley, USA, in 1986, where he is the Chair of Electrical Engineering and Computer Sciences. Dr. Russell is a winner of the Computers and Thought Award, the principal research award in artificial intelligence, and co-authored the standard textbook in the field of artificial intelligence.

SHEILA VAIDYA
is Deputy Programme Director of Non-proliferation at the Global Security Principal Directorate, Lawrence Livermore National Laboratory, California, USA. During her career, Dr. Vaidya has built programmes in data exploitation, remote sensing, high performance embedded computing, integrated circuit manufacturing, quantum electronics, and semiconductor materials, devices and circuits.

RONAN LE BRAS
joined the CTBTO's International Data Centre (IDC) in 2001 and is now Head of the Software Integration Unit. Dr. Le Bras has contributed key items to the IDC system and managed projects and teams in nuclear monitoring for the past 16 years.

Humpback whale

Using hydroacoustic stations to monitor large whales

A case study in the South West Indian Ocean

BY FLORE SAMARAN

The hydroacoustic network is a key component of the International Monitoring System (IMS). The network contains 11 stations to monitor compliance with the Comprehensive Nuclear-Test-Ban Treaty (CTBT) in the world's oceans. IMS hydroacoustic stations around the world collect a wide range of signals from numerous sources, including large whale vocalizations, that could be used for scientific applications. By providing critical information on these endangered species, IMS hydroacoustic data could be of great significance.

MOST LARGE WHALE POPULATIONS REMAIN AT LOW LEVELS

Overexploitation during the 20th century from commercial whaling reduced large whale populations to a fraction of their original number. Despite gaining complete international legal protection several decades ago, most large whale populations remain at low levels and their recovery is uncertain. Today, basic knowledge regarding the distribution, abundance, specific habitat preferences or migration patterns of many large whale populations is very limited. Monitoring these mammals to evaluate their post-whaling recovery remains difficult due to their wide-ranging distribution, low density, extensive migration, difficult visual identification, and inaccessibility. However, the long-term deployment of passive acoustic recorders has proved to be a very efficient and non-intrusive way to assess and monitor large whale populations over ocean basins and for long periods.

ADVANTAGES OF PASSIVE ACOUSTIC MONITORING

Most of the year large whales emit low frequency calls (10-100 Hz) with high intensity, which propagate over ranges of many hundreds of kilometres. Using passive acoustic monitoring to assess whale populations has several benefits in comparison with conventional survey methods (i.e. visual sightings). The animals can be studied continuously without any negative impact. This method is also less dependent on weather conditions than visual methods and does not rely on animals surfacing in order to be detected. It can be applied globally, including remote areas where visual sightings are usually either too sparse to be relevant, difficult, or costly. Other advantages of passive acoustic monitoring are that it helps to identify areas of concentration, assesses seasonal occurrence and distribution patterns, and can facilitate the long-term monitoring of whale abundance through variations in call rates over the years.

POSSIBLE SCIENTIFIC APPLICATIONS OF IMS HYDROACOUSTIC DATA

IMS hydroacoustic stations record whale sounds around the world, including remote locations such as sub-tropical or sub-Antarctic areas. These stations have been making such recordings continuously for several years. They therefore represent a unique data set for obtaining critical information on large whales. Studying IMS hydroacoustic data for biological purposes helps to expand our knowledge on the occurrence

and movements of large whales on an ocean-wide scale. Moreover, multi-year acoustic monitoring using IMS data should facilitate the assessment of large whale population sizes and trends. This new and valuable information could be helpful for determining the conservation status and the management of these important species. In addition, such studies could improve the CTBTO's processing efficiency by characterizing hydroacoustic events and periods of important large whale vocal activity.

MONITORING THE AREA AROUND THE CROZET ISLANDS

To test and carry out this kind of research, data recorded by the IMS hydroacoustic station located near the Crozet Islands in the southern Indian Ocean - HA04 (FIG. 1 – see overleaf) from May 2003 to April 2004 were made available to the CNRS-Centre d'Etudes Biologiques de Chizé (Villiers en Bois, France). The data were provided by the Commissariat à l'Energie Atomique (CEA) centre DAM-île de France (Bruyère-Le-Châtel, France) within the framework of the South Indian Ocean biological noise identification and characterization project[1].

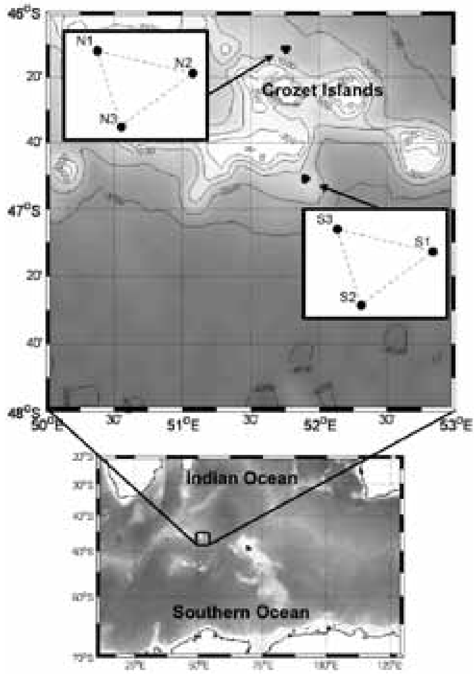
[1] The IMS data have been made available through the CEA under contract. The information released in this article conforms to the conditions set forth in the contract.

HYDROACOUSTIC MONITORING

Hydroacoustic technology is used to measure changes in the water pressure caused by sound waves. Data obtained from hydroacoustic monitoring provide information on the location of a nuclear explosion underwater, near the ocean surface or near its coasts.

WATCH ONLINE:
ctbto.org/hydroacoustic

FIGURE 1:
Location of the two arrays of the IMS hydroacoustic station HAO4 moored in the South West Indian Ocean near Crozet Islands.



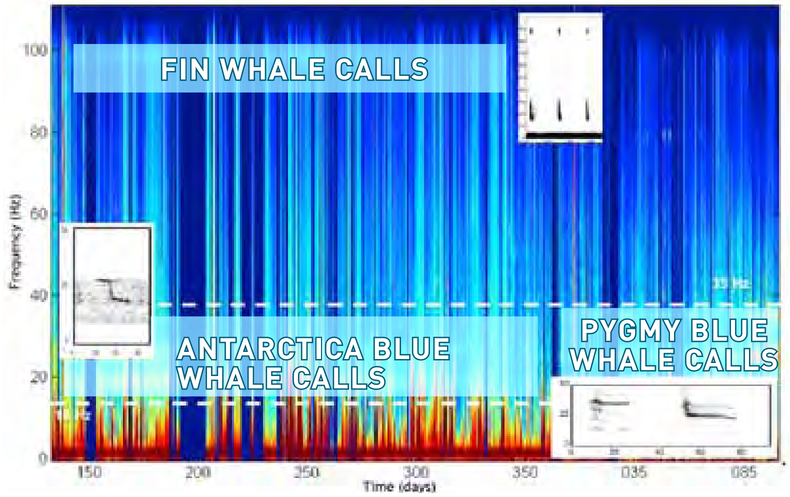


FIGURE 2:
Spectrogram of one year of acoustic data recorded at HAO4 which contained different specific sounds produced by large whales and detected with a seasonal occurrence.

The main objective of the research was to identify biological noise. Monitoring the area around the Crozet Islands is particularly interesting for baleen whale biology and ecology. This is because it encompasses two main but poorly monitored whale sanctuaries created by the International Whaling Commission for the preservation of habitats of whale species, which were decimated extensively as a result of whaling.

Simple spectrogram observations from these long-term acoustic recordings have revealed that the low frequency (< 100 Hz) sea noise spectrum was dominated by a band of sound at 15-35 Hz, corresponding to large whale vocalizations (FIG. 2). Five species, sub-species and sub-populations of calling whales were also identified based on their similarity to large whale calls, which had been previously recorded in the Southern Hemisphere (i.e. the fin whale, the Antarctic blue whale and the pygmy blue whale 'Madagascan' type, 'Australian' type, and 'Sri Lanka' type).

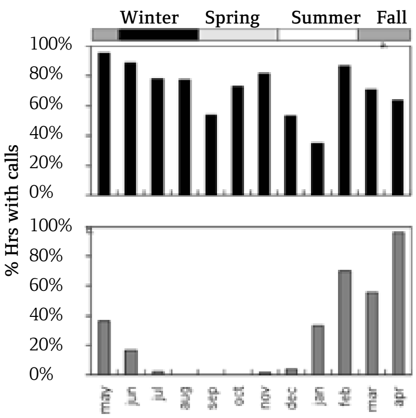
WHALE VOCAL ACTIVITY FOUND TO BE HIGHLY SEASONAL

Each call type exhibited a variation in occurrence and intensity over the recorded period. Algorithms for automatic whale call detection, extraction and discrimination have been developed and used on the available data in order to assess the seasonal occurrence of each large whale species, sub-species and sub-population. Vocal activity was found to be highly seasonal and varied according to the species (FIG. 3). Results have revealed the seasonal occurrence and migration patterns of whales, providing information about ecology and habitats in this former commercial whaling area. Fin and Antarctic blue whale calls were recorded all year-round indicating their continuous presence in the region, which contradicts the migration pattern attributed to these species. Three geographically distinct types of pygmy blue whale calls were recorded only during summer and autumn. The 'Madagascan' type call was the most frequently recorded while 'Sri Lankan' and 'Australian' type calls recorded in this area suggest basin scale longitudinal and latitudinal movements. During spring and summer, blue whale calls were often associated with the high frequency 'D' call, which has been attributed to feeding activity. The co-occurrence of fin whale and blue whale sub-species during the summer has highlighted the importance of this productive sub-Antarctic area as a large whale hotspot, providing new insights into blue whale seasonal distribution and segregation.

ANTARCTIC BLUE WHALE

Photo: Kate Stafford

FIGURE 3: *Spectrogram of one year of acoustic data recorded at HAO4 which contained different specific sounds produced by large whales and detected with a seasonal occurrence.*



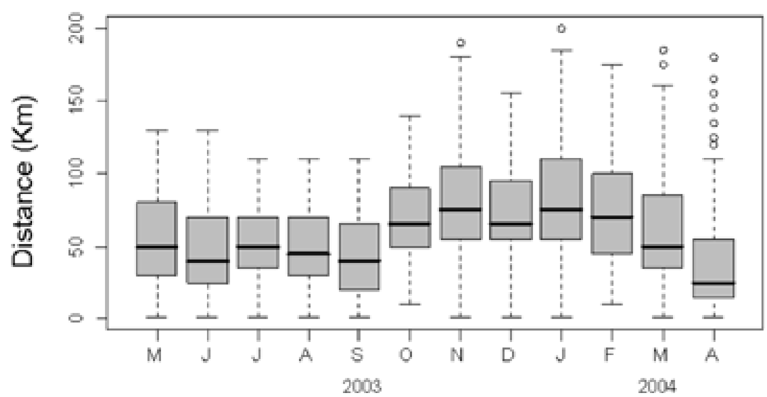


FIGURE 4: *Distribution of the ranges where Antarctic blue whale were detected on the northern array of HA04 using the range-dependant acoustic model.*

FIRST REPORTED SOURCE LEVEL ESTIMATIONS FOR BLUE WHALES IN THE INDIAN OCEAN

In addition, the triangular configuration of the calibrated hydrophones of HA04 (FIG.1) has permitted localization methods to be applied in order to track calling whales and to estimate the movement and detection range between the recording system and the animals. Such data are critical to study the habitat of calling whales without human disturbance. The differences in arrival times of the signals at the three hydrophones were used to calculate the location of whales. The sound levels of received calls may also be used to estimate the level of sound emitted by the vocalizing whales. These were the first reported source level estimations for blue whales in the Indian Ocean.

A mathematical model – a range-dependent acoustic model (RAM) – was used to predict how sound levels changed with distance between vocalizing whales and IMS receivers. This approach allowed the size of the monitored area to be estimated. The maximum detection area of the whale calls was estimated within a radius of 200km. Over the course of the year, acoustic detection ranges varied according to the whale species; e.g. pygmy blue whales seemed to be present closer to the station than Antarctic blue whales. The distribution of the estimated distances confirmed the presence of whales close to the Crozet Islands, showing the importance of this sub-Antarctic area for these endangered species especially during the austral summer feeding season (FIG. 4).

To conclude, this case study highlights the value of some of the possible scientific applications of IMS hydroacoustic data, which have provided a unique data set for obtaining crucial information on large whales. The study also demonstrates how the CTBTO and the scientific community can both benefit from close cooperation. Further monitoring of these endangered mammals on a larger scale could provide valuable information about their seasonal occurrence, distribution and relative abundance.

FLORE SAMARAN *after helping to moor automated hydrophones in the southern Indian Ocean in January 2010. The hydrophones record seismic activity and biological sounds.*

BIOGRAPHICAL NOTE

FLORE SAMARAN
is a post-doctoral researcher at the Centre d'Études Biologiques de Chizé in France. Dr Samaran specializes in bioacoustics and whale conservation and uses passive acoustics to study blue whale distribution in the Southern Hemisphere.

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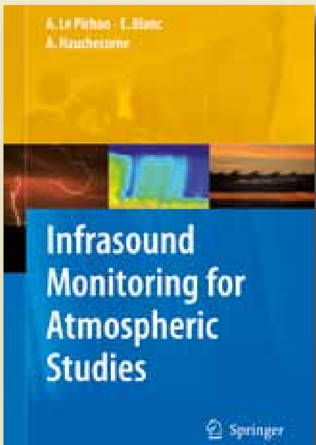
BOOK REVIEWS

Infrasound Monitoring for Atmospheric Studies

Edited by Le Pichon, A; Blanc, E; Hauchecorne, A.
Published by Springer in January 2010. 735 pages



This publication provides a unique review of the latest infrasound-related research such as instrumentation, engineering, signal processing, source monitoring, propagation modelling, atmospheric dynamics, global changes, and remote sensing methods. A number of experts in the field have contributed to this publication, which also describes ways in which this important research can contribute to Comprehensive Nuclear-Test-Ban Treaty (CTBT) infrasound monitoring.

Over 70 percent of the 60 stations making up the International Monitoring System's (IMS) infrasound network are now operational. The IMS infrasound stations monitor the atmosphere for signs of a nuclear test by measuring sound waves at frequencies below the hearing threshold of humans. The potential of this network is unprecedented in terms of its detection capability, which has greatly increased the interest in infrasound technology around the world. Infrasound technology can also help detect volcanic explosions, thus contributing to aviation safety, as well as assisting in the detection of other man-made and natural events on the Earth's surface including chemical explosions, meteors entering the atmosphere, severe storm systems and aurorae. By supporting studies of meteorological phenomena, infrasound data can also contribute to climate change research.

For more information please see:
www.springer.com/earth+sciences+%26+geography/book/978-1-4020-9507-8

Recent Advances in Nuclear Explosion Monitoring

Edited by Becker A, Schurr B, Kalinowski M, Koch K, and Brown D
Published by Springer in April 2010, 245 pages

This publication provides a follow-up to a series published in *Pure and Applied Geophysics* between 2001 and 2002, highlighting significant advances since then in fields of research related to nuclear test ban monitoring. Progress made in seismo-acoustics is addressed, with additional papers on radionuclide monitoring and atmospheric backtracking. It also explores how recent developments have enabled a better understanding of the characteristics of the 2006 North Korean nuclear test. Several experts in the CTBT verification technologies have contributed to this publication.

There has been considerable progress in nuclear explosion monitoring, especially noble gas monitoring, which was considered to be in its infancy when the CTBT opened for signature in 1996. The International Monitoring System now includes over 50 radionuclide and 20 radioxenon stations, which are fully operational and sending data to the International Data Centre. Progress in the development and testing of new radionuclide measurement systems and methods to determine the region of origin of a suspicious radionuclide improves the detection, location and characterization capabilities of the CTBT verification regime. It also provides entirely new insights into the origin of background concentrations (i.e. whether the radionuclides are from natural or human sources), especially CTBT relevant noble gases.

For more information please see:
www.springer.com/birkhauser/geo+science/book/978-3-0346-0370-6

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The exhibition features the history of nuclear testing and the arduous path to adopting the Comprehensive Nuclear-Test-Ban Treaty (CTBT). It provides realistic impressions of the CTBT's globe-spanning alarm system that monitors the planet for signs of a nuclear test. It also shows how the system promptly detected the two recent nuclear explosions in North Korea. And it illustrates how the state-of-the art technologies can help make a difference in people's everyday lives.

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