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CTBTO SPECTRUM

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HOSHYAR ZEBARI

IRAQ'S FOREIGN MINISTER

THOMAS R. PICKERING

FORMER U.S. UNDER SECRETARY OF STATE FOR POLITICAL AFFAIRS

TIBOR TÓTH

CTBTO EXECUTIVE SECRETARY

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

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

As of June 2013, 183 countries had signed the Treaty and 159 had ratified. Of the 44 nuclear capable States which must ratify the CTBT for it to enter into force, the so-called Annex 2 countries, 36 have done so to date while eight have yet to ratify: China, the Democratic People's Republic of Korea, Egypt, India, 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. As of 3 June 2013 over 85 percent of the facilities of the International Monitoring System (IMS) were operational.

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ANNIKA THUNBORG
CTBTO SPOKESPERSON

When North Korea announced that it had conducted its third nuclear test in February, CTBTO Member States had already been informed. So had the media. Over the years, the CTBTO has become a reliable, credible and swift source of information for any journalist who follows nuclear issues - be it nuclear tests or a nuclear accident such as Fukushima – or any other man-made or natural phenomenon that our global monitoring system picks up.

The unique information registered by our infrasound sensors when a meteor exploded over central Russia in February appealed to new audiences. The video we produced went viral on YouTube and was watched by outer space geeks and entertainment buffs alike. The media and online interest was unprecedented: in February alone, the number of press reports exceeded 2,500 plus broadcast coverage by CNN, BBC and other major networks. With the detection of radioactivity in April that could be attributed to the North Korean test, interest surged again.

Naturally, these results are due to the impressive performance of the CTBT verification regime. But they are also due to the advocacy work developed by CTBTO Public Information over the years.

From having been reactive, public information has become proactive, strategic and transparent. The public website has been turned into a "one-stop-shop" for everything relevant to the CTBT, including the history of nuclear testing and its effects on human health and security, the history of arms control efforts, the current debate on entry into force, and daily press clippings.

We soon discovered that video-audio, animations and multimedia were the ideal means to explain the complexities of the verification regime. We built up video-audio capabilities from scratch and produced broadcast quality reports from the on-site inspection exercise in Kazakhstan, maintenance work at stations in Greenland, Argentina and Canada, and the triple disaster in Japan in March 2011. Social media were embraced and online campaigns such as the "infamous" nuclear test anniversaries helped reach millions of new, young viewers, including audiences in countries less accessible through the traditional media.

Exhibitions were set up for visitors to the UN in Vienna, New York and Geneva. CTBTO Spectrum *developed into a professional and intellectually stimulating magazine.*

These developments would not have been possible without the support of Member States, colleagues in the technical divisions who have mainstreamed public information into their activities and have contributed through articles, blogs, interviews and visuals, my professional and dedicated team of ten staff members and consultants plus interns. The transformation also had the full support of the Executive Secretary Tibor Tóth and his successor, International Data Centre Director Lassina Zerbo, who both understand how crucial advocacy is for achieving the objectives of the CTBTO, for completing and enhancing the performance of the CTBT verification regime and for promoting the universality and entry into force of the Treaty.

The debate about the CTBT has always been vibrant in the United States with the participation of all aspects of society. Recently, we have also witnessed a stronger engagement in Asia, including China, India and Pakistan, and partially also in the Middle East. The media reports and publishes op-eds, and experts and students visit the CTBTO where they receive in-depth briefings. I expect this trend to continue.

I hope you will enjoy the articles in this issue – each one of which develops a topic touched upon above. Iraq's Foreign Minister Hoshyar Zebari reports on the Iraqi Parliament's steps towards ratification. Ambassador Thomas Pickering, who helped the Kennedy administration draft the Partial Test Ban Treaty, describes how much the United States has to gain from ratifying the CTBT. Zia Mian from Princeton University focuses on the role of civil society in South Asia in advocating nuclear disarmament.

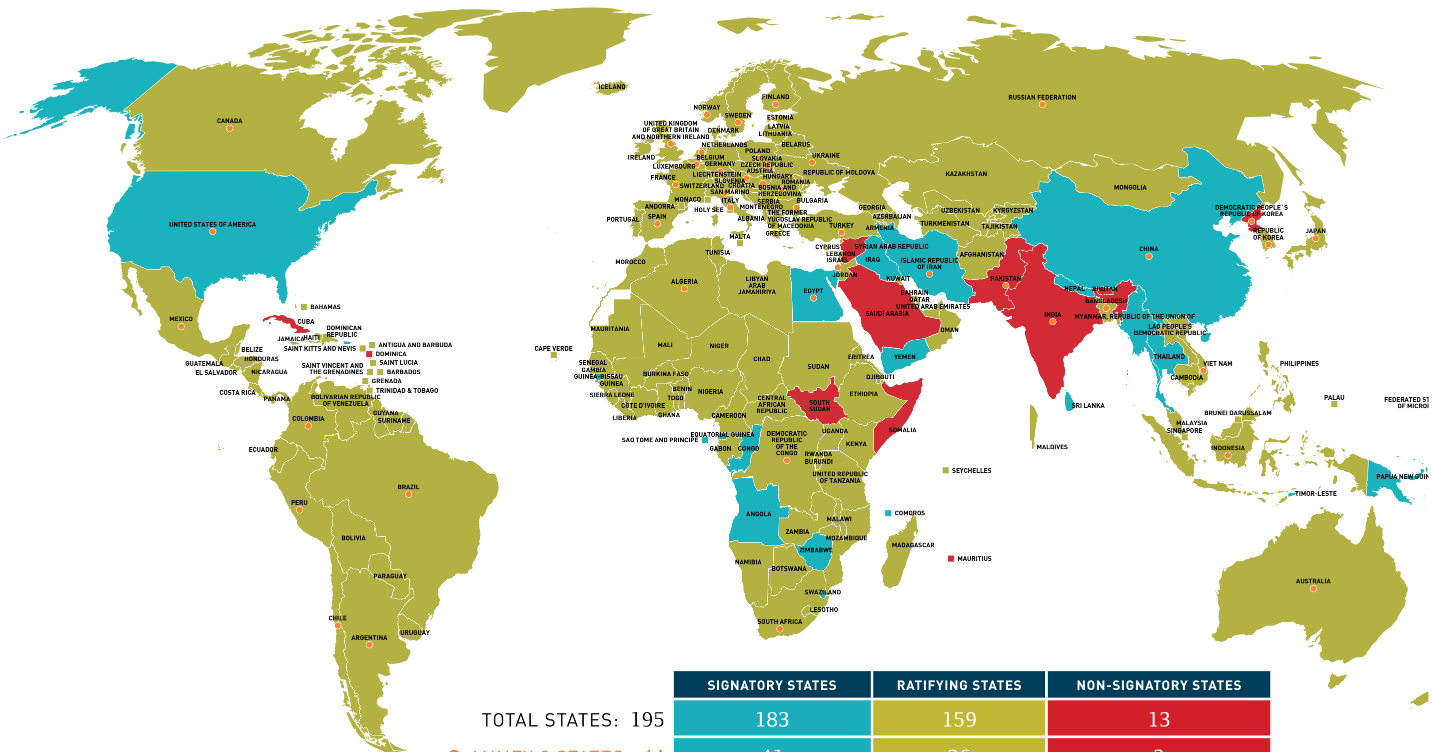
Columbia University's Paul Richards explains the seismic findings of the announced North Korean nuclear test. We also elaborate on the radionuclide findings. Astronomer Margaret Campbell-Brown explains how CTBTO data help us understand the characteristics of the meteor over the Ural mountains. Anders Ringbom and Anders Axelsson of the Swedish Defense Research Agency draw lessons from the detection of noble gases from the Fukushima nuclear accident. An overview of the recent Science and Technology Conference in Vienna is also presented.

The paintings by Elin o'Hara Slavick show the power of the arts in communicating political messages.

We look forward to hearing from the next Executive Secretary of the CTBTO, Lassina Zerbo, who will take office on 1 August, in the next issue of CTBTO Spectrum, and wish him every success as the new head of the organization.

Last but not least, let me take this opportunity to thank the Executive Secretary, Tibor Tóth, for his visionary and creative leadership and professional and efficient management during his eight years in office. His own reflections can be read on page 16. We wish him all the best and look forward to our continued collaboration in the future.

STATUS OF SIGNATURES AND RATIFICATIONS
AS OF 12 JULY 2013



TOTAL STATES: 195	SIGNATORY STATES	RATIFYING STATES	NON-SIGNATORY STATES
TOTAL STATES: 195	183	159	13
● ANNEX 2 STATES: 44	41	36	3

FOR MORE DETAILED INFORMATION ON SIGNATURE AND RATIFICATION VISIT WWW.CTBTO.ORG/MAP

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The CTBT:

One of the most important international instruments

BY HOSHYAR ZEBARI
IRAQ'S FOREIGN MINISTER

We are striving to create a safer world for ourselves and for future generations, a world free of weapons of mass destruction (WMD). The international commitment to the Comprehensive Nuclear-Test-Ban Treaty (CTBT) represents one of the most prominent mechanisms for achieving a nuclear-weapon-free world. I was keen to take part in the last two CTBT Ministerial Meetings in 2010 and 2012 to promote the Treaty's entry into force, which were held on the fringes of the UN General Assembly sessions. I participated not only to express Iraq's desire to reiterate the importance of supporting the Treaty but also to reaffirm the support of Iraq for the entire disarmament and non-proliferation regime.

IRAQ'S DESIRE TO ENHANCE THE INTERNATIONAL SYSTEM FOR DISARMAMENT AND NON-PROLIFERATION

When we tackle the subject of WMD, in Iraq we are talking about our personal experience and the intense suffering to which we were subjected because of the possession of these weapons. We have also been greatly affected by the international sanctions imposed by United Nations Security Council (UNSC) resolutions that prevented Iraq from making any technological and scientific progress for a number of years, most specifically between 1990 and December 2010. As a result of this suffering but equally because of our sincere desire to rid the Middle East of the menace of nuclear weapons, Iraq is keen to contribute to global efforts to enhance an international system for disarmament and the non-proliferation of WMD.

We consider both the Nuclear Non-Proliferation Treaty (NPT) with its three interrelated pillars (disarmament, non-proliferation and the peaceful use of nuclear energy) and the CTBT as the main cornerstones of this system. In Iraq we have made a number of achievements in this regard. We have ratified the Additional Protocol to the Safeguards Agreements with the International Atomic Energy Agency (IAEA), we signed the CTBT in 2008 and the Iraqi Council of Representatives approved a law on ratification by the Republic of Iraq of the CTBT on 9 October 2012.

Iraq is taking these steps towards disarmament and non-proliferation and the destruction of all kinds of WMD not only as a fulfilment of UNSC resolutions, but also because the Iraqi Constitution, which was approved in 2005 after the collapse of the former regime in 2003, bans the use and the possession of such weapons. Here, I would like to draw attention to Article 9 of the Iraqi Constitution on the banning of WMD for its importance in our internal and foreign policy:

'The Iraqi Government shall respect and implement Iraq's international obligations regarding the non-proliferation, non-development, non-production and non-use of nuclear, chemical and biological weapons and shall prohibit associated equipment, material, technologies and delivery systems for use in the development, manufacture, production and use of such weapons.'

In this regard, it might be useful to indicate that Iraq has documented all the steps it has taken in that matter within the respective international forums. Iraq has also expressed its respect and commitment to disarmament, arms control and non-proliferation- related international treaties, agreements and arrangements.

The Government of Iraq has adopted a number of legislative and executive measures in this regard in order to reflect its commitments in a practical way. The Government of Iraq also believes that the total elimination of WMD would provide the international community with a true guarantee against the use or the threat to use these weapons.

CTBT'S ENTRY INTO FORCE WILL ENHANCE THE INTERNATIONAL SYSTEM OF DISARMAMENT AND NON-PROLIFERATION

There is no doubt that the entry into force of the CTBT, after its ratification by the eight remaining States in Annex

»The Iraqi Council of Representatives approved a law on ratification by the Republic of Iraq of the CTBT on 9 October 2012.«

2 of the Treaty[1], would enhance the international system of disarmament and non-proliferation. Moreover, ratification of the CTBT by the main nuclear weapon States would encourage other remaining Annex 2 States to ratify or sign the Treaty. In Iraq, we welcome the voluntary moratorium on nuclear testing as an important pathway to reaching the goals of the Treaty, although it cannot be a substitute for a comprehensive universal and legally binding agreement.

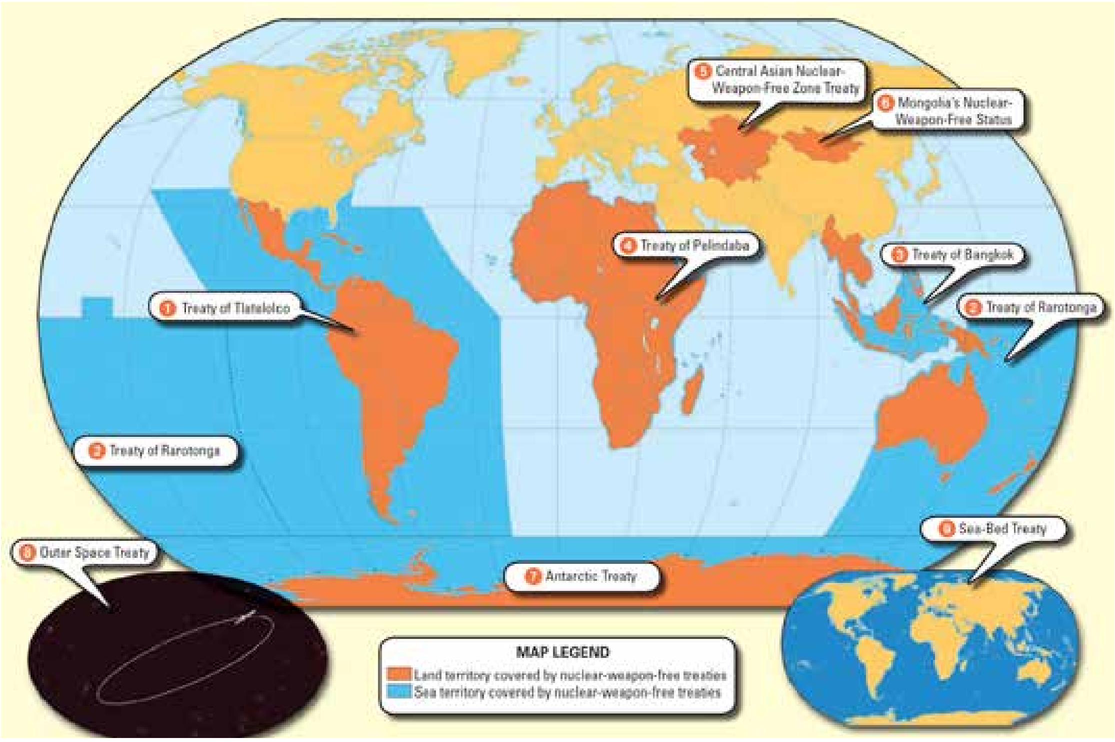
[1] Annex 2 lists 44 countries that possessed nuclear power or research reactors when the CTBT was being negotiated. The eight Annex 2 States that must still ratify before the Treaty can enter into force are: China, the Democratic People's Republic of Korea, Egypt, India, Iran, Israel, Pakistan and the United States.

In 2009 the international community received positive signs when President Barack Obama declared that his Administration would follow up the matter of ratification of the CTBT by Congress. Since Congress did not ratify the Treaty during the first term of President Obama, we truly hope that this will be achieved during his second term, especially since there is a moral responsibility borne by the United States as it was the first and only State that has ever actually used a nuclear weapon in wartime.

CTBT AS AN EFFICIENT MONITORING SYSTEM FOR DISASTER MITIGATION

The world has witnessed the tragedies caused by the use of nuclear weapons and other WMD during the past century. We have also witnessed so far in the 21^{st} century the devastating aftermath

Foreign ministers attending the sixth CTBT Ministerial Meeting on 27 September 2012 in New York, USA. Foreign Minister Hoshyar Zebari is standing in the back row third from right.



Demarcation of nuclear-weapon-free zones, nuclear-weapon-free status and nuclear-weapon-free geographical regions.

Iraq supports the creation of a nuclear-weapon-free zone in the Middle East.

Map courtesy of the United Nations Office for Disarmament Affairs.

of natural disasters caused by tsunamis, in addition to the dangers resulting from damage to energy generating nuclear power plants (such as the Fukushima Daiichi nuclear power plant accident in March 2011). The CTBT and its verification system which, when complete, will consist of 337 monitoring facilities spread around the globe, can help tsunami warning centres issue earlier alerts as well as monitoring the distribution of radiation in the event of a nuclear accident These civil and scientific applications can definitely help in mitigating the dangers resulting from such disasters, despite the fact that the verification system has been designed to enable the Preparatory Commission for the Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO) in Vienna to monitor all nuclear tests that might be conducted around the world.

GLOBAL CONCERN REGARDING THE POSSESSION OF WMD BY TERRORIST GROUPS

The world would be much safer for all of us and for future generations without nuclear weapons and all other WMD. Reality, however, indicates that terrorist groups might be able to obtain the necessary technology and materials needed to produce such weapons. Meanwhile, we are facing various challenges in that field but most importantly, the fact that many countries possess the materials and knowledge necessary to produce nuclear weapons. Moreover, the technology to produce these weapons is widespread and available on the black market. What really concerns the international community is the danger of terrorist groups acquiring nuclear weapons and the threat they would pose to our security. It is imperative that we coordinate regional and international efforts as a *sine qua non* requirement in order to deter these threats against international peace and security.

OUR GOAL IS TO ESTABLISH A ZONE FREE OF NUCLEAR WEAPONS AND OTHER WMD IN THE MIDDLE EAST

With regard to the Middle-East, it is one of the most notable regions of tension in the world. Just as it is vital for the sake of security in the region that all of the States in the Middle East ratify the CTBT and the NPT and that their nuclear facilities are subject to the IAEA safeguards system, we also consider it necessary that the international community mobilizes support to convene a conference in Helsinki, Finland, in 2013 on the establishment of a Middle East zone free of nuclear weapons and all other WMD. Such a conference was planned for 2012 but did not take place. This would help prevent fears of a nuclear arms race in the region from becoming a reality, a race that represents a threat to the region's stability and consequently to international peace and security.

BIOGRAPHICAL NOTE

HOSHYAR ZEBARI
was first appointed Minister for Foreign Affairs of Iraq in September 2003, continuing to serve in this position with successive governments. Prior to this, he became a member of the Iraqi Opposition Coordination and Follow-Up Committee in 2002 after serving as a member of the Iraqi National Congress Leadership Council from 1999. In 1992 he became Head of International Relations of the Iraqi Opposition and was also elected to the Kurdistani National Assembly, serving as the principal negotiator in the Kurdish peace process in 1994.

U.S. leadership needed to prevent nuclear testing by North Korea

BY THOMAS R. PICKERING
FORMER U.S. UNDER SECRETARY
OF STATE FOR POLITICAL AFFAIRS

Four years ago, President Obama warned that "the threat of global nuclear war has gone down, but the risk of a nuclear attack has gone up." On 12 February 2013, North Korea's nuclear weapons test explosion – its third and the world's 2,053rd – underscored the urgent need for stronger barriers to prevent the testing, spread, and use of the world's most dangerous weapons.

In his first term, Mr Obama made significant progress to reduce nuclear dangers. This included cuts in excess U.S. and Russian cold-war nuclear stockpiles and locking up vulnerable nuclear material from terrorists. But there is more to be done.

U.S. leadership is especially critical to the implementation of the 1996 Comprehensive Nuclear-Test-Ban Treaty (CTBT), which bans all nuclear test explosions. The United States and 183 other nations have signed the CTBT, but America must still ratify the Treaty to bring it into force.

The U.S. has not conducted a nuclear test explosion for more than 20 years. Since there is no technical or military need to do so ever again, ratifying the Treaty would not hinder U.S. nuclear readiness. Other countries like North Korea, or even China, however, could use further nuclear tests to perfect more sophisticated and deadly warhead designs. U.S. ratification of the Treaty would send a clear message to nuclear capable countries like Pakistan, India, and North Korea that are not signatories. And it would establish a clear norm for countries like China and Iran that have both signed, but not ratified, the Treaty.

During his first term, Obama repeatedly pledged to work with the Senate to secure U.S. ratification of the CTBT. Now is the right time for the White House to launch a high-level push for ratifying the Treaty and for the Senate to join in closing the door on nuclear testing.

> »Now is the right time for the White House to launch a high-level push for ratifying the Treaty and for the Senate to join in closing the door on nuclear testing.«

THE CASE FOR THE CTBT IS STRONGER THAN EVER

U.S. ratification of the CTBT would increase the global leverage necessary to

President Barack Obama speaking at the Brandenburg Gate in Berlin, Germany, 19 June 2013, where he reiterated his call to build support in the United States to ratify the CTBT.

curtail North Korea's nuclear weapons programme and help deter Iran's leaders from pursuing a nuclear weapon. Completing work on the Treaty would also reduce nuclear tensions between India and Pakistan and between India and China, and enhance security and stability throughout Asia.

U.S. leadership on the Treaty would also build support to strengthen the beleaguered nuclear non-proliferation system. At the 2010 conference to review the Nuclear Non-Proliferation Treaty, the 183 Member States unanimously reaffirmed the vital importance of entry into force of the CTBT "as a core element of the international nuclear disarmament and non-proliferation regime."

Like any treaty-ratification effort, securing Senate approval will be tough, but is within reach. The Senate's approval of the New START treaty (a nuclear arms reduction agreement between the U.S. and Russia) in December 2010 shows that the White House and the Senate can work together when U.S. national security interests are at stake.

The case for the CTBT is stronger than ever. Since the Treaty was last considered in 1999, substantial investments in the U.S. nuclear labs and scientific advances in nuclear weapons science mean that we know more now about how to sustain the arsenal than years ago when the U.S. conducted nuclear tests.

AN ADDITIONAL TOOL TO DETER POTENTIAL TESTING

Critics oppose U.S. CTBT ratification because they say the Treaty is unverifiable – that signatory countries may cheat, and that their actions are largely unknown. But today, the Treaty's global nuclear test monitoring system is now more than 85 percent complete and is more capable than anticipated a decade ago. U.S. intelligence and test monitoring tools are highly effective, as their rapid reporting on the North Korean test showed.

When the Treaty enters into force, the U.S. and other States will have an additional tool to deter potential testing: short-notice, on-site inspections to investigate any suspicious events. With the Treaty in place, no would-be proliferator could be confident that a nuclear explosion of any military utility would escape detection.

NUCLEAR PROLIFERATION IS A THREAT TO WORLD PEACE AND SECURITY

The Treaty can also be enforced by action from the UN Security Council. The Security Council found unanimously at a summit-level meeting in January 1992 that nuclear proliferation is a threat to world peace and security. If a signatory country violated the nuclear testing ban, action to enforce the Treaty could include sanctions and use of force if authorized. If that action were to be vetoed, Treaty members would be free to act individually in response, including resuming testing if they believed it was necessary.

Beginning with Dwight Eisenhower, U.S. presidents have sought an end to nuclear testing. It has been a half-century since President John F. Kennedy sought to negotiate a comprehensive test ban but achieved only the Limited Test Ban Treaty. A quarter century has passed since Presidents Ronald Reagan and George H. W. Bush secured the ratification of the treaties banning high-yield test explosions and so-called "peaceful" nuclear explosions.

Today, the United States is acting within the framework of the responsibilities of the Comprehensive Nuclear-Test-Ban Treaty but is not reaping the full security benefits in return because it has not yet ratified the pact. As Obama said in 2009: "After more than five decades of talks, it is time for the testing of nuclear weapons to finally be banned."

This op-ed first appeared in The Christian Science Monitor on 20 February 2013.

BIOGRAPHICAL NOTE

THOMAS R. PICKERING served as U.S. Under Secretary of State for Political Affairs from 1997 to 2000 and as the U.S. Ambassador to the United Nations from 1989 to 1992. In a diplomatic career spanning five decades, he also served as U.S. Ambassador to the Russian Federation, India, Israel, El Salvador, Nigeria, and the Hashemite Kingdom of Jordan. Ambassador Pickering is Chairman of the Board of the International Crisis Group and the American Academy of Diplomacy.

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VOICES

Wanted: An end to nuclear nationalism in South Asia

But the public mood for peace needs international support

BY ZIA MIAN, RESEARCH SCIENTIST
PRINCETON UNIVERSITY

Photo by Gudrun Georges. www.gudrungeorges.com

Since their back-to-back nuclear weapon tests in May 1998, Pakistan and India have been rapidly developing and expanding their nuclear arsenals. While the two countries have maintained a moratorium on nuclear testing, they have refused to sign the Comprehensive Nuclear-Test-Ban Treaty (CTBT). They are both producing highly enriched uranium and plutonium—the key ingredients for nuclear weapons—and increasing their production capacity. They are estimated to have approximately 100 nuclear weapons each and they are also testing and deploying a diverse array of nuclear-capable ballistic and cruise missiles.

UN RESOLUTION CONDEMNED 1998 NUCLEAR TESTS

The headlong pursuit by Pakistan and India of their nuclear weapon ambitions flies in the face of a unanimous UN Security Council resolution calling for restraint in South Asia —Resolution 1172 (6 June 1998). The resolution "condemns the nuclear tests conducted by India on 11 and 13 May 1998 and by Pakistan on 28 and 30 May 1998" and "demands that India and Pakistan refrain from further nuclear tests." It also:

"Calls upon India and Pakistan immediately to stop their nuclear weapon development programmes, to refrain from weaponization or from the deployment of nuclear weapons, to cease development of ballistic missiles capable of delivering nuclear weapons and any further production of fissile material for nuclear weapons, to confirm their policies not to export equipment, materials or technology that could contribute to weapons of mass destruction or missiles capable of delivering them and to undertake appropriate commitments in that regard."

GREATER EFFORT NEEDED TO MOVE PAKISTAN AND INDIA TOWARDS NUCLEAR RESTRAINT

Having passed Resolution 1172, the United Nations Security Council and the larger international community has made no substantial effort to move Pakistan and India towards nuclear restraint, to say nothing of nuclear disarmament. Pakistan and India appear to recognize no international legal obligation to restrain or end their nuclear weapons and missile programmes. They did, however, agree bilaterally in 1999 that: "The two sides shall continue to abide by their respective unilateral moratorium on conducting further nuclear test explosions unless either side, in exercise of its national sovereignty decides that extraordinary events have jeopardised its supreme interests." They also reached agreement in 2005 on advanced notification of ballistic missile flight tests.

International concern has flared during crises in South Asia. Most notably, during the three month-long India-Pakistan Kargil War in 1999 and the long military crisis of 2001-2002, when the two countries threatened the use of nuclear weapons. For the international community as a whole, in the decade since then the South Asian nuclear arms race has taken a back seat to the opportunities afforded by the emergence of India as a rising economic and strategic power in Asia and the importance accorded Pakistan since September 2001 in supporting the war against Al-Qaeda and the Taliban in Afghanistan. These opportunities have included massive arms sales to the two countries. The 2012 Stockholm International Peace Research Institute Yearbook reports that India was the largest arms importer in the world from 2007-2011 and Pakistan was the third largest importer for this period.

CIVIL SOCIETY: MAKING THE CASE FOR PEACE AND COOPERATION

As Pakistan and India have lurched from crisis to crisis and both governments poured scarce resources into a ruinous conventional and nuclear arms race, a growing number of activists in the two countries have mobilized to make the case for peace and cooperation. One key group is the Pakistan-India People's Forum for Peace and Democracy, which began in 1994 as a group of 25 people from the two countries meeting together in Lahore, Pakistan. It organized its first convention in 1995 in New Delhi, which brought together almost a hundred people from each country. Since then, the annual convention has alternated between Pakistan and India – when the respective governments have granted visas.

This effort at people-to-people diplomacy has grown to be the largest regular gathering of citizens of the two countries. The effort now embraces thousands of activists working on peace and justice, women's rights, human rights, and labour rights. It includes teachers and students, journalists, former soldiers, scholars, business people, and retired government officials[1]. An important focus of this effort has been opposing further India-Pakistan wars, reversing the arms race and promoting a process of South Asian nuclear disarmament.

»In the wake of the May 1998 nuclear tests, civil society groups began to focus more strongly on nuclear issues and the importance of banning further testing.«

INDIA AND PAKISTAN SHOULD CONCLUDE THEIR OWN CTBT WITHOUT WAITING FOR A GLOBAL TREATY

A ban on nuclear testing has been a recurring demand of this citizens' diplomacy movement. The first Pakistan-India Peoples' Convention on Peace and Democracy, held in 1995, agreed on a joint resolution that "India and Pakistan should conclude their own Comprehensive Test Ban Treaty without waiting for a global treaty." The Convention also supported the demand that "All states must commit themselves to cease production of additional fissile materials for nuclear weapons and other explosive purposes." An end to the production of fissile material would cap nuclear arsenals and help lay a basis for reducing and eliminating them.

In the wake of the May 1998 nuclear tests, civil society groups began to focus more strongly on nuclear issues and the importance of banning further testing. Sometimes this opposition to further nuclear testing came at great cost. On 3 June 1998, at a press conference organized in Islamabad by the Pakistan-India People's Forum, leading Pakistani public intellectual Eqbal Ahmad and prominent physicist and peace activist Abdul Hameed Nayyar were fiercely denounced as traitors for speaking against the nuclear tests by some of the journalists there to cover the event. They were then physically attacked by a mob of activists from an Islamist political party.

In marked contrast, the governments in both Pakistan and India offered nuclear testing as a symbol of national achievement. In both countries the nuclear tests were announced on television by the respective prime ministers. The scientists responsible for carrying out the nuclear tests were publicly feted as national heroes. In Pakistan, the scientists

[1] These efforts are documented and assessed in Smitu Kothari and Zia Mian eds., Bridging Partition: People's Initiatives for Peace between India and Pakistan, Orient Blackswan, 2010.

People speaking out against nuclear testing at a press conference in Islamabad in June 1998 were abused and then assaulted. Photo courtesy of Isa Daudpota.

»As India seeks the capacity to put multiple nuclear warheads on missiles that can threaten China, and Pakistan seeks compact nuclear weapons for use on the battlefield to counter Indian conventional forces, there will be resistance in particular from the respective nuclear weapon complexes to sign the CTBT.«

were shown returning from the test site in Balochistan and speaking at a live press conference on national television. In India, there were glossy photos of scientists with Prime Minister Atal Behari Vajpayee at the test site in Rajasthan.

On the first anniversary of the 1998 nuclear tests, dubbed the "Day of Deliverance," Pakistan's government ordered 10 days of national celebrations. National television and radio networks all carried programmes lauding the nuclear tests. Cities and towns were decorated with banners and posters of leading nuclear weapons scientists and Prime Minister Nawaz Sharif against a backdrop of mushroom clouds. Giant glowing models of the mountain where the tests were carried out were erected in several cities.

PAKISTAN SHOULD SIGN THE CTBT IMMEDIATELY

Civil society remained undaunted. A national network of peace and justice groups came together in Karachi to establish the Pakistan Peace Coalition in January 1999. Its founding statement called on Pakistan's people and government to:

"Recognise that nuclear war is not just an abstract possibility but something very real. Pakistan and India must enter into negotiations on nuclear issues, initially with the aim of creating confidence-building measures to decrease the chances of the accidental use, but with complete denuclearisation as the ultimate goal. Pakistan should sign the CTBT immediately."

India's national Campaign for Nuclear Disarmament and Peace, founded in 2000, which brings together over 200 grass roots groups, called for the "halt and roll back [of] India's nuclear weapons-related preparations and activities." This included a demand for "No explosive testing, sub-critical testing, or production or acquisition of fissile materials and tritium, for nuclear weapons purposes" by India.

This is only a small part of a largely hidden history of local opposition to the nuclear future in South Asia[2]. This history is being made by people far removed from the corridors of national power and invisible in the great halls where States meet to talk about arms control and disarmament, war and peace. The sites of struggle are nuclear facilities, from uranium mines to nuclear power plants, at the nuclear weapon test sites and the missile testing sites. Here local communities have fought back, trying to defend their livelihoods and community rights, resisting displacement and destruction of the environment, and demanding the basic rights of citizenship: the rights to know and to be heard. They have marched, fasted, blockaded, occupied, gone to court, and they have protested to survive.

PUBLIC MOOD FOR PEACE

The public mood has shifted. Despite the wars and the hostility, and the decades of being taught that the other was a mortal enemy, the people of India and Pakistan say they are ready for peace. A 2012 public opinion poll conducted by the Pew Research Center found that more than 60 percent of people in Pakistan and India want better relations between the two countries, with 67 percent in Pakistan and 58 percent in India supporting peace talks. About 80 percent in Pakistan and 60 percent in India think it is "very important" for the two countries to resolve their differences over Kashmir.

Despite the public mood for peace between their countries, and the obvious and pressing need to direct greater resources to meet the basic social needs of their people, there is no sign that governments in Pakistan and India are ready to curb their nuclear build ups. As India seeks the capacity to put multiple nuclear warheads on missiles that can threaten China, and Pakistan seeks compact nuclear weapons for use on the battlefield to counter Indian conventional forces, there will be resistance in particular from the respective nuclear weapon complexes to sign the CTBT. The votes by both Pakistan and India at the United Nations General Assembly in support of the CTBT are clearly at odds with these policies to develop their nuclear arsenals. But few other countries seem to care.

It is hard to see civil society in Pakistan and India alone being able to overcome the entrenched power of the nuclear weapons complexes and the political forces that foster nuclear nationalism in the two countries. Their efforts would benefit greatly from determined efforts by the international community to confront Pakistan and India over their nuclear weapons programmes. This task would of course be made much easier if the United States and other powers that have not yet ratified the CTBT were to do so and if they were to take more seriously their long evaded obligation to nuclear disarmament.

BIOGRAPHICAL NOTE

ZIA MIAN
directs the Project on Peace and Security in South Asia at Princeton University's Program on Science and Global Security and teaches at Princeton's Woodrow Wilson School of Public and International Affairs. His work focuses on nuclear weapons and nuclear energy issues, especially in South Asia. He is co-editor of Science & Global Security, the international technical journal of arms control, non-proliferation and disarmament science and co-deputy chair of the International Panel on Fissile Materials (IPFM).

[2] see Smitu Kothari and Zia Mian eds., Out of the Nuclear Shadow, Zed Press, 2001.

COMPREHENSIVE NUCLEAR-TEST-BAN TREATY:

SCIENCE AND TECHNOLOGY 2013 CONFERENCE

CTBTO PREPARATORY COMMISSION

CTBT: Science and Technology 2013 Conference (SnT2013) from 17-21 June was the fourth in a series of conferences that help establish interactions and partnerships between the scientific and technological community and the CTBTO.

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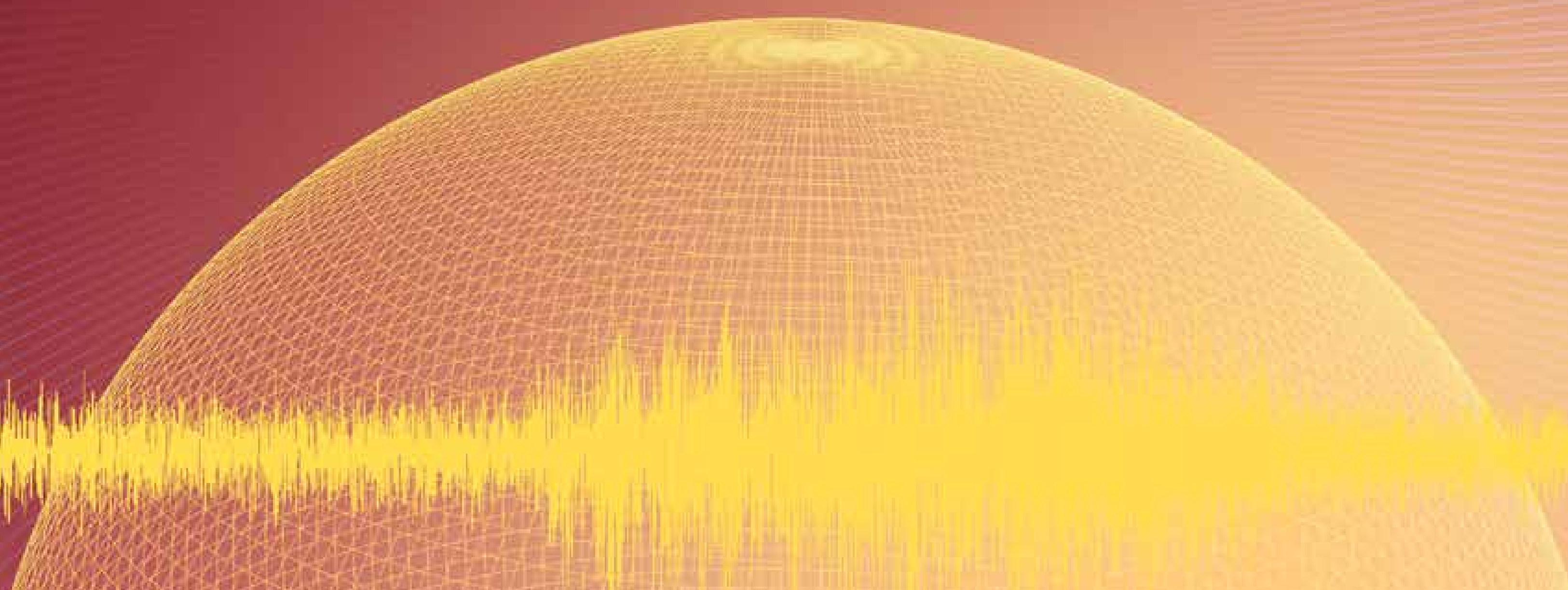

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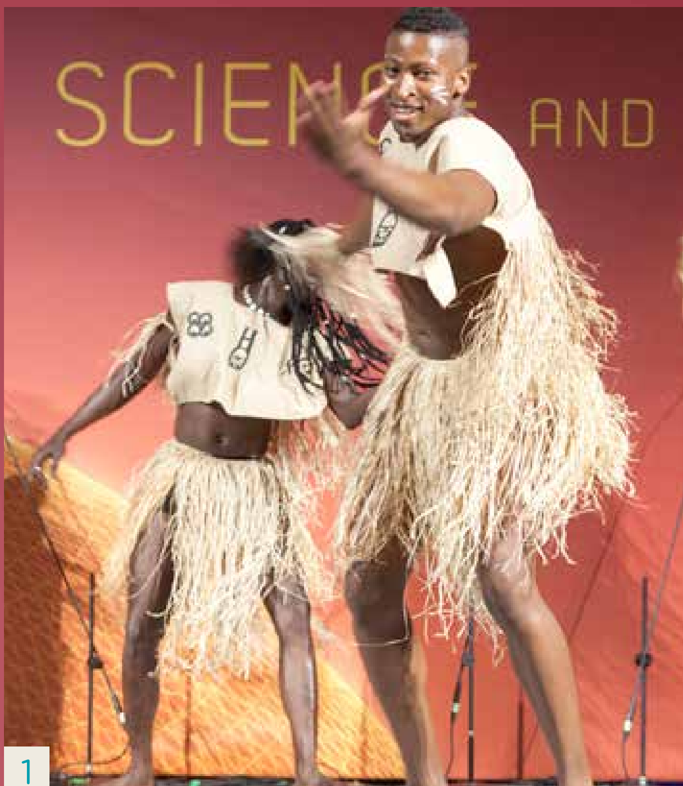
1: DANCE AND DRUMMING GROUP AFROCOCO PERFORMING AT THE OPENING CEREMONY OF THE CONFERENCE.
2: THE MUSIKGYMNASIUM VIENNA CHOIR PERFORMING AT THE OPENING CEREMONY OF THE CONFERENCE.
3: PANEL DISCUSSION WITH PATRICIA LEWIS, RESEARCH DIRECTOR FOR INTERNATIONAL SECURITY, CHATHAM HOUSE (CENTRE) SIEGFRIED HECKER, CENTER FOR INTERNATIONAL SECURITY AND COOPERATION, STANFORD UNIVERSITY (RIGHT), AND MICHEL MIRAILLET, DIRECTOR FOR STRATEGY AFFAIRS AND DEFENSE POLICY, FRENCH MINISTRY OF DEFENSE (LEFT).
4: PARTICIPANTS IN THE POSTER EXHIBITION AREA.



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»By engaging the scientific community in strengthening its own abilities, the CTBTO advances its vital work of preventing and deterring further nuclear tests…I renew my call for the entry into force of the CTBT.«

Ban Ki-moon, UN Secretary-General, in a video message to the Conference.

4

5

5: PRESS CONFERENCE WITH KEYNOTE SPEAKERS: ELLEN TAUSCHER, FORMER U.S. UNDER SECRETARY OF STATE FOR ARMS CONTROL AND INTERNATIONAL SECURITY AFFAIRS (LEFT), AND HANS BLIX, FORMER HEAD OF THE IAEA.
6: NADEZDA TSYBULSKAYA FROM THE A. M. OBUKHOV INSTITUTE OF ATMOSPHERIC PHYSICS, RUSSIAN ACADEMY OF SCIENCES, MAKING HER PRESENTATION.
7: LASSINA ZERBO, CTBTO EXECUTIVE SECRETARY-ELECT (LEFT) AND JEAN-MICHEL VANDERHOFSTADT, CEO-GENERAL MANAGER, INSTITUTE FOR RADIO ELEMENTS, SIGNING A MEMORANDUM OF UNDERSTANDING ON COOPERATION IN NOBLE GAS MITIGATION.
8: GROSSER REDOUTENSAAL, HOFBURG PALACE, VIENNA.

6

»You stand for those who promote science for human security. Instead of building and improving the nuclear bomb, you are devising ways and means of controlling it through global cooperation.«

Michael Linhart, Secretary General, Austrian Federal Ministry for European and International Affairs, addressing scientists during the Opening Ceremony.


7

»The Science and Technology conference series is a process; it provides an opportunity to integrate results of scientific research into operation to improve the CTBT verification regime.«

Lassina Zerbo, CTBTO Executive Secretary-elect and Project Executive for the Conference.


8

Photos courtesy of Marianne Weiss Photography

INTERVIEW

Face to Face with CTBTO Executive Secretary Tibor Tóth

Looking back, looking forward

Tibor Tóth addressing UN Secretary-General Ban Ki-moon and other high-level dignitaries attending the CTBTO's 15th anniversary celebrations in Vienna, Austria, on 17 February 2012.

What is your first memory of nuclear weapons? How did it impact you at the time – and later in life?

As a general introduction to this interview let me say that I personally like history, but I do not like personal history. Whenever someone looks backwards it distracts the focus from the road ahead.

However, my first vivid recollection of the nuclear threat was a doomsday-like discussion with my family at the dining table. I was around eight years old at the time and did not understand too many of the details. Only decades later could I date this memory back to the October 1962 Cuban Missile Crisis and understand how close the world had come to nuclear annihilation during those fateful days. The gloomy feeling at the family dining table – and probably at all dining tables around the world – is best described by what Jacqueline Kennedy told her husband John F. Kennedy at the height of the crisis: "I would like to die next to you, and the children do too." While I don't claim that this experience propelled me into nuclear arms control from the age of eight, it has reminded me in later years that the Cuban Missile Crisis was not an abstract historical event that just happened there, then and to them – and that we might be wrong in assuming that something like this could never happen again.

How did you first become involved professionally in nuclear arms control issues?

I started my career in 1977 with the Hungarian Foreign Ministry where I dealt initially with European security and cooperation known as the Helsinki Process. My interest in arms control began with a six-month UN Disarmament Fellowship in 1980. It fascinated me how in arms control, policy is intertwined with very technical issues; I had some limited exposure to the latter through chemistry and physics at secondary school. During the fellowship, I saw all the major disarmament fora, and gained not just theoretical and practical knowledge, but also the longer historical perspective of ups and many downs. For example, I had the chance to follow the activities of the Group of Scientific Experts (GSE) in Geneva, the forerunner of an effort to design a system to monitor the future test-ban treaty. Although the GSE actually started out a couple of years earlier, in the late 1970s, the CTBT was only concluded in 1996. For me this serves as a reminder of the required time frame for some of these efforts.

You have devoted a large part of your life to these issues. How would you analyse the current situation against a historical background?

I have been dealing throughout my career with the whole spectrum of global issues within the UN system, with the exception of trade, starting as a deputy attaché in Geneva and later as ambassador in Geneva, Vienna and The Hague. But weapons of mass destruction issues have provided the real learning curve about how much time and perseverance is needed for these efforts to succeed. I've spent 15 years of my career dealing with the regulation of chemical weapons, another 15 years with biological weapons, and 17 years of my professional career concerned with nuclear weapons. If I try to apply what I have seen in these fields to the whole area of multilateralism, I think it really boils down to regulation: how much regulation is enough, and where a regulation deficit might be a problem. There are parallels to other areas of multilateralism such as economic governance. The commonality is that in different areas the lack of cooperation through regulation, a "free-for-all" approach, might be critical and even lead to disasters over time – a major recession, in the case of economics. For nuclear arms control, we have to ask ourselves: Do we have a sufficient and sustainable level of cooperative security versus open ended competition? And there is the time factor, too: Are we moving at the right pace if we want to reduce over 17,000 nuclear weapons to global zero?

You were one of the first office-holders at the newly established CTBTO when you were appointed Chairperson of Working Group A for administrative and financial issues. What memories do you have?

We literally started from scratch back in March 1997. In order to draft the organization's first programme and budget, I had to find a box to put the computer on, look for a chair and organize a secretary. I admit that our first draft programme and budget (P&B) bore a striking similarity to the IAEA's P&B; with its multi-layered programmatic approach it was a bit of an overkill for an organization that was just starting up. But we got off to a flying start, and in record time we succeeded in putting in place all of the key financial and administrative regulations, which enabled the organization to run smoothly. This was really the administrative/legal glue for everything else that we have done since then.

What have been the key technical and political developments relating to the CTBT since it opened for signature in 1996?

In a nutshell: We managed to push the nuclear test genie back into the bottle. Before the CTBT, there were on average four to five hundred nuclear weapon tests every decade. They were both political and environmental pollutants. This decade, there have only been three – still, three unfortunate nuclear tests too many. One hundred and eighty-three countries have thrown their political and moral weight behind the no-test norm. We have built a system unprecedented not only in reach but also in complexity: Both the basic monitoring technologies– seismic, infrasound, hydroacoustic, radionuclide and noble gas – as well as the support technologies– atmospheric transport modelling, information and communication, could each function as independent global systems. Together, they constitute a system of systems. And with on-site inspections, you have

Tibor Tóth addressing participants attending the Advanced Science Course in Vienna, Austria, 28 November 2011.

Tibor Tóth addressing the audience at the Reykjavik event in New York,USA, 27 September 2012.

»Our monitoring network has increased from around 80 to nearly 300 stations since 2005, so around 90% of all our assets are in place, despite all of the challenges we've encountered.«

an additional layer of verification muscle, a cluster of another one dozen technologies with sub-sets of technologies.

What effect do you think ratification by the United States will have on other hold out states?

Let me come back to the parallels of security and economic policies. If country 'A' tries to maximize its financial and trade advantages at the expense of country 'B', it must ask itself, "Could it lead to less prosperity for me as well? Is this a sustainable solution for my own well-being?" There are striking similarities between unilateral protectionism in the economic fields and nuclear arms races, be it globally or regionally.

Most, if not all of the eight missing countries are in the Asian-Pacific and Middle Eastern regions, where the world's political hotspots can be found. A deficit in regulation, in cooperative norms between countries, is characteristic for these regions in the field of security policy. An absence of insurance policies, if you will. So each of the eight countries should ask itself whether the absence of cooperative norms in the field of nuclear weapons testing is beneficial to its own long-term security. They should ask of themselves whether the Cuban missile crisis was an event which happened "there, then and to them" but it cannot happen "here, now and to us." I firmly believe that it's not up to the other 159 countries that have ratified the Treaty to convince the remaining eight. The only country that can convince the United States is the United States itself; even if the U.S. ratifies, the only one to convince China is China, the only country to convince India is India, and so on. Again, we need patience and perseverance. Take a look at the issue of chemical weapons: the first time they were discussed was in St. Petersburg in 1868, while the Chemical Weapons Convention only entered into force in 1997 and still we are only 80% through with the destruction of chemical weapons stockpiles. The only question is how much additional time leased from our future do we have and will we be given the luxury of spending another 50 years without a 21st Century equivalent of the Cuban missile crisis?

What importance do you attach to disarmament education?

My experience of being introduced to this issue through a disarmament fellowship programme at the very beginning of my career was an eye-opener. We have to think about the future and reach out early enough to those who will be pushing for arms control regulations in the years to come. Through the CTBTO's Capacity Development Initiative, we've trained and educated station operators, National Data Centre staff, diplomats and other experts involved in the Treaty, hundreds of them in 2012 alone.

Besides enlarging the pool of CTBT experts, we have reached out to new audiences, to universities around the world. Just a month ago we hosted an event with representatives from more than 30 universities, not just from the United States or Europe but from all corners of the world. Participants included professors who are educating the future leaders. We are reaching out to countries which we could not reach otherwise and in 2012 we trained four times as many experts as people who work at the organization.

Multilateral security has become a business as complex as piloting an aircraft. It's extremely important that our future leaders have the right level of understanding about how complex this world is with the volume and the velocity of changes which are forever increasing.

Why is gender balance important in international organizations? How has the CTBTO helped to promote gender equality during your tenure? What remains to be done?

I coined the phrase "security is too important to be left just to men." I think it's important that we bring on board as many women as possible. I don't think the fact that this is an organization dealing with highly technical issues is an acceptable excuse not to do so. Yes, it is true that the percentage of women applicants for some of the technical jobs is less than 10%. But I am proud that now one-third of our professional colleagues are women. I am proud of the fact that two of my five deputies are women. But a lot remains to be done. In order to increase the percentage of women applying for technical jobs, and following a "double up" pledge I made on International Women's Day on 8 March 2012, the organization trained in just one year the same number of women as there are people working in the organization through the CTBTO's Capacity Development Initiative.

How has the CTBTO evolved since you became its Executive Secretary in 2005? What would you consider the biggest *challenge you have encountered and your greatest achievement?*

I'd answer the first question with one phrase: "coming of age." The organization was eight years old when I took over; it will soon be 17 years old. It's very similar to watching a young child grow up and approach adulthood, becoming more self-confident, more mature. I think this is the best way to describe how the organization has evolved.

A challenging period was from 2006 to 2008, when the CTBTO underwent fundamental restructuring. Also, due to the tenure limitation, I had to replace all the professional staff after seven years of service. While it was possible to negotiate a certain degree of flexibility for the tenure limitation, both these issues caused a lot of upheaval for the organization and, of course, stress for the individuals concerned.

Then in 2006, the CTBTO had to react to the first nuclear test by the Democratic People's Republic of Korea, the first of three unfortunate tests for the verification system, but it passed each test with flying colours. On top of that, the shortfall in contributions by one major contributor caused serious financial problems.

In terms of achievements, our monitoring network has increased from around 80 to nearly 300 stations since 2005, so around 90% of all our assets are in place, despite all of the challenges we've encountered. Monitoring capabilities have also improved qualitatively, with the integration of the new infrasound component and including noble gas systems in our routine operations; the number of operational systems has increased during this time from eight to 30. We have found new ways of processing data, of improving the reliability and quality of data products, and of making all data available in near real-time to our 183 Member States. This is now a one billion dollar monitoring system supported by 4,000 people working around the globe and around the clock. This is a joint venture, unprecedented not just in size, complexity, and the way in which all of the elements work in synergy but also in terms of all-inclusiveness: all-inclusive data gathering, transmission, processing and sharing of all the benefits.

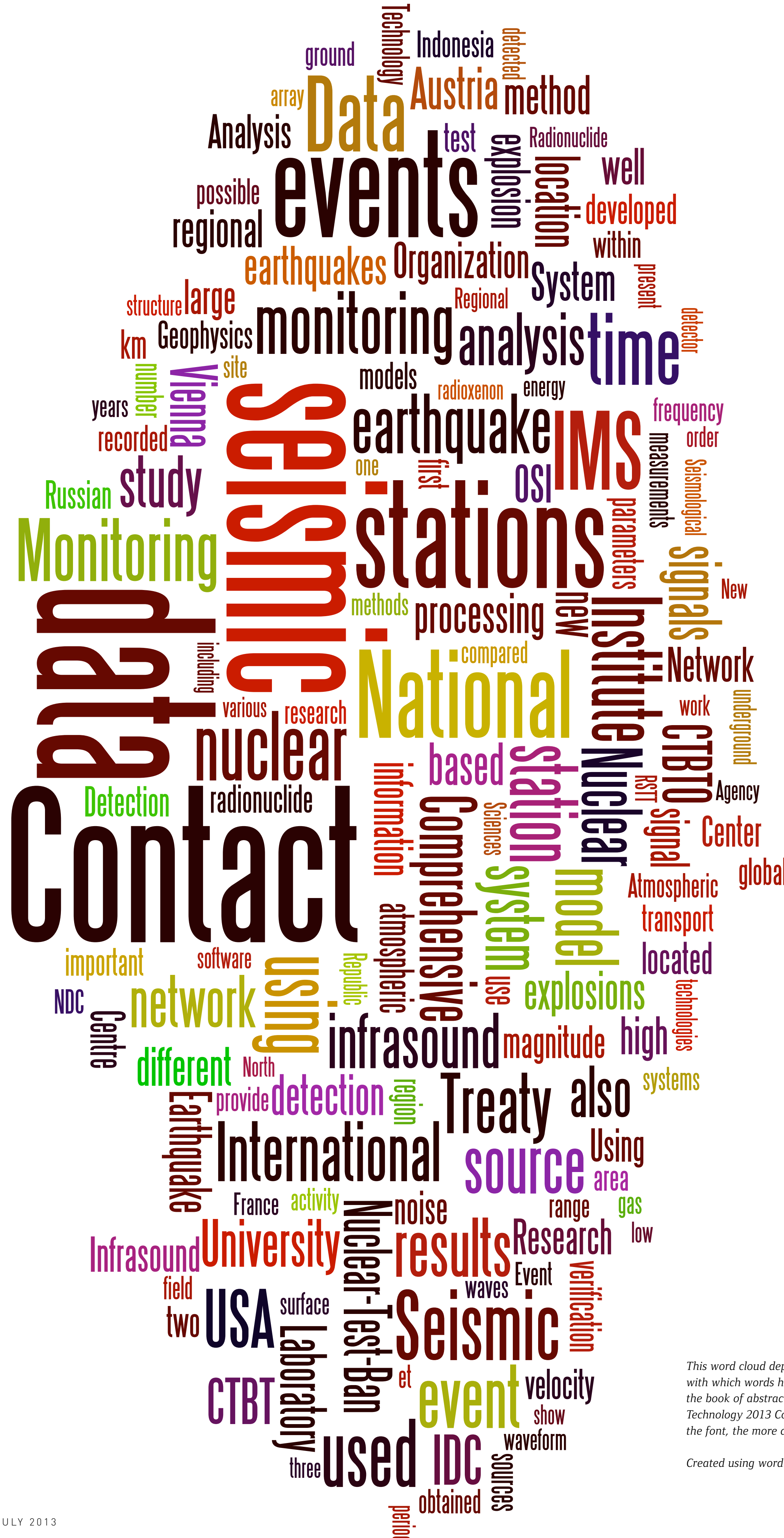
»This is a joint venture, unprecedented not just in size, complexity, and the way in which all of the elements work in synergy but also in terms of all-inclusiveness: all-inclusive data gathering, transmission, processing and sharing of all the benefits.«

I think that multilateral processes could take inspiration from this arrangement. There was a lot of soul-searching after the sobering United Nations Copenhagen Climate Change Conference in 2009. One of the explanations offered was that such conferences do not work because there are simply too many players around the table. At the CTBTO with its near universal membership, we have proven the opposite. We have built, managed, operated and improved an incredibly complex system. And we have run it efficiently not just from a technical and management standpoint but also politically with the support of our Member States, for example, by reacting jointly to challenges such as the DPRK nuclear tests. And we provided the right return to our member states and their citizens on their enormous investment in this organization and its monitoring system at the difficult moments of the Great East Japan earthquake, tsunami and the subsequent melt-down of the Fukushima nuclear power plant.

So the message is that all-inclusive multilateralism is not a passé matter. The other way around: it is very much alive and is the way to go in the future, if done correctly. I'm extremely proud of this organization's track record in this regard. It is multilateralism at its best.

BIOGRAPHICAL NOTE

TIBOR TÓTH
has served as the Executive Secretary of the CTBTO since 2005 and will remain in that position until 31 July 2013. He has been actively involved in international disarmament and non-proliferation issues for over three decades. From 1990 to 1993 and from 2003 to 2005, he was the Ambassador and Permanent Representative of Hungary to the UN in Geneva and to the UN in Vienna from 1997 to 2001. From 1996 to 2004 he served as Chairperson of the CTBTO's Working Group dealing with budgetary and administrative matters. He chaired the Biological Weapons Convention negotiations on an implementation and verification regime from 1992 to 2004.



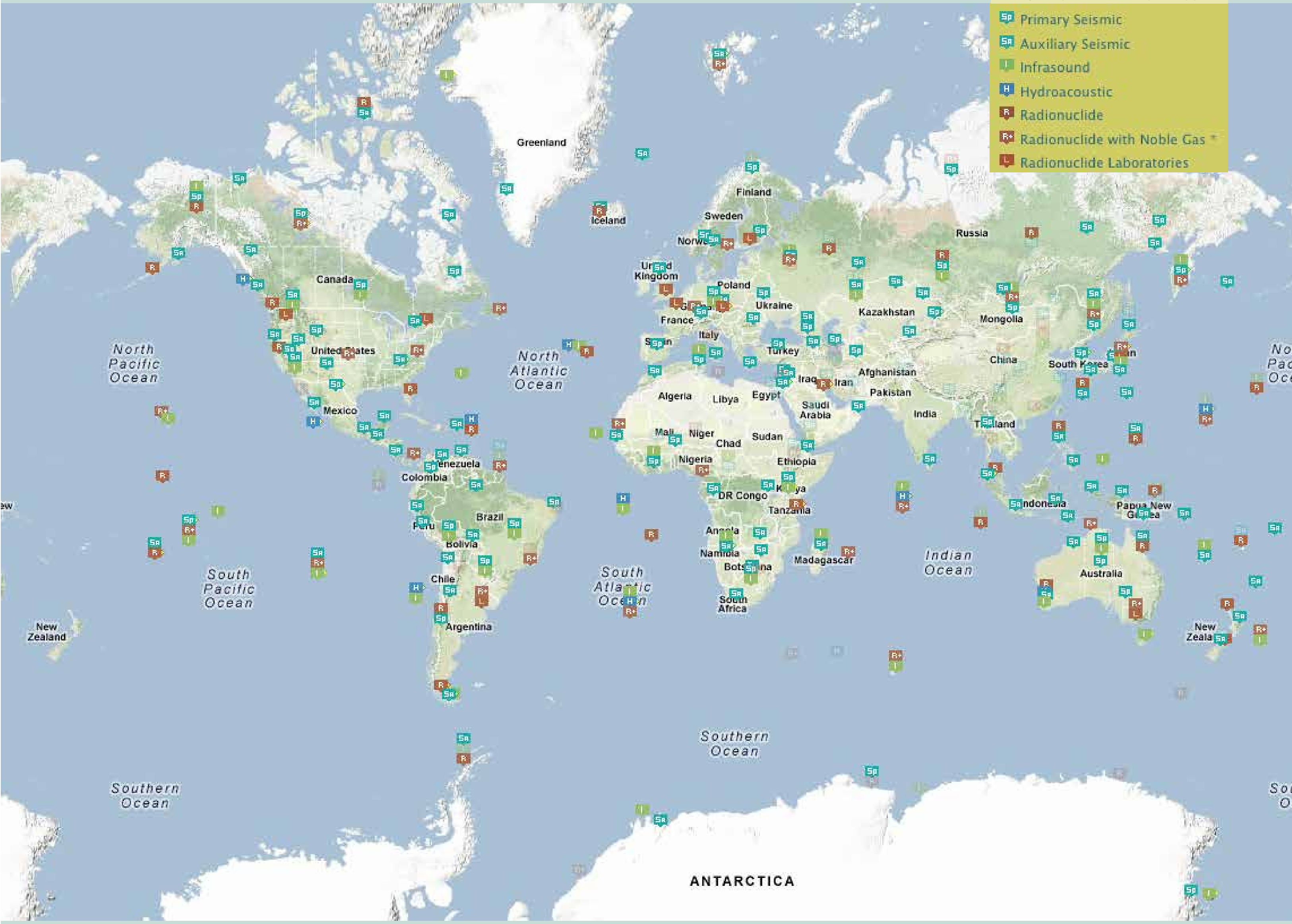
This word cloud depicts the frequency with which words have been mentioned in the book of abstracts (for the Science and Technology 2013 Conference): the larger the font, the more common the word.

Created using wordle (www.wordle.net)

STATUS OF CERTIFIED IMS FACILITIES
AS OF 12 JULY 2013

CERTIFIED	INSTALLED	UNDER CONSTRUCTION	PLANNED	TOTAL
275	20	19	23	337

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



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

PDF MAP CREATOR
which allows you to create a printable colour version of the signature/ratification maps on a global and regional basis.

PDF REPORTS
which provides a comprehensive breakdown of the map that was selected

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INTERVIEW WITH PAUL RICHARDS
SPECIAL RESEARCH SCIENTIST, COLUMBIA UNIVERSITY

Seismic Detective Work:

CTBTO monitoring system 'very effective' in detecting North Korea's third nuclear test

Upgrading the CTBTO's auxiliary seismic station AS02 at Ushuaia, Argentina. Photo courtesy of Owen Kilgour.

On 12 February 2013 the Democratic People's Republic of Korea (DPRK) announced that it had conducted its third nuclear test. Based on seismic monitoring data provided to CTBTO Member States by the International Data Centre (IDC), other data, and your own analysis, how confident are you that this was indeed a nuclear test? What do the data tell you and what conclusions can you draw?

The data from more than a hundred seismographic stations indicate that this was an explosion, conducted in North Korea at a location very similar to that of a previous explosion – the one on 25 May 2009. I was impressed at the number of stations that recorded signals, as reported by the IDC and also by the United States Geological Survey.

It is not possible to tell from seismograms alone that a recorded explosion is nuclear or is a chemical explosion in which all the explosive material is fired at the same time. Such single-fired chemical explosions do occasionally occur – at small size. But the explosions in North Korea have been large. If not nuclear they would have required the simultaneous firing of thousands of tons of chemicals, which would have to have been assembled clandestinely to generate the signals we have recorded. Thus an origin other than nuclear is not plausible.

What do the seismic data tell us about the approximate size of the yield?

We can tell from comparison with the signals recorded in May 2009 that this latest explosion was about 2.5 to 3 times larger in yield, but this is a relative measure and there is greater uncertainty in estimating an absolute size. In absolute terms, I would expect the yield to lie somewhere in the range from about 5 to 15 kilotons.

How do seismic waves generated by an earthquake differ to those caused by an explosion? What was significant with this particular event?

Different seismic sources – such as earthquakes, landslides, explosions in the ocean, atmospheric explosions, and underground explosions – all generate a mix of different types of seismic waves. Furthermore, each type of seismic wave can be recorded across a range of frequencies. In practice, from studies of recordings from thousands of seismic events, the mix of different seismic waves is diagnostic of the type of seismic source that generated them.

For example, earthquakes and explosions all generate the fastest type of seismic wave, called the primary wave (or P-wave) because it is the first to arrive; they can all generate a secondary type of wave (or S-wave); and they can all generate so-called surface waves that arrive last. But the efficiency of generation of these waves is distinctively different between earthquakes and explosions. For example, using data of the quality recorded from earthquakes and explosions, large and small, that have occurred in East Asia since the 1980s (when wide access to high-quality data began), we know that P-waves are most efficiently generated by explosions, and S-waves by earthquakes. Furthermore, these differences are accentuated when we focus on the higher-frequency content of the recorded signals. With surface waves, some features of the signals are seen only for seismic sources that are very shallow – say, less than two or three kilometres, which is the case for almost all explosions but is rare for earthquakes. Other surface-wave features are more commonly seen for earthquakes than explosions.

The above is but a short summary of the fact that there is a long list of different features in seismic waves that can be used to discriminate between earthquakes and explosions; and there is also a substantial infrastructure of regional, national, and international agencies that routinely acquire seismograms and analyse them for purposes of characterizing the different types of seismic event.

To a remarkable degree the seismograms generated by the 12 February 2013 event had features that repeated what was observed from North Korea's second underground test except that signals were significantly larger than those recorded previously. This similarity indicates that the third and second tests were conducted in almost the same location.

»To a remarkable degree the seismograms generated by the 12 February 2013 event had features that repeated what was observed from North Korea's second underground test except that signals were significantly larger than those recorded previously.«

When complete, the seismic network of the International Monitoring System (IMS) will comprise 170 stations. More than 90% of these stations are already up and running. How effective have IMS stations been in detecting events such as the three nuclear tests announced by the DPRK?

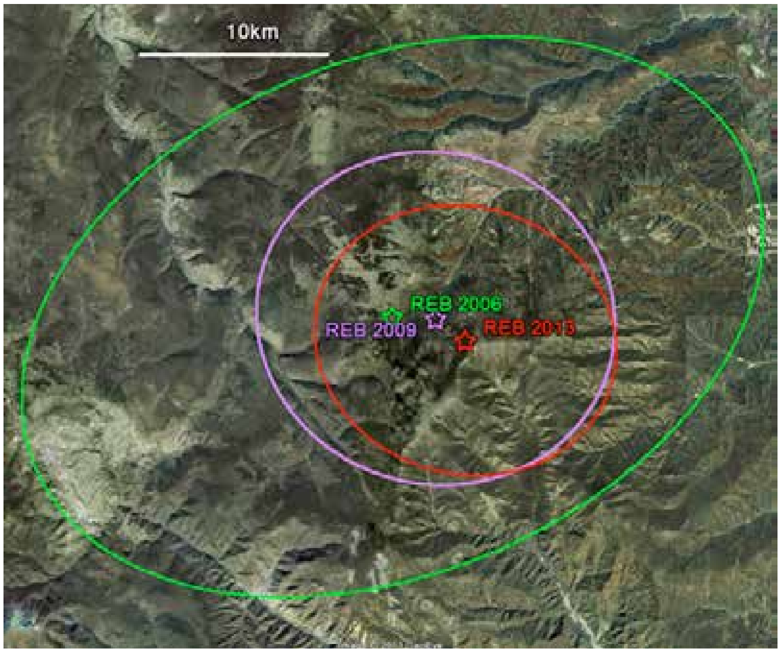
They are very effective, in the sense that signals from key stations had large signals (well above the level of background noise) and were promptly available to analysts. Even if the explosion had been hundreds of times smaller, in my opinion its signals would have been detected and appropriately characterized as coming from an explosion.

The United States Geological Survey (USGS) measured the event in the DPRK on 12 February 2013 as 5.1 in magnitude whereas the CTBTO's International Data Centre (IDC) measured it as 4.9. Could you explain why there are different magnitude scales?

These two agencies use a different set of stations, and analyse their signals in slightly different ways, so it is not surprising that their measurements result in slightly different magnitude values.

The IDC works with a fixed set of primary and auxiliary seismic stations. As these two networks near completion, the IDC has the opportunity to provide a magnitude that could become authoritative. The USGS typically can use more stations – and the International Seismological Centre (ISC) based in the UK can use even more – but the stations used by the USGS and the ISC change from year to year and even more from decade to decade, which in a sense means that their magnitude scale changes slightly as new stations are added and some are closed (or are operated with new equipment).

In my opinion it would be very worthwhile for the IDC to make the effort to provide magnitude measurements based upon generally-agreed procedures and using a fixed station-set with stations (of the IMS) that are operated according to fixed procedures.



The seismic data registered by the CTBTO's monitoring stations help define the area to be searched under an on-site inspection (OSI). This area has been set at a maximum of 1000 km². The ellipses on the map show the location estimates of the 2006 (green), 2009 (purple) and 2013 (red) declared nuclear tests by North Korea. The CTBTO located the 12 February event to within an area of 181km². (red ellipses). Once the CTBT has entered into force, an OSI can be carried out to search on site for any evidence of a nuclear explosion.

How confident are you that the IMS would detect an explosion with a yield of less than one kiloton and would an explosion smaller than that be of any military significance?

I am confident that the IMS would detect an explosion in North Korea well below one kiloton, because that part of the world is monitored very well indeed. However, even in that region there is some level of yield below which monitoring becomes uncertain. It is the goal of monitoring organizations to drive that level down so far that militarily significant activities are inhibited. The question you are asking here raises many different issues especially if it is asked without reference to any specific country (such as DPRK). I participated in a U.S.

National Academy of Sciences study on technical issues related to the CTBT and I support the findings of the report, which was released in March 2012. The report concluded that 'the status of U.S. national monitoring and the International Monitoring System has improved to levels better than predicted in 1999.'

Which technological developments are allowing scientists to improve their analyses of seismic events?

The archives of seismograms that are gradually built up by stations that have been operated for a period of years (in some cases, more than two decades), are turning out to be a resource for improvements in detecting and analysing the signals from small seismic events occurring today. The relevant technological developments here are in computing capability and the management of large databases, including the ability to search for and extract signals from seismic events in the past that occurred in the vicinity of a current event. It is going to be important to manage the growth of seismogram archives effectively, so that signals recorded today can be easily used in future decades, for purposes of interpreting the signals that will be recorded then by the same stations.

In addition to its primary mandate of detecting nuclear explosions, what other civil and scientific applications can seismic data offer?

A complete answer to this question would be extremely long, because seismic data have so many different uses. In my experience, even seismologists are often not aware of the breadth of human activities that engage with, and sometimes depend upon, seismic data. There are communities of users of the raw data (the seismograms themselves), and then a far larger set of communities that use data products such as bulletins of seismicity. Here, I shall emphasize the former applications.

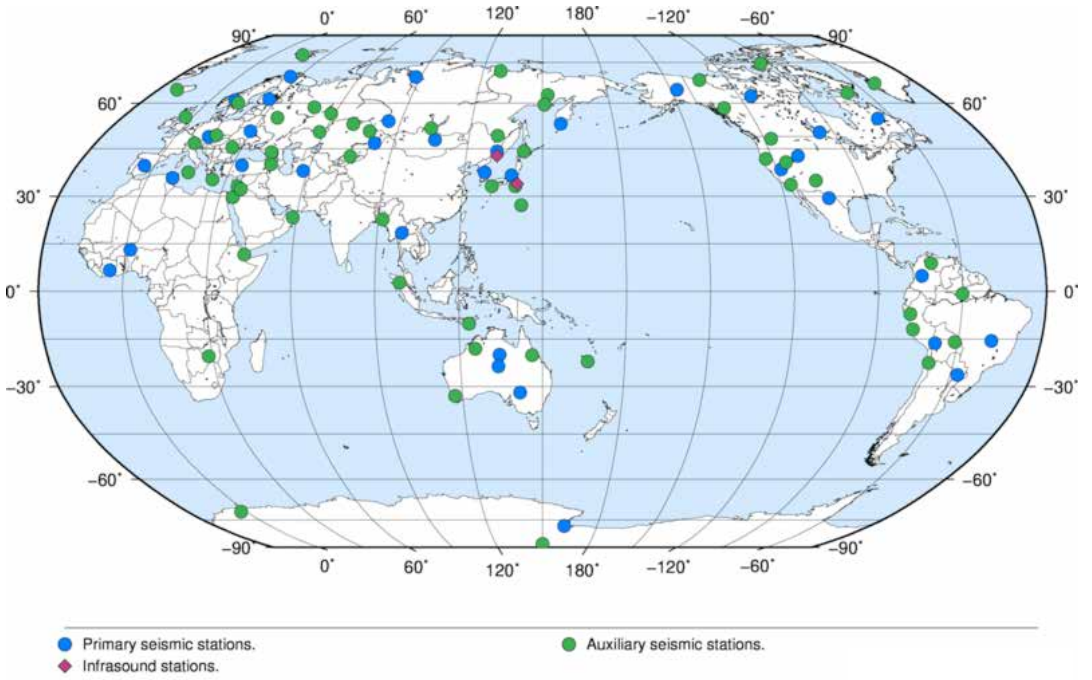
Those who use seismograms directly include researchers who study features of the Earth's crust, mantle and core. The fundamental ideas behind such work are that:

(1) seismic waves are influenced by the material in our planet through which they have travelled in their path from the seismic source (typically, an earthquake or an explosion) to the station where the signals are recorded;

(2) these influences, which include the exact time of arrival, the signal amplitude, and even the detailed shape of a seismic wave, can be regarded as potential information that must first be extracted in a quantitative way from the recorded signals; and

(3) the information must then be interpreted to enable estimates to be made, for example, on the thickness and composition of the layers in the Earth through which the signals have passed. In this way, seismologists first discovered the thickness of the crust in different regions, plus features in the vicinity of the core-mantle boundary, and features associated with the Earth's inner core. This knowledge continues to be refined.

Amazingly, it appears that the inner core at the centre of the Earth, which is largely composed of solid iron and is comparable in size to the Moon, is slowly moving with respect to the rest of the solid Earth, in a fashion which is driven by the same processes that generate the Earth's magnetic field.



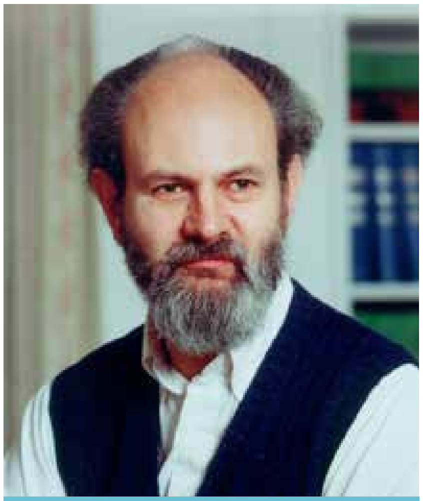
By 14 February 2013, a total of 96 CTBTO monitoring stations had detected the unusual seismic event in North Korea on 12 February 2013. The first data generated by the stations were made available to CTBTO Member States in less than two hours, and before North Korea announced that it had conducted a nuclear test.

On 12 January 2010, a 7.0 magnitude earthquake struck near Port au Prince, Haiti's capital city, claiming between 230,000 and 300,000 lives and leaving 1.5 million people homeless. The study of seismograms from such damaging events enable scientists to learn how much slip occurred between opposite faces on the causative faults whose fracture generated the waves recorded all around the world. Screen shot from NASA WorldWind software of NW Caribbean area.

Original seismograms are also used by scientists who are interested in making estimates of the overall extent of faulting that underlies each large earthquake. Such natural events can be the most devastating phenomena influencing the life and health of millions of people, as we have seen with earthquakes at the magnitude 9 level offshore Sumatra (Indonesia) in December 2004, and offshore Japan in March 2011. Even earthquakes with far less energy can be devastating, as was found in December 2003 in Bam (Iran); in October 2005 in Kashmir; in May 2008 in Sichuan (China); and in January 2010 in Port-au-Prince, Haiti. The study of seismograms from such damaging events enable scientists to learn how much slip occurred between opposite faces on the causative faults whose fracture generated the waves recorded all around the world. And, most importantly, this work enables estimates to be made of the likely time scale for such earthquakes to be repeated.

New programmes are being developed to improve emergency management, in real time, as soon as a large earthquake is detected, with the general goal of providing information as soon as possible to those who might be affected by a soon-to-arrive tsunami, or the arrival of strong shaking that could damage trains and prevent deliveries of electrical power. Such programmes, delivering vital information to enable preparation, require prompt assessment of strong seismic signals from near their point of origination, and then conveying a characterization of the potentially damaging waves that could damage structures at greater distance.

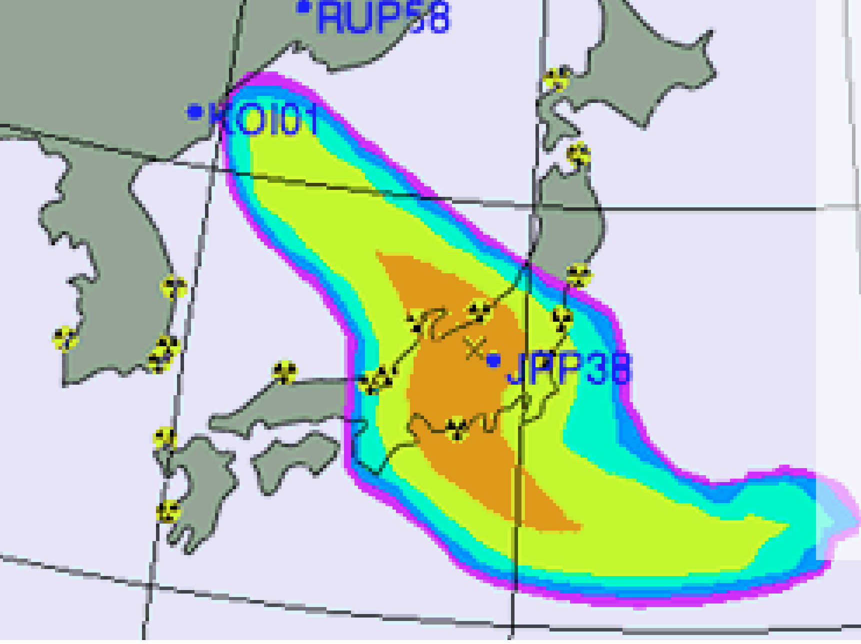
Users of bulletins of seismicity include thousands of scientists and engineers engaged in fault mapping and in general studies of seismic hazard, for broad regions as well as for specific locales where there is the need for guidance on the degree of resistance to earthquake ground motions that must be built into new structures, or perhaps to be achieved by retro-fitting old buildings. The general point here is that hundreds of earthquakes are documented each day around the world; and basic information on where and when they occurred, and how big they could be at different levels of probability, is the starting point for numerous quantitative studies in geology and the physics of earthquakes; in the assessment of risk to large structures; and in the design of building codes.



BIOGRAPHICAL NOTE

PAUL RICHARDS
is a Special Research Scientist at Columbia University, USA, where he was a professor from 1971 to 2008. He co-authored an advanced text in seismology in 1980 (translated into Russian, Chinese, and Japanese), still in print (2nd edition 2002). He has researched methods of explosion and earthquake monitoring since the mid-1980s, has written about 40 professional papers on these subjects, and spent two separate years in U.S. government service (on leave from academia) working on technical issues of nuclear explosion monitoring and test ban negotiations.

Detection of radioactive gases consistent with North Korean test underlines strength of CTBTO monitoring system



Forward Atmospheric Transport Modelling showed that the radionuclides could have come from the North Korean test site.

WHAT WAS DETECTED?

On 8 and 9 April 2013, significant quantities of airborne radioactivity were detected by the CTBTO's radionuclide station in Takasaki, Japan. Additional, smaller detections were made between 12 and 14 April by another station in Ussuriysk, Russia. The detections consisted of the radioactive noble gas xenon. The isotopes in question — xenon-131m and xenon-133 — are typical fission products of plutonium or uranium and therefore used as indicators of a nuclear explosion.

WHY COULD THE RADIOACTIVITY HAVE COME FROM THE DPRK NUCLEAR TEST SITE?

The detection of radioactivity at Takasaki was made 55 days after the announced nuclear test by North Korea on 12 February 2013. The station is located at around 1,000 kilometres, or 620 miles, from the North Korean test site. The noble gases that were detected provided us with information about the nature and timing of a nuclear event. By using atmospheric transport modelling (ATM), the calculation of the three-dimensional travel path of airborne particles or gases, the North Korean nuclear test site was found to be a possible source. "According to the Austrian Meteorological Agency, ZAMG, which performed high resolution ATM calculations, there is a perfect match with our models and the timing of the [12 February] event," CTBTO radionuclide expert Mika Nikkinen said.

In addition, CTBTO Member States in the region were consulted and helped to exclude other sources, such as a leak from a nuclear installation.

WHY WAS THE DETECTION MADE SO LONG AFTER THE ANNOUNCED NUCLEAR TEST?

The observations indicate that the radioactive gases had initially been contained in the test tunnel, and were released instantaneously around 7 April 2013 – for reasons unknown. A more usual scenario for underground nuclear explosions is that radioactive gases may gradually seep through cracks to the surface, a process known as venting, possibly leading to an earlier detection.

This was the case after the 2006 North Korean announced nuclear test, when traces of xenon-133 were detected two weeks later at a station in Yellowknife, Canada. Lassina Zerbo, Director of the International Data Centre explained: "The detections in 2006 and 2013, from which the Atmospheric Transport Modelling gave us an indication that they came from the Korean peninsula, say that we had one isotope in 2006 and two isotopes in 2013, with a higher concentration. This is probably because we have a station that is much closer to the peninsula or within the peninsula, that detected at a higher concentration, as opposed to 2006, where we had a detection 7,000 kilometres away from the potential source."

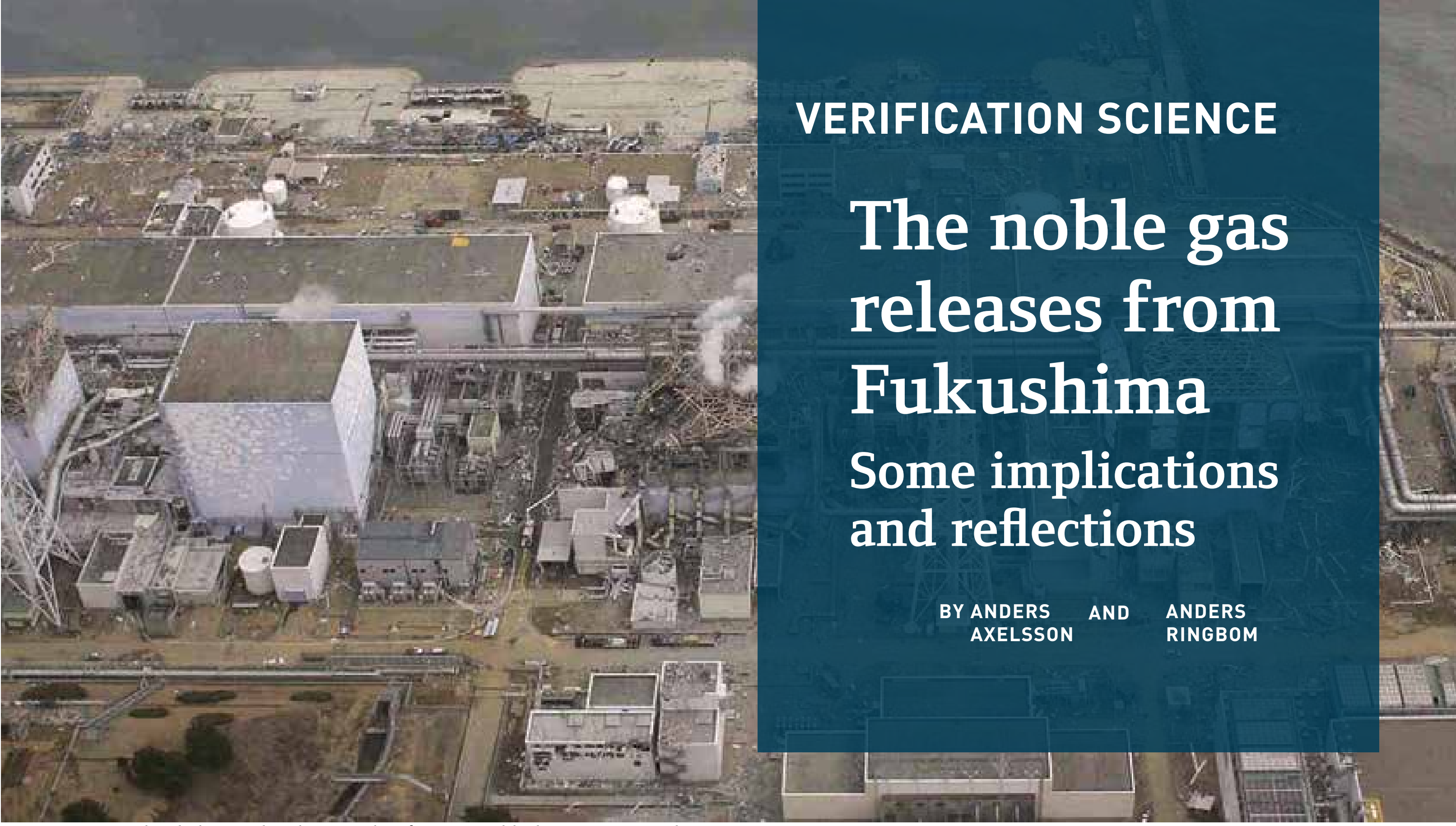
When the network is complete, half of the CTBTO's 80 planned radionuclide stations will be equipped to detect radioactive noble gases, in addition to radioactive particles. Of the 66 radionuclide stations installed so far, 30 have noble gas capabilities, compared to only 11 in 2006.

WHY COULD THE RADIOACTIVITY NOT HAVE COME FROM THE FUKUSHIMA POWER PLANT?

The combination and concentration of the two radionuclides that were detected by the Takasaki station were very different to what one would expect to see from Fukushima more than two years after the accident. ATM calculations also pointed to a source to the west of Takasaki, while Fukushima and other Japanese nuclear facilities in the area are predominantly east of the station.

WHAT DOES THE DETECTION SAY ABOUT THE DPRK'S NUCLEAR WEAPONS PROGRAMME?

"The detection doesn't indicate the type of fissile material used because nuclear fission happened a long time ago. In order to be able to distinguish between uranium and plutonium, it is preferable to have a good sample much earlier. With these detected xenon isotopes the difference in ratio between uranium and plutonium based fission is so small that the differentiation cannot be made after such a long time," Nikkinen said.



VERIFICATION SCIENCE

The noble gas releases from Fukushima

Some implications and reflections

BY ANDERS AXELSSON AND ANDERS RINGBOM

The Fukushima Daiichi nuclear power plant after it was struck by the tsunami on 11 March 2011. Photo courtesy of Air Photo Service Co. Ltd., Japan.

The tsunami caused by the large underwater earthquake close to the north-east coast of Japan on 11 March 2011 resulted in large releases of radionuclides from the Fukushima Daiichi nuclear power plant in the days that followed. Particle-borne radionuclides like Cs-137 and I-131, as well as noble gas isotopes like Xe-133 (see fact box on page 30) were released into the Earth's atmosphere. Based on measurements from the Preparatory Commission for the Comprehensive Nuclear-Test-Ban Treaty Organization's International Monitoring System (IMS) in combination with atmospheric transport modelling (ATM)[1], several research groups have estimated that all of the xenon contained in the nuclear reactor was released. After a few weeks the entire northern hemisphere contained radioxenon concentrations about 1,000 times above the normal background level[2]. It should be pointed out that atmospheric radioxenon concentrations at that level are still insignificant from a human health perspective.

The estimated total release of Xe-133 exceeded 1019 Bq[3]. This is one of the largest radioxenon releases in history, even exceeding the release from Chernobyl in 1986. As a source of noble gases, the Fukushima accident corresponds to an atmospheric nuclear explosion of 1 megaton. The design criterion for the IMS is 1 kiloton , or 1,000 times less. Nevertheless, consideration of the Fukushima releases and their aftermath can prompt several interesting points of discussion regarding the design of the Comprehensive Nuclear-Test-Ban Treaty (CTBT) monitoring network, the incorporated technologies, the use of the data and future lines of development for technology and data use. In this article we will address some of these issues, focusing in particular on the noble gas component of the IMS.

HOW NOBLE GASES DIFFER FROM OTHER RADIONUCLIDES

The key property that makes noble gases different from other radionuclide releases is the fact that they do not react chemically with surrounding material. This means, for instance, that they are difficult to contain in an underground nuclear test and will not be washed down by precipitation. The latter property was also well illustrated by the Fukushima accident, resulting in a very even distribution of Xe-133 observed by the IMS network a few weeks after the accident. All stations in the northern hemisphere measured very similar concentrations. This can

[1] Atmospheric Transport Modelling (ATM) is the calculation of the travel and dispersion of radionuclides released into the atmosphere, using meteorological data. This calculation can be performed in two ways:
- As backtracking ATM, which identifies the area from which radionuclides may have been released, calculated from the location where they were observed.
- As forward ATM, which identifies where radionuclides may travel from their known point of release.

[2] On a global scale, the background is dominated by releases from medical isotope production facilities, locally, the background can be strongly influenced by releases from nuclear reactors and from hospitals.

[3] A Becquerel (Bq) is the amount of radioactive material in which 1 atom decays every second.
1 milli-Becquerel (mBq) = 10**-3 Bq
1 micro-Becquerel (uBq) = 10**-6 Bq

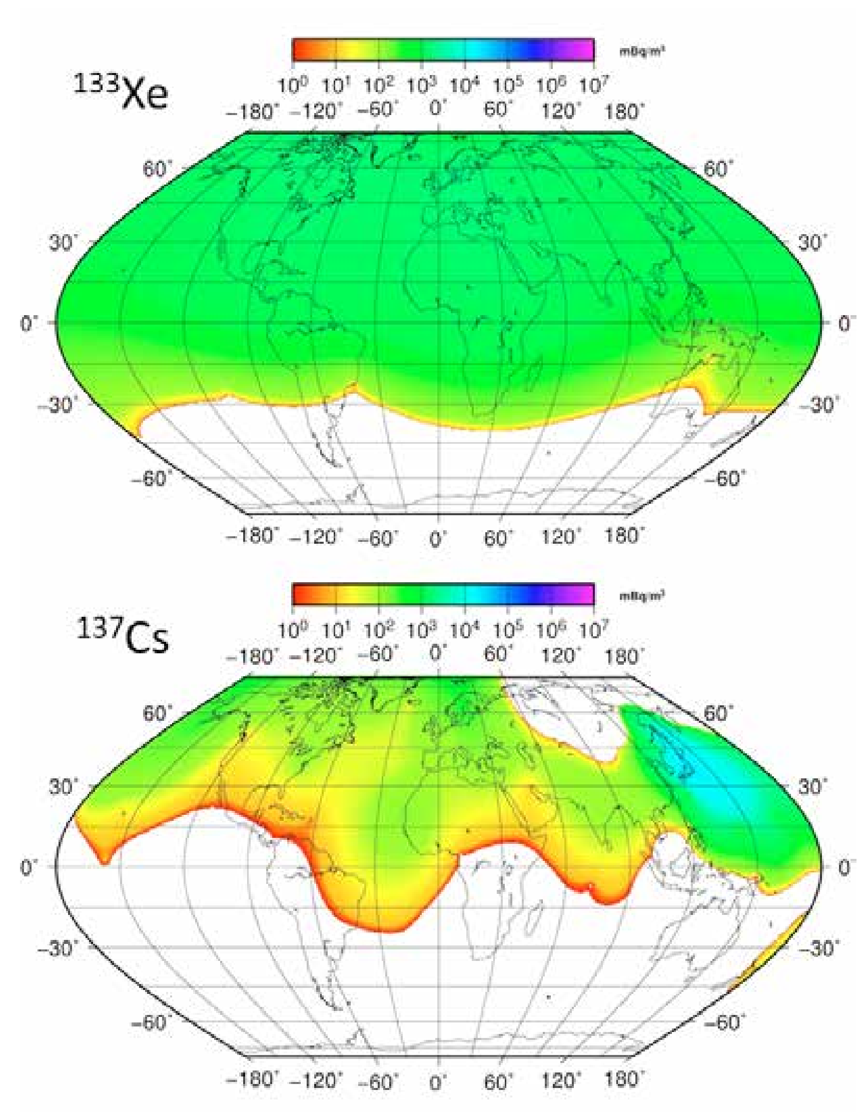


Figure 1:
Approximate distribution of the atmospheric activity concentration of the noble gas isotope 133Xe and the particle-borne radionuclide 137Cs on 30 March 2011, almost three weeks after the massive earthquake in Japan. The maps were obtained by interpolating data collected by the IMS radionuclide network. Note the homogenous distribution of xenon in the upper panel. The maps illustrate only the main features of the activity concentration, and should not be used to draw any quantitative conclusions for any specific geographic locations. In particular, the xenon concentration did not reach as far south as illustrated by the upper map.

be compared to the distribution of a particle-borne nuclide like Cs-137, which had a more inhomogeneous spatial activity distribution (see Figure 1).

KEY ROLE OF NOBLE GAS DETECTION SYSTEMS

Had the event occurred ten years earlier, before the IMS was equipped with noble gas detection systems, it would have been impossible to obtain a global picture of the noble gas releases from Fukushima. The development of the measurement systems that made this possible started some 15 years ago within the framework of the so-called International Noble Gas Experiment (INGE) which was set up in 1999 to test the measuring of radioactive noble gases in the atmosphere (see page 31). Of the 80 IMS radionuclide stations foreseen in the Treaty, 40 are to have additional noble gas detection capabilities. More than 75% of the noble gas network is now complete and equipped with these very sensitive measurement systems. A common way to represent the measurement capability of this network is to estimate the average number of stations that would detect a nominal explosion-size release of radionuclides from each point on the planet. This notion of coverage indeed captures an essential feature of the network. However, in judging how well the radionuclide network fulfills its part of the CTBT verification mission, one also needs to consider under which circumstances detections are most likely to be useful. These include possibilities for determining the source location and time of an event and the ability to distinguish it from detections that are not relevant to the CTBT, such as noble gas emissions by the radiopharmaceutical industry.

From this point of view, the releases from Fukushima constituted an enormous, if temporary, increase in background. To what extent was the effectiveness of the noble gas network hampered? The question is interesting both on a measurement level and on a data evaluation level. In fact, the noble gas detection systems responded very well to the impact of the Fukushima radiation releases. Apart from the very first samples measured at the IMS station in Takasaki, Japan, (the station located closest to the Fukushima Daiichi power plant which was hit by the largest concentrations of radionuclides), it was possible to use the data generated by the station to obtain accurate concentration values – even at such high levels – after appropriate corrections had been made.

On a measurement level, the strong global signature of the Fukushima releases reminds us of the need to overcome the so-called "memory effect" by which the measurement of a sample in systems using plastic scintillator detectors such as the SAUNA and ARIX systems (see page 31) containing a high amount of radioxenon activity will degrade the sensitivity of subsequent measurements for some time. Recent advances in the surface treatment of detector cells (i.e. reducing the amount of radioactivity retained by the detector from previous measurements) promise to radically shorten or totally eliminate this recovery time following the measurement of a sample with a high concentration.

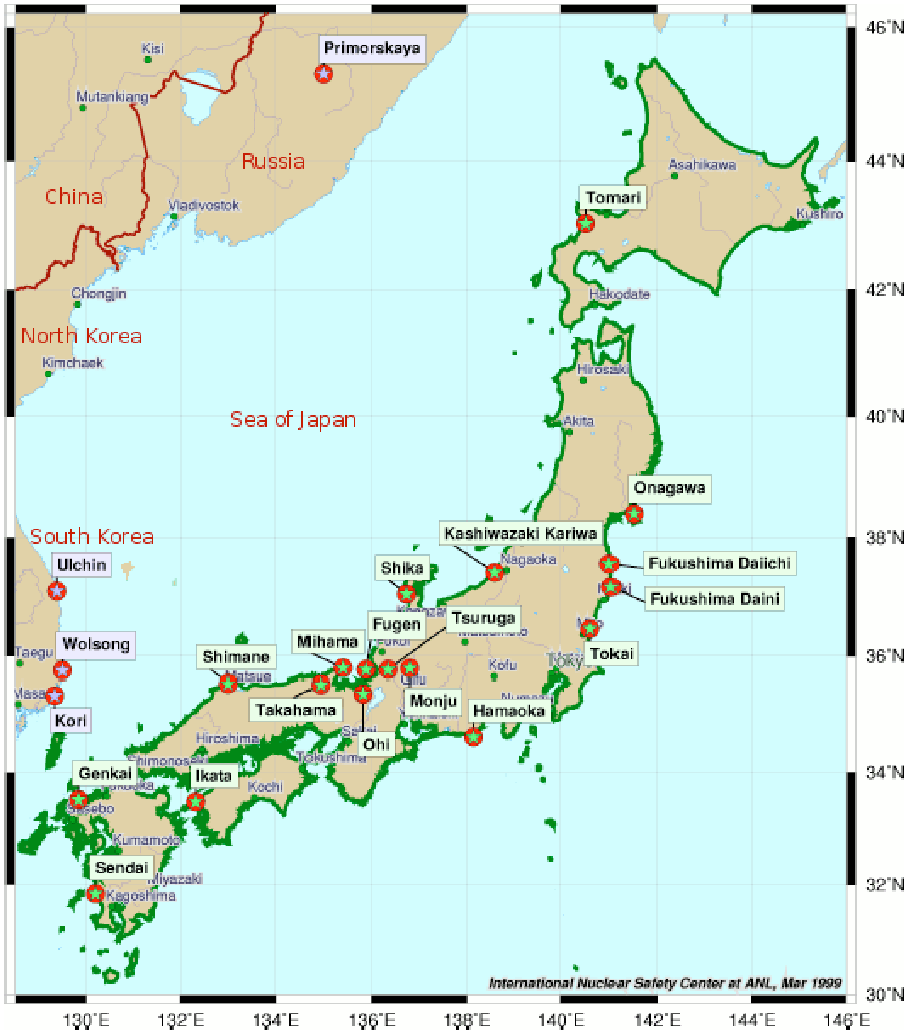
KNOWLEDGE OF RADIOXENON BACKGROUND LEVELS IS ESSENTIAL

On a network response level, the experience highlights the need to understand and discriminate against background from non-explosion radioxenon sources such as nuclear power plants and radio-pharmaceutical production facilities. The latter type of background source constitutes the greater problem, both in terms of released amounts (obviously, Fukushima is an exception) and, more seriously, released signatures: the short irradiations used in medical isotope production can produce radioxenon with isotopic ratios similar to those produced in a nuclear explosion. The solution lies partly in improved source location to screen out known background sources, and partly in mapping and understanding specific background sources as well as generic background in various regions of the world. The use of mobile or transportable radioxenon detection equipment in various campaigns around the world for this purpose has been highly successful and is expected to continue to yield valuable knowledge to improve background discrimination.

THE NEXT GENERATION OF DETECTION SYSTEMS

The experience that is being accumulated from operating a global network of sampling stations can now be used to design a next generation of detection systems, which will also be more specialized for the intended mission and incorporate a more holistic view of that mission. The overall task is to detect and identify nuclear explosions as part of a global network of monitoring stations incorporating a number of technologies. The optimal use of data from all relevant technologies embodies the concept of data fusion, which is increasingly discussed today. It is evident that while seismic signals would be the preferred primary source of location information pertaining to an event, the usefulness of radionuclide detections in demonstrating the nuclear character of that event depends on how well the source region of detected radionuclides can be defined.

Obviously, the sensitivity for the detection of nuclides of interest is important. Source timing and source discrimination are typically obtained from ratios of concentrations measured in one nuclide to another. Thus, simultaneously detecting and quantifying two or more radioxenon isotopes will be considerably more valuable than the simple detection of only one. There are examples of detections of other radioxenon sources only a few weeks after the Fukushima accident, which could be identified despite high background concentrations. However, sensitivity is not the only parameter of interest. Given an ambient concentration of radionuclides around a station, the more air that is sampled, the better the detection sensitivity, but sampling more air takes more time. However, the time resolution of a measurement directly impacts the source location effectiveness of ATM. The 12- or 24-hour sampling periods of the systems deployed in the network may not in fact represent the optimum



Map of Japan showing the Fukushima Daiichi Nuclear Power Plant.

ARIX noble gas system

balance between detection sensitivity and time resolution from the point of view of source location.

HOW TO AUGMENT NETWORK DENSITY

The most favourable case for using ATM to estimate a well-defined source region is when several network stations at different locations detect radionuclides from the same source event. However, there is no guarantee that this will be possible if the releases are from a nuclear explosion with a yield in the kiloton range. This is due to the current density of radioxenon measurement systems deployed by the IMS, even though the systems themselves exceed the initial sensitivity specifications. The operation of national monitoring stations contributing data to the CTBTO's International Data Centre (IDC) in Vienna and National Data Centres should be encouraged as a way to augment network density.

In the context of the Fukushima releases, it is important to remember that the IMS radionuclide network is not designed as a radiological emergency system. However, unlike national networks, the IMS network is a globally integrated radionuclide

FACT BOX

CAESIUM-137 (Cs-137):
Cs-137 has a half-life of 30.1 years. This is the most common radioactive form of caesium and is produced by nuclear fission. Cs-137 is one of the major radionuclides in spent nuclear fuel and radioactive wastes associated with the operation of nuclear reactors and fuel reprocessing plants. Large amounts of Cs-137 and other radioactive isotopes were released into the environment by atmospheric nuclear weapon tests between 1945 and 1980. Cs-137 did not occur in nature before nuclear weapon testing began.

IODINE-131 (I-131):
I-131 has a half-life of 8.0 days. I-131 is a radioactive isotope released into the environment mostly in gaseous form as a result of the atmospheric testing of nuclear weapons and accidents that have occurred at nuclear power plants (e.g. the Chernobyl nuclear power plant in 1986 and the Fukushima power plant in March 2011). It was a significant contributor to the effects on human health from atmospheric nuclear weapon testing and from the Chernobyl disaster.

XENON
is a chemical element in gaseous form. It is one of the noble gases which is inert and rarely reacts with other chemicals. Several of its radioactive isotopes, of which one of the isotopes is xenon-133 (Xe-133), are short-lived and typical of technological processes and are therefore measured to detect clandestine underground nuclear explosions.

BIOGRAPHICAL NOTES

ANDERS AXELSSON
is a Senior Scientist at the Swedish Defence Research Agency, Division of Defence & Security Systems and Technology. He is manager of the Swedish National Data Centre for Comprehensive Nuclear-Test-Ban Treaty monitoring. Dr Axelsson has previously worked at the Preparatory Commission for the Comprehensive Nuclear-Test-Ban Treaty Organization with on-site inspection noble gas equipment and at the International Atomic Energy Agency with environmental sampling data for international safeguards.

ANDERS RINGBOM
is the Deputy Research Director at the Swedish Defence Research Agency, Division of Defence & Security Systems and Technology. He is a technical advisor to the Swedish Government and Swedish representative at the CTBTO's Working Group on verification issues. Dr Ringbom was the main developer of the noble gas system SAUNA and has developed equipment and analysis techniques for radioxenon detection used by the CTBTO. In 2006 he conducted a measurement in cooperation with South Korea that detected radioxenon from the first nuclear test in North Korea.

monitoring system, the only one of its kind. The global nature of the IMS network enabled the global tracking of radionuclides released in the Fukushima incident, and made the data available to the governments of all CTBTO Member States. The IMS network clearly has some special qualities which make the data valuable. The extent to which the data can be made public is governed by both practical and political constraints. On the practical side, only data which have been properly evaluated in the context of a possible radiological emergency should be released to the public. On the political side, the operation of the IMS is a collaborative endeavour among all Member States. It is in some ways an intrusive verification measure, with very sensitive monitoring stations located on the territory of a large number of States. In order to preserve long-term support for the CTBT verification regime and the continued availability of data, decisions on the handling of the monitoring data need to be made with due regard for the different perceptions that Member States may have of their national interests in this respect.

A WEALTH OF DATA HELPING TO INCREASE KNOWLEDGE

The build-up of the noble gas system component of the IMS has been very successful. New technology that many doubted would work 15 years ago has been developed and implemented in a short time. The new systems provide us with a vast amount of data that results in new knowledge every day. The tragic Fukushima accident reminded us how important the global detection network can be beyond its primary mission of verification. We now have to start gathering ideas on how to use this new knowledge in a broader context in order to fulfill the CTBT verification mission to the maximum extent possible, and to further investigate the possibilities that exist for using the system for other purposes as well.

THE DIFFERENT 'NOBLE GAS' SYSTEMS USED TO DETECT RADIONUCLIDES IN THE ATMOSPHERE

Radioactive xenon (radioxenon) isotopes are produced in abundance by a nuclear test. Four of them are used in CTBT monitoring: Xe-131m, Xe-133, Xe-133m, and Xe-135. They have a half-life of between 9.10 hours and 11.9 days (the half-life of any given nuclide is the time required for one half of the sample to decay). Although Xe-131m has the longest half-life of these four isotopes, its yield is the smallest. With a half-life of 5.2 days, xenon-133 (Xe-133) is in most circumstances the most abundant of the isotopes. With suitable equipment, it is therefore possible to detect radioxenon isotopes days or even weeks after their release and at great distances from their source.

The CTBTO uses three noble gas systems to detect radioxenon. Forty of the CTBTO's network of 80 radionuclide stations are being equipped with one of these special systems designed to detect noble gases:

- The Swedish Automatic Unit for Noble Gas Acquisition (SAUNA)
- Le Système de Prélèvements et d'Analyse en Ligne d'Air pour quantifier le Xénon (SPALAX)
- The Analyzer of Xenon Radioisotopes (ARIX). (See below for more information).

HOW RADIOXENON IS ISOLATED

The systems work by continuously and automatically separating xenon from ambient air using a purification device that contains charcoal. Contaminants such as dust as well as air constituents like oxygen, humidity, CO^2 and radon are all removed during this process. Radioactive levels in the isolated xenon are then measured in a radiation counting device. The resulting spectrum is sent to the International Data Centre (IDC) in Vienna on a daily basis for analysis. The noble gas systems that are currently deployed were developed in the late 1990s and have been tested under the International Noble Gas Experiment.

SPALAX noble gas system

SAUNA was developed by the Swedish Defence Research Agency and made commercially available in 2004. SAUNA samples up to 15m^3 of air during a 12 hour sampling interval, thus producing two samples per day. The system uses a measurement technique called 'beta-gamma coincidence'.

ARIX was developed and commercialized by the Khlopin Radium Institute in the Russian Federation. ARIX samples up to 15m^3 of ambient air and extracts xenon from it in 12-hour cycles This system produces two samples per day and also uses the beta-gamma coincidence technique.

SPALAX was developed by the French Commissariat à l'énergie atomique. This equipment samples up to 75m^3 of air continuously in 24-hour cycles. At the end of each collection cycle and after final purification, the xenon gas is transferred into a High Purity Germanium detector counting system.

THE ROLE OF THE ANALYST

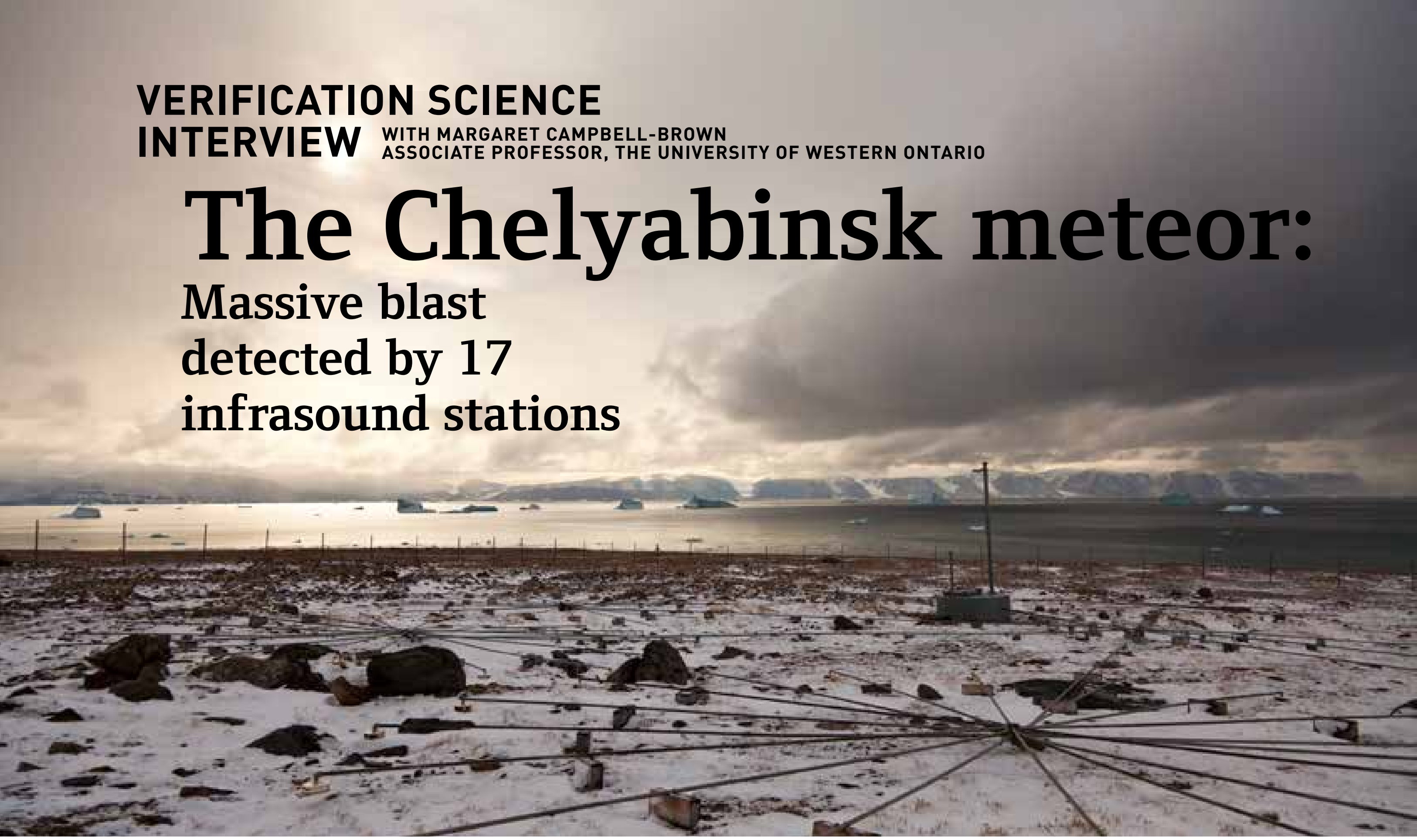
Analysts need to know which radionuclides occur naturally and which are man-made. It is imperative to know which radionuclides are generated by a nuclear explosion since xenon radionuclides also enter the atmosphere from other man-made sources. Analysts must also be familiar with the quantities and ratios in which these nuclides are produced during a nuclear explosion. Based on the analysis by National Data Centres and the IDC, Member States can then determine whether or not the sample suggests that a nuclear explosion has indeed taken place.

VERIFICATION SCIENCE

INTERVIEW WITH MARGARET CAMPBELL-BROWN
ASSOCIATE PROFESSOR, THE UNIVERSITY OF WESTERN ONTARIO

The Chelyabinsk meteor:

Massive blast detected by 17 infrasound stations



The CTBTO's infrasound station IS18 in Qaanaaq, Greenland, one of the stations that detected the Chelyabinsk meteorite on 15 February 2013. Photo courtesy of Owen Kilgour.

»Statistically, something this size hits the Earth approximately once every 50 years (though nothing this size or larger has been observed to hit the Earth since 1908). This event was nearly ten times as energetic as the Sulawesi, Indonesia fireball of 2009.«

On 15 February 2013 at 03:22 GMT, 17 of the CTBTO's infrasound stations detected signals from an object that entered the atmosphere and disintegrated in the skies over Chelyabinsk, Russia. The furthest station to record the sub-audible sound was 15,000km away in Antarctica. How did data from these infrasound stations allow scientists to refine their estimates for the size of the meteor?

A great advantage of infrasound is that data are quickly available and energy estimates can be made relatively quickly. Given the speed of the meteoroid, its mass could be calculated directly from the energy. There was tremendous interest in the size of the object, but the video records are very difficult to calibrate, so infrasound was the first publicly available, accurate size estimate.

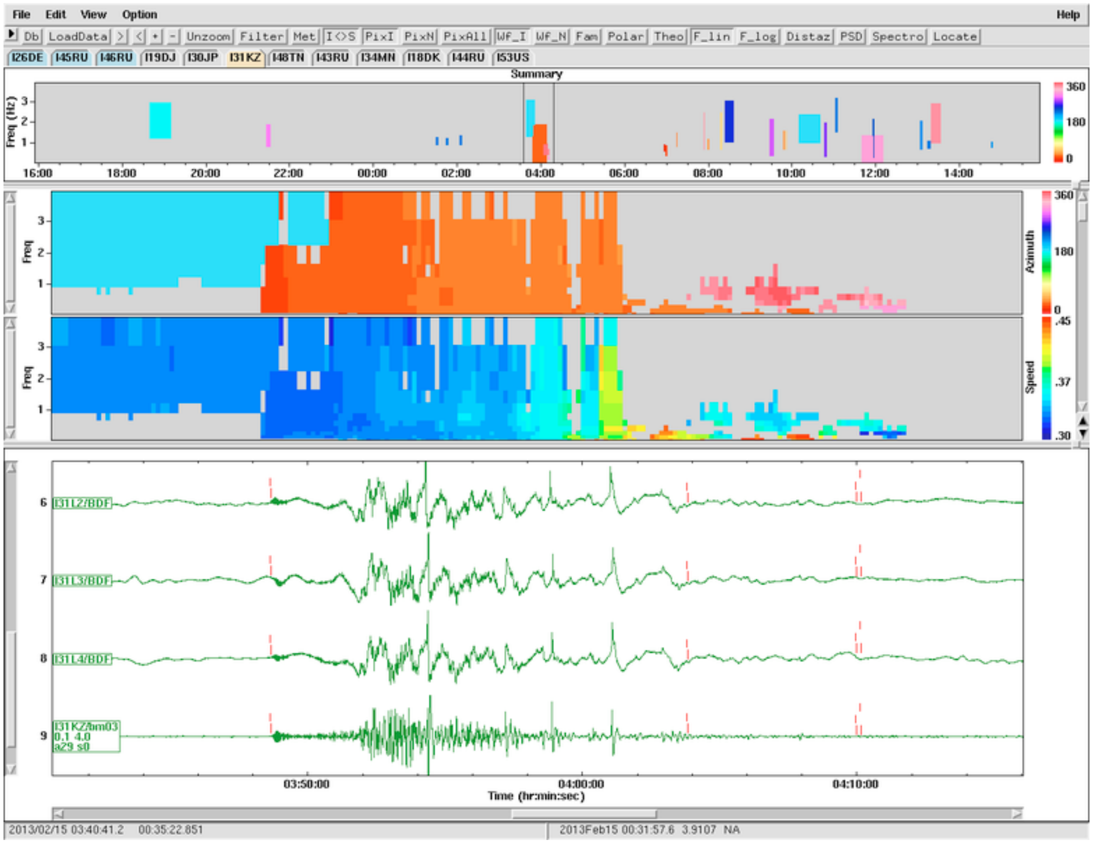
Why did the meteor go undetected until it hit the atmosphere?

Very few objects in this size range are currently tracked. There are likely hundreds of thousands of objects this size in orbits which intersect the Earth's, but they are faint objects, and currently operating surveys cannot track a meaningful number of them (though some planned surveys may allow many of them to be discovered and monitored). An object smaller than this one was observed for about a day before it struck the Earth in 2008 (object TC3 2008, which fell in the Sudanese desert), but that is the only time an object has been observed in space and subsequently collided with the Earth. A detection just before impact was not possible for this object, because it approached the Earth from the direction of the sun, and was obscured by the sun's glare.

How often would you expect an event of this magnitude to occur and how large was it in comparison with the bolide that exploded over Sulawesi, Indonesia, in October 2009, which was recorded by 15 of the CTBTO's infrasound stations?

Statistically, something this size hits the Earth approximately once every 50 years (though nothing this size or larger has been observed to hit the Earth since 1908). This event was nearly ten times as energetic as the Sulawesi, Indonesia fireball of 2009.

Just days earlier on 12 February 2013, the Democratic People's Republic of Korea (DPRK) claimed that it had conducted a nuclear test. A total of 94 of the CTBTO's seismic sensors registered



A visual representation of the infrasound waves and parameters by the CTBTO's International Data Centre, from the fireball recorded by the CTBTO station in Kazakhstan.

the event, which measured 4.9 in magnitude. In addition, two infrasound stations that are part of the network also detected signals. This was the first time that the CTBTO's infrasound stations had registered a nuclear test. How large would you estimate the size of the explosion over Chelyabinsk to have been in comparison with the nuclear test that the DPRK claims to have carried out?

I don't know the energy of the 12 February event, but the meteor was certainly orders of magnitude more energetic.

Since the Comprehensive Nuclear-Test-Ban Treaty (CTBT) opened for signature in 1996, infrasound technology has experienced a renaissance. While the primary purpose of CTBTO infrasound monitoring is to monitor compliance with the CTBT, the data also offer a range of potential civil and scientific applications. In addition to providing information on meteors entering the atmosphere, the data could be used to monitor aurorae, chemical explosions, volcanic ash clouds as well as contributing to climate change research. What more do you think scientists can learn about the Russian meteor explosion on 15 February 2013 from CTBTO infrasound data?

The infrasound data provided excellent near-real-time information on the size of the impactor. With more refined models of the atmospheric conditions at the time, the various parts of the signal may be associated with fragmentation events and points along the trail, giving a better idea of what was happening to the object as it disintegrated in the atmosphere.

BIOGRAPHICAL NOTES

MARGARET CAMPBELL-BROWN is an Associate Professor in the Department of Physics and Astronomy at the University of Western Ontario, Canada. Her research focuses on small bodies in the solar system, particularly meteoroids. Current research topics include the interaction of meteoroids with the Earth's atmosphere for large and small impactors, characterizing the sporadic meteoroid environment, and high resolution studies of meteoroid ablation to determine the composition and structure of meteoroids.

ART AND NUCLEAR TESTING

Featuring

Elin O'Hara Slavick

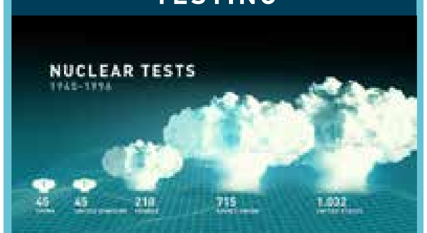
"As a university professor, I can attest to the power of art to educate. If we can interject a discussion of peacemaking and an understanding of our involvement in war after war into the deafening noise of patriotism and the chaotic speed of information and communication systems, then we have begun to challenge the status quo.

Art can teach us in so many ways about so many things: it can literally help us understand space and perspective, relationships between objects, scale, colour, composition, texture and all those formal qualities; but it can also open our mind to new ways of seeing and thinking in this world – that history is usually told from one perspective and usually by men and the winners; that art can and does change the world, as much as anything else does; that we can make beautiful things amidst so much ugliness; that art is hope, a constructive, positive process, and often a collaborative one – not only between artists but between artist and viewer.

In my series of bomb drawings, it is important to show places unknown to most Americans, like Enewetak Atoll in the Marshall Islands, alongside infamous sites like Iwo Jima where a major battle took place during the Second World War. It is imperative that I not only represent the places familiar to everyone but include the lesser known locations so that people can make connections and begin to have a sense of the unimaginable scope of our violence against civilians, even against ourselves, especially the lingering perils of nuclear weapons. I use a ground of abstract swirling or bleeding to depict the manner in which bombs do not stay within their intended borders. Radioactive materials and chemical agents contaminate the soil, travelling in water and currents of air for decades. Mines and unexploded bombs lay in wait for unsuspecting victims who were not even alive during the war. Bombs lay the groundwork for genocide, cancer, more war, terrorism, widows, orphans and a vengeful populace on all sides of conflict."

Elin O'Hara Slavick has been a Distinguished Term Professor at the University of North Carolina in the USA since 1994. Slavick teaches Conceptual and Experimental Photography, Collaborative Visual Projects, Drawing, Mixed Media and Body Imaging.

NUCLEAR TESTING



The history of nuclear testing began early on the morning of 16 July 1945 at a desert test site in Alamogordo, New Mexico, USA, when the United States exploded its first atomic bomb.

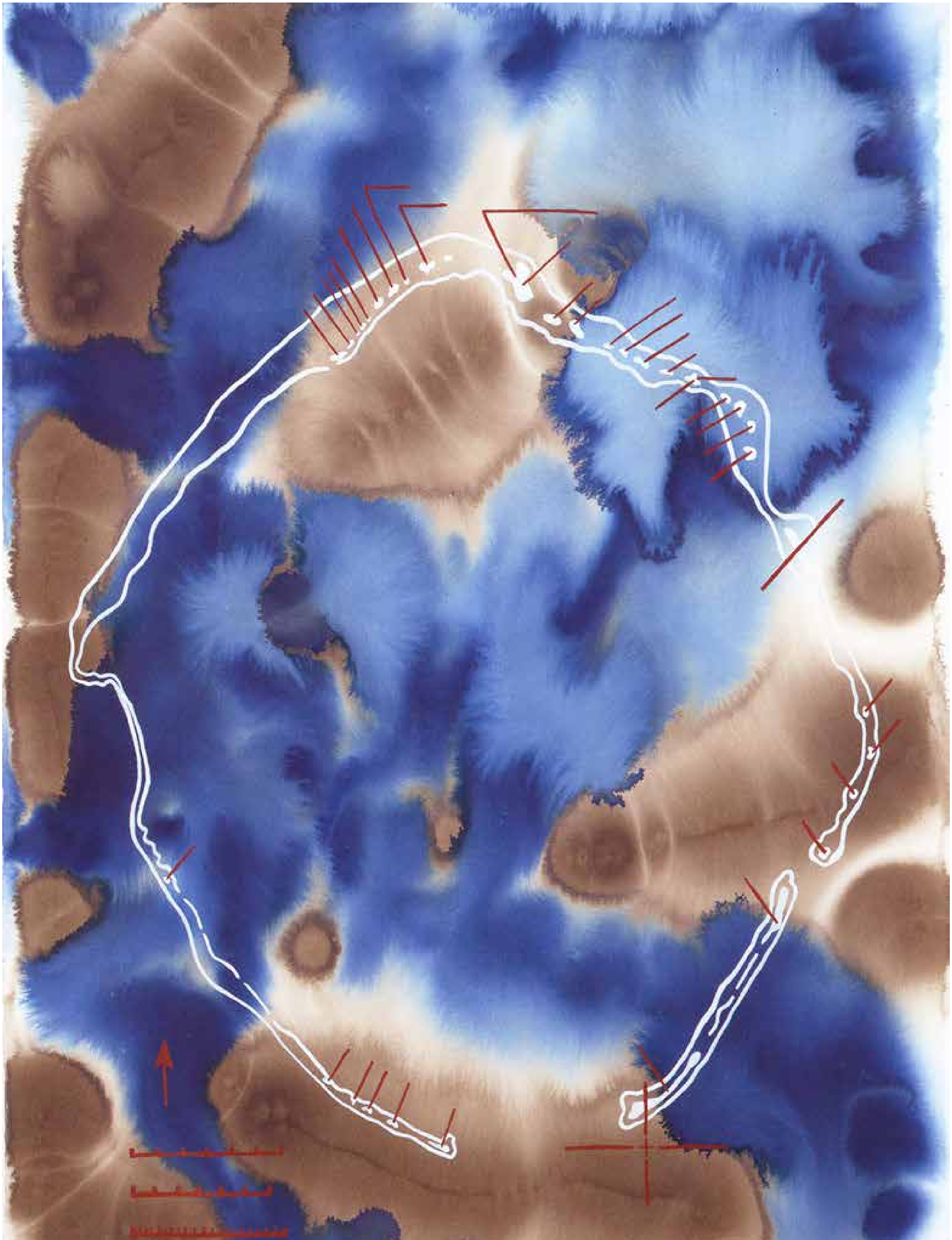
In the five decades between that fateful day in 1945 and the opening for signature of the Comprehensive Nuclear-Test-Ban Treaty (CTBT) in 1996, over 2,000 nuclear tests were carried out all over the world.

COUNTRY	NO. OF TESTS	TIMESPAN
United States	1,032	1945-1992
Soviet Union	715	1949-1990
United Kingdom	45	1952-1991
France	210	1960-1996
China	45	1964-1996

The figures above are approximate and based on official government sources, as well as on information provided by research institutions such as the Natural Resources Defence Council in Washington D.C., and the Stockholm International Peace Research Institute (SIPRI).

Enewetak Atoll
by Elin O'Hara Slavick

The Enewetak Atoll drawing takes as its reference a map from a world atlas. The United States conducted forty-three atmospheric tests at the Enewetak Atoll in the Marshall Islands between 1948 and 1958. Several of these tests were thermonuclear. The small islet of Elugelab was vapourized and the radioactive fallout produced by the tests contaminated the islands and the lagoon of the atoll.



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We Are Our Own Enemy, Alamogordo, New Mexico, USA,1945

by Elin O'Hara Slavick

This drawing by Elin O'Hara Slavick takes as its reference an aerial photograph from the Los Alamos National Laboratory Archive of the crater formed by the first atomic explosion.

On 16 July 1945 the Trinity test took place at the Alamogordo Test Range in New Mexico, USA. It was the first nuclear explosion in history.

The detonation is credited as the beginning of the Atomic Age.

See page 34 in this issue for more information about the artist and her work.

Saucer-shaped craters caused by subsidence following the underground nuclear tests at the Nevada Test Site. Courtesy of U.S. Department of Energy.

Crater from the 1962 "Sedan" nuclear test, the largest man-made crater ever created. Courtesy of U.S. Department of Energy.