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

CTBTO Spectrum

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Who we are

The Comprehensive Nuclear-Test-Ban Treaty (CTBT) bans all nuclear explosions on Earth. It opened for signature on 24 September 1996 in New York.

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.

Editorial

The significance of the Conference on Facilitating the Entry into Force of the Comprehensive Nuclear-Test-Ban Treaty (Article XIV conference) in New York on 24 and 25 September 2009 cannot be overstated. It is being held in a new positive climate, a veritable renaissance of nuclear disarmament and non-proliferation. In particular, it is the first Article XIV conference in which the CTBT's entry into force has become a realistic political objective in the near to medium term.

An increasing level of support for the Comprehensive Nuclear-Test-Ban Treaty (CTBT) is reflected in statements by groups such as the G8, the Non-Aligned Movement, and the European Union, and by the majority of delegations at the Preparatory Committee for the Nuclear Non-Proliferation Treaty (NPT) Review Conference in May 2009. The statement adopted by the Foreign Ministers participating in the September 2008 CTBT Ministerial Meeting was endorsed by 91 ministers, more than any previous statement.

Reflecting the renewed political prominence of the CTBT, this issue of Spectrum has an abundance of political and scientific contributions from prominent authors. No less than four foreign ministers explain why the CTBT is important to their countries: French Foreign Minister Bernard Kouchner and his Moroccan counterpart, Taieb Fassi Fihri, who will be jointly presiding over the Article XIV conference; Alberto Romulo, Foreign Minister of the Philippines and Carl Bildt, Foreign Minister of Sweden, the country currently holding the Presidency of the European Union.

With regard to the articles by political analysts, Chinese academic and nuclear arms control expert, Shen Dingli, explains why the CTBT should be ratified by China. James Goodby, former U.S. diplomat and specialist on nuclear non-proliferation and security issues, places the CTBT into the wider context of nuclear non-proliferation.

On the more scientific side, physicist and verification expert David Hafemeister presents a detailed analysis on the CTBT's verifiability. Sidney Drell, physicist and longtime adviser to the U.S. government and the nuclear weapons laboratories, reflects on the Stockpile Stewardship Program, an important factor for the U.S. discussions on CTBT ratification. The North-West Pacific Tsunami Information Center in Japan explains how it profits from International Monitoring System (IMS) data for tsunami warning purposes. And finally, our own experts provide insights into the CTBTO's findings on the May 25 North Korean nuclear test.

The global support for the CTBT is evident from the sheer numbers of signatures and ratifications: As of today, the Treaty has been signed by 181 States, 149 have ratified, and it is fast approaching the level of universality of the NPT and the Chemical Weapons Convention.

Since the fifth Article XIV conference in September 2007, four additional States have signed the CTBT: Barbados, Iraq, Timor-Leste and St. Vincent and the Grenadines. Nine have ratified: Bahamas, Dominican Republic, Malaysia, Barbados, Colombia, Burundi, Lebanon, Malawi and Mozambique. I applaud these countries for having taken this important step, each in itself a powerful beacon of support for the Treaty.

In particular, I would like to highlight Colombia's ratification in January 2008. To enter into force, the CTBT must be signed and ratified by the 44 States listed in Annex 2 to the Treaty. These States participated in the negotiations of the Treaty in 1996 and possessed nuclear power or research reactors at the time. With Colombia's ratification, the number of remaining Annex 2 States was reduced to single digits.

Let me turn to another important Annex 2 State – the United States. The support for the CTBT as expressed by President Barack Obama in his milestone speech in Prague on 5 April 2009, to "immediately and aggressively pursue U.S. ratification", is of course extremely crucial. To achieve this goal, the growing bipartisan support for the Treaty is very important. The landmark Wall Street Journal op-eds by the four former U.S. foreign and defense policy leaders George Shultz, William Perry, Henry Kissinger and Sam Nunn in 2007 and 2008 started this movement. This and, most recently, indications of an increasing openness for reconsideration of the CTBT by some key Republicans, make U.S. ratification seem more likely than before.

All these developments have also stimulated discussions in some of the other remaining Annex 2 States. Indonesian Foreign Minister Hassan Wirajuda announced that his country would "immediately follow suit" when the United States ratifies.

But we should be careful not to let these positive signs slacken our efforts. Neither can ratification by the United States nor by any of the other countries be taken for granted. Determination, conviction and persistence at the highest political level in all CTBT supporting countries are needed now more than ever.

It is significant that the UN Security Council, which will gather at the Heads of State level at its meeting on 24 September in New York, will focus on nuclear non-proliferation and disarmament issues, including the CTBT. The meeting, which will be presided over

by President Obama, will be held back-to-back to the Article XIV conference. Taken together, these two meetings will give unprecedented attention to the CTBT at the highest political levels. This is an opportunity that should not be missed.

Of course, the decision to sign and ratify the CTBT will remain the sovereign decision of each country. Already the security benefits derived from a global freeze on the qualitative development of nuclear warheads are a compelling argument for every country that values cooperation over weaponization in dealing with its neighbours.

But the real benchmark for the political value of any arms control treaty is its verifiability, and this is the CTBT's greatest asset: Over 75 percent of the IMS' 337 monitoring facilities have been certified to date. Due to immense progress in monitoring technologies, the IMS is already performing better than envisaged by the Treaty's negotiators for the complete system.

Again, the facts speak for themselves. When the Democratic People's Republic of Korea (DPRK) announced that it had conducted its second nuclear test on 25 May 2009, the CTBT's monitoring system demonstrated its reliability by performing in a timely, integrated and coherent manner, as it had done at the first DPRK test in October 2006.

Twenty-three seismic stations succeeded in detecting the event immediately. Two hours later the first automated waveform data were made available to over 1100 secure user accounts in 110 Member States, in accordance with the Treaty's time lines. Analyses sent to Member States later and in the form of bulletins, provided further information on the DPRK event. By the time the UN Security Council convened in New York, all members, big or small, permanent or non-permanent, had first hand information from the CTBTO at their disposal.

Although a substantial number of noble gas systems had been built in the region and the system's detection capability was excellent at the time of the second nuclear test, no radioactive noble gas was measured this time. Apparently none – or less than 0.1 percent – of the noble gases from the explosion had escaped into the atmosphere. However, the overwhelming seismic evidence alone would have provided a firm basis for a decision by the CTBTO's future Executive Council to dispatch an on-site inspection.

The CTBTO proved that it is able to launch such an on-site inspection through the Integrated Field Exercise (IFE08) in September 2008, the most elaborate on-site inspection exercise ever conducted by the organization. Two hundred participants, including 40 inspectors and 50 tonnes of equipment, were transported to the remote former Soviet nuclear test site of Semipalatinsk in Kazakhstan.

The IFE08 tested all elements of an on-site inspection under conditions that were as realistic as possible. The exercise provided yet further proof of the CTBT's verifiability. It has demonstrated that this final layer of the CTBT's verification regime, on-site inspections, will serve as a strong and reliable deterrent to potential violators of the ban on nuclear explosions once the Treaty enters into force.

To stay abreast of the latest technological developments, the CTBTO has forged partnerships with relevant industries and the scientific community. A recently launched platform for interaction with the scientific community is the International Scientific Studies (ISS) project, a year-long series of independent assessments and studies of the CTBT's verification regime. Approximately 500 scientists from roughly 80 countries participated in this project, which culminated in a conference in Vienna, Austria, from 10 to 12 June 2009. A separate publication on the ISS project will be available from the CTBTO in October 2009, featuring articles by many of the key scientists who are leading and coordinating the different studies.

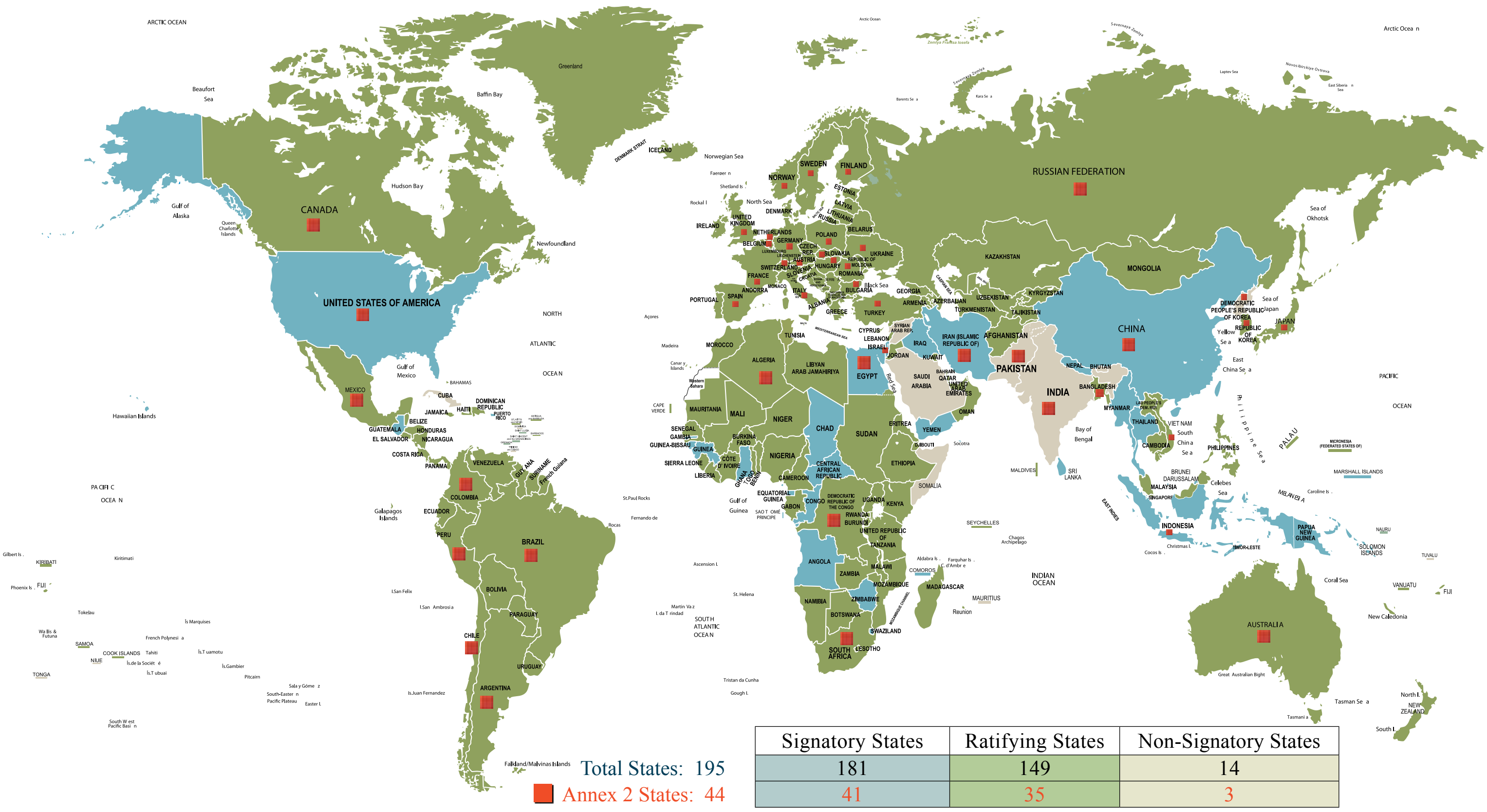
Apart from demonstrating that the CTBT's verification regime functions efficiently, the recent DPRK test also provided evidence of the international community's zero tolerance for nuclear testing. Every nuclear test since the CTBT opened for signature on 24 September 1996 has been condemned unanimously by the UN Security Council. This condemnation reflects international public opinion, which is vehemently opposed to nuclear testing. In a global environment characterized by multilateralism, diplomacy and the peaceful resolution of conflicts, nuclear testing is simply out of place.

Nuclear testing concerns all countries, whether big or small, whether North, East, South or West. With dedicated support from all, entry into force of the CTBT can finally be reached. We will have made a clear, visible step on the road towards a nuclear-weapon-free world.

Tibor Tóth
Executive Secretary
Preparatory Commission for the Comprehensive Nuclear-Test-Ban Treaty Organization

Treaty signatures and ratifications

CTBT signatures and ratifications as of 1 September 2009



	Signatory States	Ratifying States	Non-Signatory States
Total States: 195	181	149	14
Annex 2 States: 44	41	35	3

Notes & quotes

"We welcome the announcement made by the President of the United States of America that he has decided to seek ratification of the Comprehensive Nuclear-Test-Ban Treaty (CTBT) and we will intensify our efforts towards the early entry into force and universalisation of the CTBT as one of the principal instruments of the international security architecture and a key measure of non-proliferation and disarmament. Meanwhile, we urge all States concerned to observe a moratorium on nuclear weapon test explosions or any other nuclear explosions."

Joint statement on non-proliferation by Heads of State at the G8 Summit on 10 July 2009 in L'Aquila, Italy.

In the spotlight

High-level action needed to promote CTBT's entry into force

Interview with Carl Bildt, the Minister for Foreign Affairs of Sweden

Q: *Sweden has always been one of the strongest proponents and contributors to the Comprehensive Nuclear-Test-Ban Treaty (CTBT) politically and scientifically. How do you explain Sweden's longstanding commitment to and involvement with the CTBT?*

A: Let me start by referring back to the situation in Sweden during the Cold War, and its general approach to nuclear weapons. Back in the 1950s, as part of an early interest in nuclear power generally, Sweden was actively planning to acquire nuclear weapons in the belief that this would improve the ability to deter military aggression.

By the late 1950s, public understanding about the destructive power of nuclear weapons and the devastating consequences of a nuclear war in Europe was starting to increase. The opposition to nuclear weapons intensified as a result of the nuclear fallout from large scale nuclear test explosions by the former Soviet Union at Novaya Zemlya, which affected northern Sweden in the early 1960s.

In 1963, the same year Sweden signed the Partial Test Ban Treaty, it was decided for a number of reasons to halt all exploratory plans related to the acquisition of nuclear weapons. This was, however, a process that proceeded in stages and took some time. In 1968 the Swedish Parliament took a decision not to develop nuclear weapons and later the same year, Sweden also signed the Nuclear Non-Proliferation Treaty (NPT).

In the early 1970s, the Swedish Defense Research Institute (FOA/FOI) recommended the creation of the Group of Scientific Experts (GSE) to design and test a global seismological system to monitor nuclear explosions. This system laid the foundation for the CTBT's verification regime. Sweden chaired the GSE from its inception in 1976 until the CTBT negotiations were finalized in 1996 and was also instrumental in proposing a draft treaty at the beginning of these negotiations in January 1994. A Swedish expert in the field, Dr. Ola Dahlman, former chairman of the GSE, chaired the Working Group on verification issues at the Preparatory Commission for the Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO) from 1996 to 2006 and is currently leading the International Scientific Studies project, which is performing an independent assessment of the capability and readiness of the CTBT's verification regime. More recently, in 2008, Sweden's Ambassador Hans Lundborg chaired the CTBTO's executive organ, the Preparatory Commission.

Sweden also developed the Swedish Unattended Noble gas Analyzer (SAUNA), which is one of the systems used by the CTBTO to measure radionuclide noble gases released by nuclear explosions.

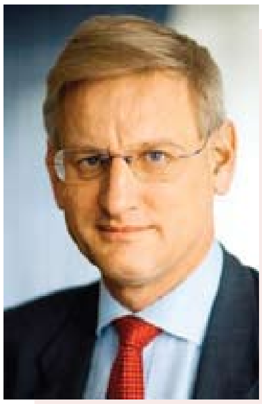
All together, I suppose one could say that my country's involvement with the CTBT both in terms of putting the legal norm in place and helping to define its verification regime has been, and remains, quite significant.

Q: *Why in your view is the CTBT important?*

A: I believe it is a vital component of the international effort to prevent nuclear weapons proliferation and to bring about nuclear disarmament. Once the Treaty enters into force, it will put a brake on the development of new weapons systems and arguably reduce the security policy significance of nuclear weapons in sensitive regions, thus making a key contribution to international peace and security. It will also convey the very important signal that the international community is once again taking disarmament and arms control issues seriously.

There can be little doubt that the CTBT's verification and control system, which is now approaching completion, makes it virtually impossible to conduct undetected clandestine nuclear testing. As the role and importance of nuclear weapons themselves decrease in a world of new and different security challenges, so does the need for any further testing.

Biographical note



Carl Bildt was appointed the Swedish Minister for Foreign Affairs in 2006. Between 1991 and 1994 he served as Sweden's Prime Minister and was leader of the Moderate Party from 1986 to 1999. He has also been noted internationally as a mediator in the Balkan conflict, serving as the European Union's Special Representative for the Former Yugoslavia from 1995 to 1997, as High Representative of the international community in Bosnia and Herzegovina from 1996 to 1997, and as the UN Secretary-General's Special Envoy for the Balkans from 1999 to 2001. ■

The nuclear tests that the Democratic People's Republic of Korea conducted in October 2006 and most recently in May 2009 have highlighted the importance of a universal, legally binding standard for banning nuclear testing and of the verification regime provided for by CTBT.

Q: *Sweden assumed the Presidency of the European Union (EU) in July 2009. It is very welcome news that you will personally deliver the speech on behalf of the European Union at the Article XIV conference on Facilitating the Entry into Force of the CTBT in September this year.*

During its Presidency of the EU, what plans does Sweden have for the EU to continue promoting the Treaty's entry into force and to encourage the build-up of the verification regime?

A: The EU plays a very special role in relation to the CTBT since all its Member States have ratified the Treaty and are strong supporters of it. This is of particular importance since the EU is composed of countries with different security policy doctrines: nuclear weapon States, countries that are members of NATO, and countries that do not belong to any military alliance. During Sweden's presidency of the EU, promoting the CTBT's entry into force at the earliest possible date will be one of our top priorities in the field of non-proliferation and disarmament. Universal ratification of the Treaty and completion of its verification regime, as well as dismantling all nuclear testing facilities as soon as possible in a manner that is transparent and open to the international community, are crucial elements for achieving not only NPT objectives but also for nuclear disarmament in general.

Sweden is determined to sustain the current momentum in favour of the CTBT, particularly in view of President Barack Obama's commitment to pursue U.S. ratification of the Treaty "immediately and aggressively." During its EU presidency, Sweden will work with partners to promote the CTBT's entry into force in the run up to the Article XIV conference. These efforts aims to address the issue of ratification and, where necessary, of signature of the CTBT, at EU meetings with relevant partners. We will appeal to all remaining Annex 2 States to sign and/ or ratify the Treaty expeditiously to facilitate its entry into force as well as urging the Treaty's signatories and ratifiers to demonstrate their support for the CTBT by participating in the Article XIV conference at the ministerial level or higher.

The EU attaches utmost importance to completing a credible and operational CTBT verification regime. A fully operational verification regime will provide the international community with independent and reliable means of ensuring compliance with the above-mentioned standard. During its presidency of the EU, Sweden will encourage the build-up of the verification regime and will continue to support the CTBTO. Three EU joint actions have been adopted within the framework of the Common Foreign and Security Policy which have enabled actions in such fields as training, strengthening verification regime performances and technical assistance for developing countries. EU support is also helping develop civil and scientific uses of international monitoring system technologies.

Notes & quotes

"If the CTBT can enter into force, and if the NPT review conference makes progress, the world would be off to a good start on its journey to a world free of nuclear weapons...President Barack Obama's support for US ratification of the CTBT is welcome – the treaty only needs a few more ratifications to enter into force. Disarmament must be rooted in legal obligations."

Op-ed by United Nations Secretary General Ban Ki-Moon titled "*My Plan to Stop the Bomb*", in The Guardian on 3 August 2009.

Under Sweden's EU presidency, we will also urge all States that have signed the Treaty to pay their full contributions to the CTBTO within the prescribed time limit and without setting conditions in order to ensure the CTBTO's financial stability as well as the consolidation and credibility of the verification regime.

Q: *What role do you think the CTBT can play in strengthening the nuclear non-proliferation and disarmament regime? And what impact do you think ratification by the United States will have on the other Annex 2 States which must ratify before the Treaty can enter into force?*

A: Although the CTBT has not yet entered into force, the fact that 181 countries have signed and 149 have ratified it has already created an international norm that condemns nuclear tests. This unquestionably strengthens the non-proliferation and disarmament regime. Any State that were to conduct a nuclear test would pay a heavy political price, as we have recently seen in North Korea with the UN Security Council voting unanimously to adopt tougher sanctions targeting North Korea's atomic and ballistic missile programmes.

Ratifications by key States such as the United States and China could potentially spark a positive chain reaction. The United States was the first country to sign the CTBT in 1996 and renewed U.S. leadership for the entry into force of the Treaty is immensely important.

On 1 April 2009, the presidents of the United States and Russia released a statement detailing a work plan for a new relationship between the two countries, starting with the goal of a nuclear-weapon-free world. Both Barack Obama and Dmitry Medvedev have pledged to bring the CTBT into force.

The accession of all remaining Annex 2 countries is, of course, equally important and necessary. Short of immediately signing or ratifying the Treaty, any direct actions or statements to that end by relevant countries would certainly aid similar processes in other Annex 2 States. In this context, the recent statement by Indonesia explaining its clear intention to ratify the CTBT once U.S. ratification has taken place is very encouraging.

Regional approaches to secure ratifications by Egypt, Iran, and Israel should also be further explored. Similarly, there is a need to engage India and Pakistan on a range of security and arms related issues. The CTBT – in conjunction with a future universal, legally binding and verifiable ban on the production of weapon grade fissile material – would naturally be one of them, making the further development of nuclear weapons virtually impossible. China could play an important role as a catalyst in South Asia. Much would be gained for confidence and security building in Asia if the continent as a whole moved towards ratification.

Q: *During an official visit to China in March 2009, you described nuclear*

Notes & quotes

"To achieve a global ban on nuclear testing, my administration will immediately and aggressively pursue U.S. ratification of the Comprehensive Test Ban Treaty. After more than five decades of talks, it is time for the testing of nuclear weapons to finally be banned."

President Barack Obama in Prague, Czech Republic on 5 April 2009, outlining his plan for a world free of nuclear weapons.

proliferation as one of the three acute issues on the agenda of the important strategic relationship between China and the EU. Could you elaborate on that?

A: The Joint Declaration between China and the EU on Non-proliferation and Arms Control that was signed in December 2004 is of great significance and commits both sides to working together to ensure strict compliance with the obligations under disarmament and non-proliferation treaties. In particular, the Joint Declaration promotes the universalization, entry into force, implementation and strengthening of the treaties, conventions and norms in the area of disarmament and non-proliferation, such as the NPT and the CTBT.

Nuclear proliferation is indeed an acute issue not only on the agenda of China and the EU but also currently one of the top priorities on the global agenda. There are already too many nuclear weapons and too many States with nuclear weapons in the world today. Although I am hopeful that we will see a reduction in overall arsenals in the years to come – after all, approximately 95 percent of them are held by Russia and the United States – I am far more concerned with the risk that we will see further States acquiring these weapons. New States with nuclear weapons in East Asia or the Middle East would be profoundly destabilizing and would significantly increase the risk that we will actually see nuclear weapons used and a nuclear war breaking out at some point in the future.

> “The EU attaches utmost importance to completing a credible and operational CTBT verification regime.”

Of immediate concern at the moment is the situation in North Korea. We all have a profound interest in both non-proliferation and in the stability of the Korean peninsula, and clear messages from the leading international actors are of importance in a situation like this. It should be clear that we are ready to consult and coordinate in order to handle any contingencies so as to preserve wider regional stability.

Q: *In the Foreign Policy Declaration that you delivered to the Swedish Parliament on 18 February 2009, you said: “A new nuclear disarmament treaty between the US and Russia and US ratification of the CTBT treaty would create considerably better conditions to prevent the proliferation of nuclear weapons in the future.”*

Please expand on your statement in light of the recent follow-on to the 1991 Strategic Arms Reduction Treaty (Start I) and the other steps that you believe need to be taken to pave the way for a successful NPT Review Conference in 2010.

A: The Joint Understanding signed by President Obama and President Medvedev on 6 July 2009 to verifiably cut U.S. and Russian strategic nuclear arsenals below the Moscow Treaty levels, is a very welcome first step in a broader effort intended to reduce the threat of such weapons drastically and to prevent their further spread to unstable regions. By setting out the basic terms of a treaty to reduce the number of strategic delivery systems and their associated warheads to the lowest levels since the early years of the Cold War, countering the spread of nuclear weapons and eventually moving towards Obama’s vision of “a world without nuclear weapons” becomes more of a reality.

In order for the NPT Review Conference to reach a successful conclusion in May next year, efforts to promote the CTBT’s entry into force must be accelerated over the following months. In many ways the NPT and the CTBT go hand in hand. After all, the commitment in the 1990s to negotiate the CTBT was one of the important factors that paved the way for the 1995 decision to indefinitely extend the NPT. One significant distinction of the CTBT is that it will, once adhered to universally, apply equally to all States on a non-discriminatory basis.

Consensus must be reached on the renewed commitment of the principles and objectives for nuclear non-proliferation and disarmament. Continued efforts to reduce nuclear dangers should be pursued to help strengthen the non-proliferation regime and increase progress on nuclear disarmament.

Further progress in strategic arms limitation talks between the United States and Russia, ratification of the CTBT and progress on the North Korean and Iranian issues would pave the way for the NPT Review Conference next year. It has to succeed – failure in these efforts could

have grave consequences for global stability in the world of the future.

Q: *Over the years, you have reiterated your personal commitment to the CTBT. On 24 September 2008 you endorsed the* Joint Ministerial Statement on the CTBT, *along with 90 other Foreign Ministers, which called for the Treaty's entry into force. In view of the influence you exert in the global arena, what would you consider to be the most effective strategy to ensure the CTBT's entry into force? And how would you convince your friends and colleagues around the world that it is in the interest of their respective countries to ratify the Treaty?*

A: We will surely continue our efforts directed towards the CTBT, and I would naturally be glad to contribute to this cause in any way I can. At the same time, I am completely convinced that – as in most international and political endeavours – it will take a broad team effort to win the confidence and support of as many stakeholders as possible. A number of reasons and arguments in support of the CTBT have already been outlined, underpinning a comprehensive strategy to ensure the CTBT's entry into force. That crucial message of united support should be continued and developed. At the same time, the issue of the CTBT – realistically – has to be seen in an integrated, political context.

As I see it, a precondition to success is to really prioritize the issue at hand. We need to devote attention at the highest possible level to the CTBT's entry into force. One step in the near future to prioritize support for the CTBT, would be – as already mentioned, but surely worth repeating – by ensuring participation at a high political level at the upcoming Article XIV conference in New York in September. ■

Conference on Facilitating the Entry into Force of the CTBT

24-25 September 2009, United Nations, New York

What is it?

- Named after the entry into force article of the CTBT.
- Article XIV states that a conference should be convened every two years to promote the Treaty's entry into force, if this has not taken place.
- Five such conferences have already taken place in New York or Vienna since 1999.

Why does it take place?

- The Treaty's entry into force depends on the ratifications of 44 specific States, which had nuclear capabilities when the Treaty was negotiated in 1996.
- Thirty-five of these States have already ratified. Nine States still need to do so: China, Democratic People's Republic of Korea (DPRK), Egypt, India, Indonesia, Iran, Israel, Pakistan and the United States. The DPRK, India and Pakistan also have to sign the Treaty.
- The Article XIV conferences strive to convince hold-out States to sign and ratify the Treaty.

Why is this year's conference different from previous ones?

- There is currently a very strong political momentum in support of the CTBT.
- The United States' participation for the first time in ten years is particularly encouraging.

It is time for the CTBT to come into force

by Bernard Kouchner, the Minister of Foreign and European Affairs of France

The Comprehensive Nuclear-Test-Ban Treaty (CTBT) stands at a crossroads. Never has the prospect of its entry into force seemed so close. President Obama's confirmation of his intention to work with Congress towards the Treaty's ratification has undeniably created momentum in that direction, momentum that it is our responsibility to foster and extend.

"Thirteen years after it opened for signature, it is time the Treaty came into force. Over the last thirteen years the need for it has become increasingly marked."

CTBT approaches near-universality

The next Conference on Facilitating the Entry into Force of the Comprehensive Nuclear-Test-Ban Treaty to be held at the end of September in New York is one of the key points in that onward momentum. It was the wish of France, along with Morocco, to chair this major gathering in order to send out a strong message to those States that have not as yet ratified the Treaty. To date, it has been signed by over 180 States and just under 150 have ratified it – including the Member States of the European Union, all of whom are strongly committed to the Treaty. I am pleased to observe such near-universality, which testifies to the concern and commitment of the international community to see the definitive cessation of all nuclear tests.

DPRK's nuclear test reinforces the urgency of CTBT's entry into force

That is not, however, sufficient in itself. Thirteen years after it opened for signature, it is time the Treaty came into force. Over the last thirteen years the need for it has become increasingly marked. The second nuclear test the Democratic People's Republic of Korea (DPRK) claimed to have conducted on 25 May this year came as a further reminder of the importance of a universal, legally binding standard for the banning of nuclear tests.

That test also highlighted the relevance of an effective regime for the verification of compliance with the standard. In that regard, I can only welcome the operational deployment of the International Monitoring System for which the Treaty makes provision, and which has demonstrated its effectiveness by detecting the two explosions in North Korea. I salute the work done by the Preparatory Commission for the Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO) which, by helping strengthen the Treaty, ensures that its credibility increases with every day that passes. As of now, the CTBTO is capable of performing the monitoring mission given to it by the Treaty. And as of tomorrow, no State will be able to carry out a nuclear test without the knowledge of the international community.

Nuclear disarmament From words to deeds

France has always provided its unfailing support for the CTBT. France signed it immediately after its adoption in 1996. Along with the United Kingdom, it was the first nuclear weapon State to ratify it in 1998. That same year, France began to dismantle its test facility in the Pacific and it no longer possesses the installations that would allow it to carry out nuclear tests. France is the only nuclear weapon State to have taken this irreversible step.

"As of now, the CTBTO is capable of performing the monitoring mission given to it by the Treaty. And as of tomorrow, no State will be able to carry out a nuclear test without the knowledge of the international community."

This support testifies, from a wider perspective, to the particular importance my country attaches to nuclear disarmament. Our commitment is reflected in practical action. But we cannot continue to go down the road to disarmament unless the determination to make progress is unanimous. Transparency, trust and reciprocity form the basis of collective security and disarmament. Prospects for progress are now becoming clearer, with the commitment of the United States and Russia to the negotiation of a new agreement on the reduction of their strategic offensive arsenals.

> "The nine States whose ratification is necessary for its entry into force bear a special responsibility: China, the DPRK, Egypt, India, Indonesia, Iran, Israel, Pakistan and the United States. I solemnly call upon them to ratify the Treaty and to strengthen, in so doing, the international non-proliferation regime and collective security."

The CTBT reminds us that a multilateral approach is also important. As the Nuclear Non-Proliferation Treaty (NPT) stresses, it is the responsibility of every State, not only the nuclear weapon States, to make its contribution to the edifice of nuclear disarmament and more generally to collective security.

CTBT's entry into force is one of the top priorities in nuclear disarmament

In this context, I am pleased to note the forthcoming launch at the Conference on Disarmament of negotiations for a treaty banning the production of fissile materials for nuclear weapons. This Fissile Material Cut-off Treaty stands, alongside the entry into force of the CTBT, as one of our twin priorities in the field of multilateral nuclear disarmament, as the President of the Republic of France recalled in his speech at Cherbourg in March 2008. In that speech, he also proposed the implementation of an immediate moratorium on the production of fissile materials for nuclear weapons. The importance of this call is all the more apparent at a time when the negotiations are about to commence. Four nuclear weapon States have already agreed to such a moratorium. It is now essential that the other nuclear powers should take an unambiguous decision to join us.

These are crucial times ahead of us. The decisions that we take today will define the security of the world in which we shall be living tomorrow. The lead-up to the NPT Review Conference next May provides a favourable context for the ratification of the CTBT by those States that have not yet done so. The nine States whose ratification is necessary for its entry into force bear a special responsibility: China, the DPRK, Egypt, India, Indonesia, Iran, Israel, Pakistan and the United States. I solemnly call upon them to ratify the Treaty and to strengthen, in so doing, the international non-proliferation regime and collective security. ■

Biographical note

Dr. Bernard Kouchner was appointed Minister of Foreign and European Affairs of France in 2007. He previously served as France's Minister for Health and Humanitarian Action from 1992 to 1993 and as the United Nations Special Representative for Kosovo from 1999 to 2001. In addition to holding senior government and international positions, he has had a distinguished career as a medical doctor and professor. He is the founder of the Nobel Prize winning Médecins sans Frontières and of Médecins du Monde. ■

Courtesy of Ministère des Affaires étrangères et européennes. Photo F. de la Mure.

The CTBT: Its crucial and overdue entry into force

by Taib Fassi Fihri, the Minister of Foreign Affairs of Morocco

The Comprehensive Nuclear-Test-Ban Treaty (CTBT) is the outcome of many years of active multilateral diplomacy aimed at preserving peace and security. It is also a consequence of decreased international tensions following the end of the Cold War.

The adoption of the CTBT in 1996, no matter how difficult and complicated the negotiations were, reflected the will of the international community to make a new step towards nuclear non-proliferation and disarmament. By banning test explosions, the CTBT prevents the development of new nuclear weapons as well as the spread of such weapons, since testing is crucial for the verification of their capabilities.

The CTBT complements and strengthens the Nuclear Non-Proliferation Treaty (NPT). The linkage was established during its negotiations and a global test ban is explicitly mentioned in the NPT's preamble. In addition, the CTBT is part of the commitments of the 1995 and 2000 NPT Review Conferences and will also be instrumental for nuclear disarmament.

The CTBT, once in force, would be a significant boost for the NPT and reinvigorating for the wider nuclear non-proliferation regime. We share the view that the Treaty would also be a confidence building measure, in particular in regions where the risk of nuclear proliferation is a real challenge due to unresolved political issues.

The common will that constitutes the basis of the Treaty has been confirmed through the worldwide political support it has received: 181 signatories of which 149 have ratified, making it clear that they are ready to be bound by the Treaty upon its entry into force. Moreover, the Preparatory Commission for the Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO) has almost completed the establishment of the global verification regime required under the Treaty.

The work of the CTBTO is valuable. The CTBTO's experts and staff deserve our appreciation for their tireless efforts under the leadership of the Executive Secretary Ambassador Tibor Tóth and his predecessor, Ambassador Wolfgang Hoffmann.

2010: A turning point for non-proliferation and disarmament

It is deplorable that such an important security and peace tool as the CTBT is not effective yet: nine ratifications necessary for the Treaty's entry into force are missing, despite the five Conferences on Facilitating the Entry into Force of the CTBT (Article XIV conferences) held since 1999 and efforts made by a significant number of ratifying States to promote signatures and ratifications and, thus, the CTBT's entry into force.

We remain convinced that the CTBT is more relevant than ever and that its entry into force is very urgent in light of the challenges the non-proliferation regime is facing.

We also believe that the Annex 2 States, namely the 44 countries that must sign and ratify the CTBT before it can enter into force, including the nuclear weapon States, bear a special responsibility in this regard. The international community has enjoyed a de facto global nuclear test moratorium and we want to make it permanent, binding and verifiable. There is only one way to get there: bringing the CTBT into force universally.

We think that efforts should be united to make the year 2010 a turning point for non-proliferation and disarmament. We should build on the progress made at the Third Session of the Preparatory Committee for the NPT Review Conference in New York in May 2009 to ensure the

Notes & quotes

"The Heads of State and Government stressed the significance of achieving universal adherence to the CTBT, including by all NWS [nuclear weapon States], which, *inter alia*, should contribute to the process of nuclear disarmament. They reiterated that if the objectives of the Treaty were to be fully realized, the continued commitment of all States signatories, especially the NWS, to nuclear disarmament would be essential."

From the final document of the XV Summit of Heads of State and Government of the Non-Aligned Movement, Sharm El Sheikh, 11-16 July 2009

success of the conference in 2010. In addition, we should take advantage of the improved political context to push for progress in disarmament.

Failure to meet this challenge will only add to the existing risk of the collapse of the non-proliferation regime. The international community cannot afford such a disaster. In spite of all the difficulties and challenges, we are determined to continue working tirelessly, in line with our commitment towards nuclear disarmament and non-proliferation, and in full cooperation with our partners and friends, to ensure significant progress in order to preserve the regime's credibility.

Article XIV conference co-chaired by Morocco and France: Improving prospects for entry into force

Difficulties are real and a lot still has to be done, but we have reasons for some optimism. In particular, the Conference on Disarmament has agreed to negotiate a Fissile Material Cut-off Treaty and President Barack Obama has renewed the commitment of his country to the CTBT, promising its ratification. If this materializes, it will greatly improve the prospects of the Treaty's entry into force. China has also started its ratification process, while Russia, which has already ratified the Treaty, has renewed its support for the CTBT as well as its willingness to move forward on the path of arms control and disarmament.

Promoting the entry into force of the Treaty is the objective of the next Article XIV conference, which Morocco will be chairing with France in New York in September 2009. This conference will be an opportunity for the international community to show its unity on the objectives of the Treaty. Ratifying States will have to agree on a means to bring on board other countries, especially the nine outstanding Annex 2 States which still need to ratify the CTBT.

> "The CTBT, once in force, would be a significant boost for the NPT and reinvigorating for the wider nuclear non-proliferation regime."

The success of the conference is important to the furtherance of the Treaty goals. It is also crucial for maintaining the political and diplomatic momentum to move this Treaty forward

Civil applications of verification technologies

Preserving peace and security is not the only advantage of the CTBT. Member States, in particular those from developing countries, attach high importance to the possible civil applications of technologies developed for verification purposes.

Experts and scientists have explored the possible role that such technologies could play in fields such as earthquakes, underwater volcanoes and the monitoring of ocean processes, tsunami predictions, climate change, and nuclear accidents.

We look forward to the possible civil and scientific applications of the technologies of the CTBT's International Monitoring System and the products of the International Data Centre, and their potential contribution to sustainable development.

For all these reasons and benefits, the international community should spare no efforts to ensure this Treaty's entry into force which would represent, undoubtedly, the most valuable achievement since the adoption of the NPT. ■

Biographical note

Taib Fassi Fihri has served as Minister of Foreign Affairs and Cooperation for the Kingdom of Morocco since October 2007. His first appointment with the Government of Morocco was with the Ministry of Planning in 1984. Mr. Fassi Fihri's career with the Ministry of Foreign Affairs spans over two decades, having first been appointed as Head of the Division in charge of relations with the European Community in 1986 and Secretary of State for Foreign Affairs and Cooperation in 1993. ■

In Pursuit of a Nuclear-Weapon-Free World

by Alberto G. Romulo, Secretary of Foreign Affairs of the Philippines

When the Democratic People's Republic of Korea (DPRK) announced that it had conducted a nuclear test on 25 May 2009, the message that humanity remains under the threat of mass destruction resonated across the globe.

The DPRK's second test in three years was an unsettling reminder of the complex challenges to the security and stability of the Asia-Pacific region and to the norms of nuclear non-proliferation that the global community is building in pursuit of world peace. It underscored the importance of a comprehensive and permanent ban on nuclear testing in the infrastructure of a global nuclear non-proliferation regime.

Shared goals, collective efforts

The 180 States that have signed the Comprehensive Nuclear-Test-Ban Treaty (CTBT), nearly 150 of which have deposited their instruments of ratification, have affirmed their collective belief in the Treaty as a critical instrument in nuclear weapons control and disarmament. This near-universal support for the Treaty will assume a more transforming significance with its entry into force upon the signature and ratification by the remaining nine Annex 2 States, which includes the DPRK.

Voluntary testing moratoria are simply not enough. These moratoria need to be enshrined into permanent and legally-binding commitments that give a clear message that the world does not accept the acquisition or development of nuclear weapons. This requires nuclear weapon States to take more decisive steps towards disarmament.

"Voluntary testing moratoria are simply not enough. These moratoria need to be enshrined into permanent and legally-binding commitments that give a clear message that the world does not accept the acquisition or development of nuclear weapons."

As confidence-building measures pave the path to our common security, the entire international community is being challenged to enshrine this principle in the 2010 Non-Proliferation Treaty (NPT) Review Conference.

Much is expected from this conference. The Philippines, as the elected President of the 2010 Review Conference, shares the desire of nations to move forward in the process and counts on the support, counsel, and cooperation of all States Parties to the NPT.

The Philippines senses a prevailing climate of good faith from States Parties to the NPT that will enable the achievement of a good measure of progress for the 2010 Review Conference. This is a welcome development since animating the process of negotiations on key substantive and procedural issues will require the commitment of all States Parties to ensure a productive, forward-looking outcome.

Working for nuclear non-proliferation in the region and beyond

The Philippines' desire to contribute to building a safer global community finds its most vital expression in its diplomacy in the region.

Leaders of the Philippines, Indonesia, Thailand, Malaysia and Singapore founded the Association of Southeast Asian Nations (ASEAN) in 1967 on the basis of a shared political outlook in response to the security environment in East Asia at that time. Having grown since then to ten member states and a cumulative population of 600 million, ASEAN has assumed a distinct political identity in the Asia-Pacific region.

In the last four decades, the ASEAN process has forged and strengthened the commitment of ASEAN members to build peace and security in the region and beyond.

The Treaty on the South East Asia Nuclear Weapon-Free Zone (SEANWFZ), which was opened for signature in 1995 and entered into force in 1997, embodies the determination of ASEAN to contribute towards complete nuclear disarmament.

The five-year SEANWFZ Plan of Action was adopted during the Philippines' chairmanship of ASEAN in 2007. This Plan of Action acknowledges the importance of ASEAN member states and ASEAN dialogue partners' accession to international instruments such as the CTBT.

The Philippine Chairmanship of the ASEAN Regional Forum (ARF) during the same year also advocated strong support in the Asia-Pacific region for the CTBT as an essential element in non-proliferation.

The ARF promotes security in the Asia-Pacific through dialogue and cooperation between and among its participants namely, Australia, Bangladesh, Brunei Darussalam, Cambodia, Canada, China,

DPRK, European Union, India, Indonesia, Japan, Republic of Korea, Laos, Malaysia, Mongolia, Myanmar, New Zealand, Pakistan, Papua New Guinea, Philippines, Russian Federation, Singapore, Sri Lanka, Thailand, Timor Leste, United States and Vietnam.

In April 2009, the ASEAN Political-Security Community (APSC) Council held its inaugural meeting in Thailand. The APSC, which exemplifies ASEAN's move towards enhanced political collaboration, subscribes to a comprehensive approach to security. It renounces aggression and the threat or use of force in the settlement of disputes and upholds ASEAN political instruments such as the Zone of Peace, Freedom and Neutrality (ZOPFAN), the Treaty of Amity and Cooperation (TAC) and the SEANWFZ Treaty.

Although still in its nascent stages, the APSC Council mechanism holds the key to the further evolution of ASEAN. In the coming years it is expected to consistently pursue ASEAN's abiding role in enhancing regional security through dialogue and cooperation and its vision for a nuclear-weapon-free world.

Beyond its efforts as an ASEAN member, the Philippines cooperated with the Preparatory Commission for the Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO) in 2007 to organize a regional workshop to promote universal support for the CTBT. Fifty-five representatives from 17 countries attended the CTBTO Workshop on International Cooperation for States of Southeast Asia, the Pacific and Far East held in Manila in June 2007.

Nuclear non-proliferation and disarmament is everybody's concern. It is useful to bring the Treaty to wider public attention with its vast range of stakeholders, particularly policymakers and legislators.

Hence the active promotion of the CTBT and the NPT is always included in the agenda of regional and international inter-parliamentary fora such as the Asia-Pacific Parliamentary Forum and the International Parliamentary Union.

> "Nuclear non-proliferation and disarmament is everybody's concern. It is useful to bring the Treaty to wider public attention with its vast range of stakeholders, particularly policymakers and legislators."

The biennial Conference on Facilitating the Entry into Force of the Comprehensive Nuclear-Test-Ban Treaty, also known as the Article XIV conference, manifests at the highest political level, the commitment of State Signatories to the CTBT and their support for the work of the CTBTO. This year's conference in New York from 24 to 25 September 2009 takes place amidst an optimistic atmosphere greatly encouraged by the commitment of the United States to ratify the Treaty and the recent understanding between the U.S. and Russia on arms reduction and control.

The CTBTO has achieved much progress in its task of establishing the monitoring and verification system in preparation for the Treaty's entry into force. The CTBTO's response to the DPRK's nuclear test in May 2009 highlighted the improved capabilities of the International Monitoring System (IMS) and the International Data Centre (IDC). The CTBTO's work requires unwavering focus and determination to ensure a competent degree of readiness of the IMS, IDC and the On-site Inspection regime upon the Treaty's entry into force.

The Road Ahead

This momentum in the political environment and the steady gains in the development of the verification system demand more than ever the active and full support of all of the CTBT's Member States.

There are key challenges ahead, but every step taken by Member States in the spirit of building confidence, improving mutual trust and broadening consensus in the global agenda on nuclear non-proliferation and disarmament, takes us closer to our goal of seeing the Treaty's timely fruition and ultimately, a more peaceful and secure world. ■

Biographical note

Dr. Alberto G. Romulo has been the Secretary of Foreign Affairs of the Republic of the Philippines since August 2004. He was Executive Secretary of the Office of the President from 2001 to 2004 and also served as the Secretary of the Department of Finance. Prior to this, Dr. Romulo was a member of the Philippine Senate from 1987 to 1998, during which time he served as Majority Leader for five years. ■

Making the CTBT Effective

by Shen Dingli, Fudan University

Thirteen years after the Comprehensive Nuclear-Test-Ban Treaty (CTBT) opened for signature, the Treaty has still not entered into force. Despite the fact that the United States and China were the first two countries to sign the Treaty, neither of them has ratified it to public knowledge.

During the CTBT negotiations, a number of countries including the U.S. and China agreed to add Article XIV to the Treaty, which relates to the Treaty's entry into force. This will take place 180 days after the 44 States listed in Annex 2 to the Treaty have all ratified. The reason for including Article XIV was presumably to reinforce the non-nuclear weapons testing regime so as to facilitate nuclear non-proliferation worldwide. In reality, however, Article XIV has never exerted political or moral pressure upon the Nuclear Non-Proliferation Treaty (NPT) hold-out States such as India, Pakistan and Israel, in an effective manner. Also, the inclusion of Article XIV has meant that every nuclear capable State can block the CTBT's entry into force. This is because any of the 44 States listed in Annex 2 to the Treaty who possessed nuclear power reactors or research reactors when the Treaty was being negotiated, could fail to sign or ratify. The process related to the CTBT's entry into force is simply too democratic.

The importance of a CTBT

While a great amount of effort has been invested in building up the CTBT and its verification regime, it is understood that nuclear weapons testing is the single most outstanding obstacle to nuclear disarmament and non-proliferation. For a nuclear weapon State, the continuation of nuclear weapons testing is directed to sustain the safety, security, reliability and/or modernization of its nuclear arsenal. Whatever its purpose may be, such efforts emphasize the political importance and military utility of nuclear weapons, thereby offering incentives to nuclear proliferation. For a non-nuclear weapon State, a nuclear test unveils its nuclear weapons programme more directly, contributing directly to nuclear proliferation.

> "...if the U.S. ratifies the Treaty, China would have less reason to argue that a nuclear superpower should ratify first. It is not impossible that Beijing will ratify before Washington – as was the case with ratification of the Chemical Weapons Convention in 1997."

Therefore, in order to address the issue of nuclear non-proliferation, it is crucial for nuclear weapon States to:

- reduce their nuclear weapons as quickly as possible;
- restrain from developing new nuclear weapons;
- cease nuclear weapons testing permanently;
- foreclose the production of fissile materials for weapons purposes; and
- declare the intention not to use nuclear weapons in the first place.

In the meantime, the non-nuclear weapon States of the non-proliferation regime ought to keep up their commitment, especially when the nuclear weapon States are moving toward nuclear disarmament.

U.S. ratification

Obviously, the United States has the least need to retain its nuclear arsenal due to its superiority in terms of conventional arms and it is most susceptible to nuclear proliferation. Whatever the reasons were for the reluctance of the previous U.S. administration to ratify the Treaty, the nuclear tests conducted by India, Pakistan and the Democratic People's Republic of Korea (DPRK) – all carried out since the CTBT opened for signature – posed a huge risk to the United States by threatening the world order in which America dominates. No other country in the world today has its interests undermined as seriously as the U.S. by nuclear proliferation. By not ratifying the CTBT, the U.S. is facing more threats now than it would otherwise be confronted with.

The unwillingness of the United States to ratify the Treaty has contributed directly to the inability of the CTBT to enter into force. If the world's most powerful country militarily – accounting for 47 percent of global military spending alone – still needs to keep its option to resume nuclear testing open, why should other countries feel more secure by foreswearing their options?

Chinese ratification

China is the only nuclear weapon State to advocate a total prohibition and thorough destruction of all nuclear weapons. Since the early 1980s, China has also urged a "three halts and one reduction" policy which includes a component of "halting nuclear weapons testing". China's traditional view is that all countries should stop nuclear weapons testing. However, China should also consider that the nuclear superpowers – the U.S. and Russia – should shoulder most

responsibilities by both undertaking drastic nuclear disarmament with the U.S. also ratifying the CTBT.

That does not reduce China's responsibility of making the CTBT effective as early as possible. After a decade of preparing for the maintenance of a nuclear deterrent without physical testing, all nuclear weapon States should be more or less better prepared for the CTBT's entry into force through various simulation schemes similar to the U.S. science-based Stockpile Stewardship Program. Therefore, it is quite likely that the reasons for two of the nuclear weapon States under the NPT not having ratified yet are more out of political considerations than technical necessity at this stage.

President Obama's Prague speech

On 5 April 2009, U.S. President Barack Obama made epoch-making remarks in Prague, calling for a nuclear-weapon-free world, with the U.S. taking the lead to further cut its strategic force along with Russia through a follow-on treaty to START which is being negotiated and will be concluded this year. President Obama has further committed his administration to ratifying the CTBT as soon as possible, among other proposals.

Given the Democratic leadership in the Senate, it is increasingly possible that the U.S. Congress will soon be ready for ratification of the CTBT. With Senator Arlen Specter's party switch in April 2009, the Democrats are close to having dominant control of the Senate floor, so the chances of clearing the hurdles for the Treaty's ratification are looking greater than ever.

And if the U.S. ratifies the Treaty, China would have less reason to argue that a nuclear superpower should ratify first. It is not impossible that Beijing will ratify before Washington – as was the case with ratification of the Chemical Weapons Convention in 1997.

Notes & quotes

"China [was] among the first to sign the CTBT and has always honoured its commitment on nuclear test moratorium. China supports early entry into force of the CTBT and will continue to make its efforts to this end."

Statement by the Chinese Delegation at the 2009 NPT Prep Com in New York on 4 May 2009.

Amending the CTBT

Even if the U.S. and China ratify the CTBT, the Treaty's entry into force may still be held hostage, as any of the 44 States listed in Annex 2 could spoil its chances. Therefore, as long as the U.S. and China aspire to the CTBT entering into force, it is critical not to allow any Annex 2 State to use a procedural process to jeopardize the Treaty's effectiveness.

One way to resolve this difficulty would be to amend the CTBT by calling for a conference to revise Article XIV. The CTBT may be the only international treaty that exerts moral pressure on ALL relevant States to sign and ratify. Alternatively, one could envisage a revised CTBT that lowers the bar for entry into force. For instance, the CTBT could enter into force provided that a certain number of Annex 2 States ratify the Treaty. This could be a touchstone to see if the nuclear weapon States genuinely want a CTBT.

This is increasingly relevant given the DPRK's most recent nuclear test in May 2009. For security or strategic reasons, Pyongyang does not seem ready to halt its testing programme anytime soon and is continuing to confront the international community. While its behaviour has been condemned and will be further sanctioned, the world should not be held hostage by such hold-outs. Revising the CTBT offers a way to lower the threshold of the Treaty's entry into force that has been unnecessarily raised too high. ■

Biographical note

Dr. Shen Dingli, a physicist by training, is Professor of International Relations at Fudan University, Shanghai, China, as well as Director of the Centre for American Studies and Executive Dean of the Institute of International Studies. His areas of research include the China-U.S. security relationship, nuclear arms control and disarmament, nuclear weapons policies of the United States and China, regional non-proliferation issues, and China's foreign and defense policies. ■

The CTBT: More Central than Ever to International Security

by James Goodby, Stanford University

After five decades of talk, the importance of the Comprehensive Nuclear-Test-Ban Treaty (CTBT) to the nuclear non-proliferation regime has grown to the point where it is now indispensable. As we take stock of recent developments, we see a series of "good news/ bad news" stories about the CTBT. The good news is that worries about the Treaty's verifiability have been assuaged by technical progress. And seventeen years of a test moratorium, in the case of the United States, have shown that nuclear explosive testing is not necessary to maintain national security. But there is also bad news. In a word, the non-proliferation regime, which we've tried to sustain over five decades, has deteriorated in the last 10 years or so. Just think about a few names: North Korea, Iran, Syria, A.Q. Kahn (the founder of Pakistan's nuclear programme). I don't need to elaborate. Those names speak for themselves.

NPT's credibility is at stake

The splits between "nuclear haves" and "nuclear have-nots" have widened; my use of those terms shows you what the roots of the problem really are. The basic bargain of the Nuclear Non-Proliferation Treaty (NPT) has lost credibility. Nations really doubt that it is still operative. The 2005 NPT Review Conference was close to a disaster. The UN summit meeting of that same year failed to reach agreement on measures to strengthen the non-proliferation regime, "a real disgrace" in the words of then UN Secretary-General Kofi Annan.

The renaissance in civil nuclear power is poised to spread technology and materials around the world in the next decades. Is it going to be safeguarded? The Additional Protocols of the International Atomic Energy Agency (IAEA) are still a long way from becoming universal. Tensions in the Middle East and South Asia have risen, no end in sight, and nuclear weapons are present in both areas. As summed up by George Shultz, William Perry, Henry Kissinger, and Sam Nunn in their *Wall Street Journal* article of 4 January 2007: "*The world is now on the precipice of a new and dangerous nuclear era.*" They described the reliance on nuclear weapons for deterrence as "*increasingly hazardous and decreasingly effective,*" – their words.

CTBT can revitalize the non-proliferation regime

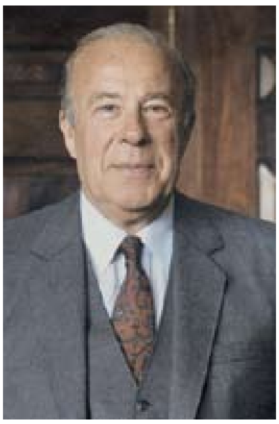
A comprehensive effort to revitalize and restore the credibility of the non-proliferation regime is needed, desperately needed, and a CTBT must be part of it. I'd like to recall the 2001 report on the test ban by General John Shalikashvili, a former Chairman of the U.S. Joint Chiefs of Staff. After the U.S. Senate had turned down the ratification of the CTBT, General Shalikashvili was asked to talk to Senators about their concerns and to make his assessment of how to proceed. I was his deputy. We talked to at least a third of the Senate, people who were interested in the issues and who would be influential. He wanted to hear their views, especially their concerns.

CTBT is a key element in a network of barriers against proliferation

And as a result of all those discussions, General Shalikashvili prepared a report, which he presented to President Clinton in January 2001. General Shalikashvili saw the CTBT as one key element in a network of barriers against proliferation – not a panacea in itself, but an element critical to the success of the whole project. His report pointed out that a CTBT would prevent the advanced nuclear weapon States from making significant improvements in their weapon stockpiles and it would prevent non-nuclear weapon States from developing nuclear weapons, particularly sophisticated weapons useful for war fighting.

General Shalikashvili understood that what the nuclear powers do affects the decision of other countries. Expectations about the future are what motivate all governments. Explosive testing is perhaps the most visible of nuclear weapons activities. Rightly or wrongly, a nuclear explosion amounts to a signal to the world that nuclear weapons are here to stay.

Notes & quotes



"[My] fellow U.S. Republicans may have been right to vote down the nuclear test-ban treaty a decade ago, but they'd be wrong to scuttle it again as President Barack Obama pushes for Senate ratification."

George Shultz, former U.S. Secretary of State, at the conference 'Overcoming Nuclear Dangers' in Rome, Italy, on 17 April 2009.

That's what testing tells the world. That lesson then becomes part of the world's expectations.

No nuclear weapons programme is risk-free

Each State, of course, has to make its own assessment of the effect of a CTBT. No agreement, especially in the nuclear field, can be considered risk-free. For that matter, no nuclear weapons programme is without risk.

General Shalikashvili's assessment of the advantages of the test ban for the United States was as follows:
"The test ban treaty will complicate and slow down the efforts of aspiring nuclear states, especially regarding more advanced types of nuclear weapons. It will hamper the development by Russia and China of nuclear weapons based on new designs and will essentially rule out certain advances. It will add to the legal and political constraints that nations must consider when they form their judgments about national defense policies."

Moratoria are inherently instable

General Shalikashvili's considered judgment was that the test ban "*is vital to the long-term health of the Nuclear Non-Proliferation Treaty, and will increase support for other elements of a comprehensive non-proliferation strategy.*" Furthermore, he stated in his report:
"The verification regime established under the Treaty will enhance the United States' own very capable nuclear test monitoring system and foster new techniques to improve verification. The Treaty will make it easier to mobilize domestic and international support for clarifying ambiguous situations and for responding vigorously if any nation conducts a nuclear test."

"A test ban treaty would be a higher barrier for Iran, for example, to jump over than is a moratorium. Probably the same is true for North Korea as well."

Much has changed both for good and for bad in the past 10 years. But those assessments, I believe, remain valid. The past 10 years have shown us how unilateral moratoria work and how they don't work. We've learned some things about them. One lesson is that instabilities are inherent in moratoria. When any participant can drop out with little or no notification, an atmosphere of the temporary is inescapable.

Another instability is that since there are no agreed standards regarding the scope of a moratorium, there are always bound to be doubts about whether there is a level playing field among the countries observing those moratoria. And a third instability is that there is no agreed way to remove doubts about other nations' actions: no on-site inspections, no transparency at test sites.

No real alternative to a fully ratified CTBT

The general expectation that a binding treaty is not in the cards obviously discourages any State that might be thinking about refraining from nuclear weapons programmes from doing so. A test ban treaty would be a higher barrier for Iran, for example, to jump over than is a moratorium. Probably the same is true for North Korea as well. There is no real alternative to a fully ratified CTBT, in short.

The importance of the context for a CTBT cannot be overstated. President Obama has said that he will work for a world without nuclear weapons. With the end of a two-tier system, a commitment made by the two leading nuclear weapon States to eliminate those weapons will make it easier for test ban hold-outs to accept the Treaty. I hope, therefore, that all possessors of nuclear weapons will rally around the vision of a world without nuclear weapons. It is also true that without a CTBT, the vision of a world free of nuclear weapons will not be perceived as realistic or possible. And the non-proliferation regime will become irrelevant. It's that important. ■

Biographical note

Ambassador James Goodby is a research fellow at the Hoover Institution and nonresident senior fellow at the Brookings Institution. His career spanned 35 years in the U.S. Foreign Service and included several assignments dealing with nuclear issues including the START treaty, what became the Helsinki Accords, and five ambassadorial rank appointments including ambassador to Finland. Goodby co-edited Reykjavik Revisited: Steps toward a World Free of Nuclear Weapons *with George Shultz and Sidney Drell in 2008.* ■

The U.S. Nuclear Stockpile and Ratification of the CTBT

by Sidney Drell, Stanford University

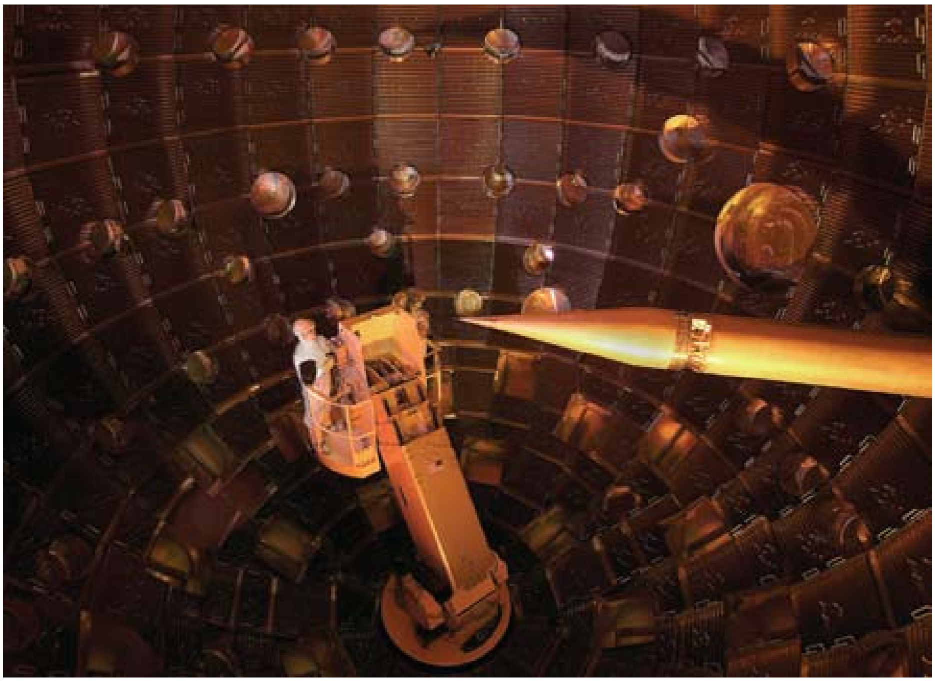
The United States was the first nation to sign the Comprehensive Nuclear-Test-Ban Treaty (CTBT) when it was negotiated in 1996, but the U.S. Senate, after a far too limited debate, failed to recommend its ratification in 1999. This negative decision was based largely on two technical concerns:

1) Can the U.S. retain high confidence in the effectiveness of its nuclear arsenal under the Treaty's ban on underground explosive testing?

2) Can compliance by other nations with a test ban be adequately verified?

During the past ten years since that Senate decision, significant technical progress has been made toward removing these concerns. Based on this progress, the Obama administration should initiate a timely bipartisan review of the value of the CTBT to the nation's security, leading to its ratification. The International Monitoring System (IMS) for identifying and locating Treaty violations has been almost entirely deployed and activated since 1999. It impressively displayed its sensitivity and effectiveness by rapidly locating, identifying and determining the very low yield of the 2006 test explosion by North Korea.

In this article I will address the important technical progress made by the United States over the past decade in maintaining high confidence in the nation's nuclear arsenal under a test ban. Taken together, these achievements give confidence that ratifying the CTBT is not tantamount to the U.S. endangering its nuclear deterrent or otherwise jeopardizing its security.



THE NATIONAL IGNITION FACILITY AT THE LAWRENCE LIVERMORE NATIONAL LABORATORY IS THE WORLD'S LARGEST AND HIGHEST-ENERGY LASER. CONTAINING 192 GIANT LASERS, THE NIF CREATES A FUSION ENERGY PROCESS THAT WILL FOCUS NEARLY TWO MILLION JOULES OF ULTRAVIOLET LASER ENERGY ONTO A SMALL TARGET, CREATING CONDITIONS SIMILAR TO THOSE THAT EXIST INSIDE STARS AND PLANETS, AS WELL AS NUCLEAR WEAPONS. THE NIF IS A CENTRAL PART OF THE U.S.'S NUCLEAR WEAPON STOCKPILE STEWARDSHIP PROGRAM, AS IT PROVIDES CRITICAL DATA NEEDED TO MAINTAIN THE RELIABILITY AND SAFETY OF U.S. NUCLEAR WEAPONS WITHOUT FULL-SCALE TESTING.
PHOTO COURTESY OF LAWRENCE LIVERMORE NATIONAL SECURITY, LLC, LAWRENCE LIVERMORE NATIONAL LABORATORY, AND THE DEPARTMENT OF ENERGY

Remarkable success of the Stockpile Stewardship Program

Following the moratorium on underground tests initiated in 1992 by the first President Bush, the United States established a broad science-based Stockpile Stewardship Program (SSP). This programme is now in its 17th year, or 10 more than at the time of the ratification debate in 1999. There is general agreement that the SSP, to date, has achieved remarkable successes that have enabled the directors of the nuclear weapons laboratories to assure the nation that there is no need to conduct nuclear test explosions for them to certify that the deterrent meets the requirements of safety, security and reliability to function as intended. Two fundamental measures of the programme's success have been the ability a) to discover causes for concerns in the stockpile, the so-called Significant Findings, whether they are due to design flaws, production errors, or aging; and b) to fix them successfully and promptly.

Here is a representative list of important technical achievements during the past decade that are responsible for the "remarkable success" that the labs have attested to:

- Successful Life Extensions Programs (LEPs) have refurbished materials and components of the weapons in the stockpile to ensure their continued viability with high confidence.

- For the first time since 1989, when the Rocky Flats plant (a nuclear weapons production facility near Denver, Colorado, USA) was closed down because of environmental concerns, the United States can now build new plutonium pits which are the core components of the primaries of thermonuclear warheads that have been certified for deployment, if replacements are needed.

- A thorough study by the Los Alamos and Lawrence Livermore National Laboratories has removed a critical concern about the stability of the plutonium metal in the pits as it ages due to radioactive decay while sitting in the stockpile. We can confirm that pit lifetimes are longer than 85 to 100 years.

- Where appropriate, the margins by which the yields of the primaries of weapons exceed the minimum values required to ignite the secondaries in thermonuclear weapons have been increased. This has been accomplished by developing more robust boost gas transfer systems.

Reliable nuclear arsenal maintained since 1992 without testing

The achievements enabling the United States to maintain a safe, secure, and reliable nuclear arsenal, without explosive testing since 1992, have been made possible by important advances in scientific understanding of nuclear explosions. Critical to this success of the SSP is its ability to maintain a strong cadre of expert scientists and engineers embedded in a programme with both the facilities and vision that allows them to retain and hone their expertise.

Understanding and assessments rely on theory, experiments (including the more than 1000 past nuclear test explosions), and computation. The development of scientific understanding of physical phenomena requires theoretical and experimental investigations. Experiments inform theorists and test their theories. Theories are incorporated into mathematical models that can be solved (approximately) with powerful computers. Powerful new instruments enabled the key experiments that served as stand-in for explosive tests to supply the crucial data.

The importance of strong peer review in this process cannot be overemphasized. In the absence of confirmatory data from a nuclear test explosion, it is necessary to take great pains to carefully assess any modification to or replacement of an existing tested design. It is equally important to subject the assessment to careful scrutiny by an independent team of scientists using an independent set of analysis tools (such as different simulation codes), both to discover any weaknesses in the assessment and to build high confidence in its validity and rigour.

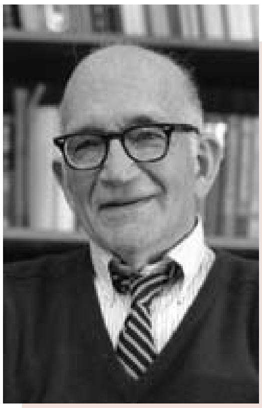
> "I conclude that technically, in terms of maintaining confidence in our nuclear stockpile, there is no barrier to ratifying the CTBT."

No more barriers to ratifying the CTBT

My conclusion from what we have learned over the past decade is that we can, and I certainly do, have higher confidence in the effectiveness of our nuclear arsenal now than in 1999. Therefore, with our current national policy that states there is no need for new nuclear warheads designed to meet new military missions, I conclude that technically, in terms of maintaining confidence in our nuclear stockpile, there is no barrier to ratifying the CTBT. The Treaty contains an article that permits a signatory nation, with six month notification of its intention, to withdraw and resume testing if it deems such action necessary for its national security. By maintaining an effective SSP, with the necessary talent and facilities, the United States will be prepared to respond, should future changes in strategic circumstances present new dangers that lead the government to conclude that withdrawal is appropriate.

I believe that it is now clearly in the national security interest of the United States to ratify the CTBT and lead a global effort to bring it into force. It would strengthen the non-proliferation regime by constraining further development and deployment of the world's most devastatingly destructive weapons. It would enhance diplomatic efforts to reduce nuclear dangers for all nations, en route toward realizing the vision of a world free of nuclear weapons. ■

Biographical note



Dr. Sidney D. Drell is a senior fellow at the Hoover Institution at Stanford University and a professor of theoretical physics (emeritus) at Stanford's SLAC National Accelerator Laboratory. An arms control specialist, he has advised the executive and legislative branches of government on national security and defense technical issues for over four decades. In recognition of his achievements, Drell has received numerous awards, including the Enrico Fermi Award. He is also a member of the U.S. National Academy of Sciences. ■

Verification highlight

CTBT Evasion Scenarios: Possible or Probable?

by David Hafemeister, Stanford University

Evasion in a cavity

A possible way to evade seismic detection of a clandestine underground nuclear test is to detonate the device in a large underground cavity, but the individual actions needed to hide the evasion are complex and can be detected and the potential military gains are relatively small. This scenario is known as cavity decoupling. If the cavity is sufficiently large, the resulting seismic waves are muffled and detection becomes more challenging.

Cavity decoupling was the most commonly cited concern during the U.S. Senate debate on the Comprehensive Nuclear-Test-Ban Treaty (CTBT) in 1999. The 2002 U.S. National Academy of Sciences (NAS) report on Technical Issues Related to the Comprehensive Nuclear–Test–Ban Treaty examined 10 evasion scenarios from the U.S. intelligence community. It concluded that: *"...the only evasion scenarios that need to be taken seriously at this time are cavity decoupling and mine masking."*

The seismic signal of a small nuclear test in a cavity can be reduced by a factor of 70, but such a covert test has additional detection risks from the other elaborate activities needed to do the test. Thus, a successful covert test is possible, but not probable, and if it took place it would not be militarily significant under the U.S. definition of effective verification of an arms control treaty, as described on page 24.

Fully decoupled explosions

An explosion is 'fully' decoupled (reduction in the measured yield by a factor of 70) if the size of the cavity is large enough to reduce blast pressure on cavity walls below the elastic limit of the media. In salt, the cavity radius in metres must be larger than 25 multiplied by the cube root of the yield in kilotons. The only "fully" decoupled nuclear test was a very small 0.38 kiloton (kt) test in Mississippi, USA, in 1966, which was exploded in a 34–metre diameter salt cavity. In 1976 the Soviet Union partially decoupled with a test in a salt cavity in Azgir, Kazakhstan.

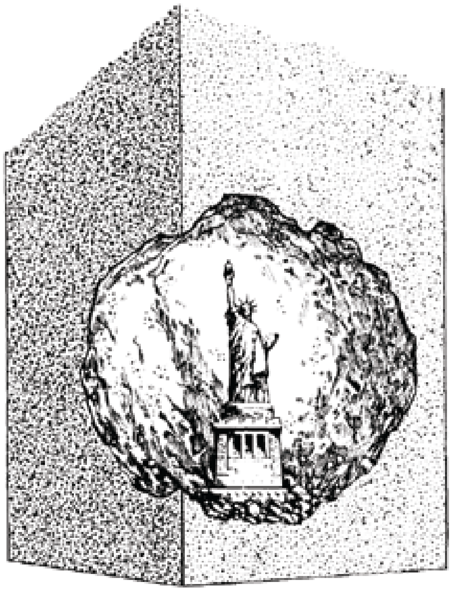


FIGURE 1. MINIMUM CAVITY REQUIRED TO FULLY DECOUPLE A 5 KT EXPLOSION. THE 73-METRE STATUE OF LIBERTY IS 15 PERCENT LESS THAN THE DECOUPLING DIAMETER OF 85 METRES. [SEISMIC VERIFICATION OF NUCLEAR TESTING TREATIES, U.S. OFFICE OF TECHNOLOGY ASSESSMENT (OTA), 1988]. IMAGE COURTESY OF OFFICE OF TECHNOLOGY ASSESSMENT, 1988.

Salt is the preferable medium because tests in hard rock vent radioactivity more easily and because it is easier to create a large cavity in salt by solution mining, which uses flowing water to dissolve salt to make the cavity. Ninety percent of Soviet underground tests at Novaya Zemlya in the Arctic Ocean vented, as did 40 percent of all Soviet tests.[1] It is highly likely that a significant amount (more than 0.1 percent) of radionuclides, especially radioxenon, would be released and then detected by the CTBT's International Monitoring System (IMS). The former U.S. Congressional Office of Technology Assessment issued a report in 1989 on The Containment of Underground Nuclear Explosions, which concluded that: *"Since 1970, 126 [U.S.] tests [out of 723] have resulted in radioactive materials reaching the atmosphere with a total release of about 54,000 Curies. Of this amount, 11,500 Curies [roughly one-fifth] were due to containment failure and late–time seeps."*[2]

Venting from smaller tests can be harder to contain, as the last four U.S. tests that vented had yields less than 20 kt. Some scientists hypothesize that smaller explosions may not sufficiently enclose cavities with a glassified cage in which the explosion melted the rock to glass to prevent venting. Available salt formations of the proper depth and thickness are limited, and are usually in regions that transmit seismic waves readily and are less seismically active, making detection easier. Suitable salt deposits can be found in China, Kazakhstan, Iran, northern Pakistan, Russia and the United States.

The NAS panel determined that an explosion in a cavity: *"...cannot be confidently hidden if its yield is larger than 1 or 2 kilotons."* Other observers quote higher thresholds, which are possible, but not probable. The higher the estimate, the more likely the clandestine test will be detected. The higher estimates ignore the additional capacity of the IMS's auxiliary seismic network, the ability to discriminate with higher frequency components, and they ignore the critical steps listed on page 23. Arrays of seismographs and other seismic capabilities can detect and identify events with yields considerably less

[1] V. Khalturin, T. Rautian, P. Richards and W. Leith, "A Review of Nuclear Testing by the Soviet Union at Novaya Zemlya, 1955–1990," *Science and Global Security* 13, 1–42 (2005). Also NAS–CTBT study, pg. 45 and P. Podvig (ed.), *Russian Strategic Nuclear Forces* (Cambridge: MIT Press, 2004), pp. 440 and 483–566.

[2] For more information see Department of Energy, *Radiological Effluent Released from U.S. Continental Tests 1961-1992*, DOE/NV (Rev. 1) UC-702, August 1996.

than one kt at distances of more than 2,000 km. And advances in regional seismology (seismic waves from distances less than 1500 km that travel within 100 km of the surface) have been dramatic in the past decade. Moreover, a successful clandestine test must avoid a significant "yield excursion", which is particularly difficult for new nuclear weapon States. The NAS panel noted that an inexperienced State that wanted to prevent detection: *"...would probably try to limit test yields to 0.1 kiloton or less,"* which is not militarily significant.

Cheating is a many step process

In the 1999 U.S. Senate debate, Treaty opponents pointed to a classified CTBT National Intelligence Estimate and other intelligence community documents that made cavity cheating appear too easy by not properly taking into account the six factors listed below. Even if each of these tasks could be carried out with high confidence (i.e. a 90 percent chance of success), there would be a cumulative 50 percent chance of avoiding detection of one test and only a 15 percent chance that three tests could be carried out without detection. Note that the small three kt, May 2009 North Korean test was observed at 61 IMS stations. It should be noted that U.S. national technical means, when directed at regions of concern, are more capable than the IMS system. It is unlikely that a State could simultaneously overcome all of the following technical hurdles at the same time at a significant yield:

FIGURE 2: THE VENTING OF BANEBERRY AT THE NEVADA TEST SITE, WHICH WAS UNCHARACTERISTICALLY LARGE. [U.S. ATOMIC ENERGY COMMISSION, 1970].

1) Violators must avoid significant yield excursions. All successful first tests, if carried out in a cavity, would be detected by the IMS: United States (21 kt), Soviet Union (20 kt), United Kingdom (25 kt), France (65 kt), India (12 kt), Pakistan (9 kt), North Korea (0.6 kt observed by 22 IMS stations in October 2006).[3]

2) It is necessary to conceal the materials removed to create a test shaft and cavity from satellites.

3) Crater and surface changes due to testing must be hidden from space-based interferometric synthetic aperture (InSAR), a remote sensing technique

[3] A 90 percent success rate on seismic cheating is a 10 percent detection rate, much lower than the usual 90 percent detection rate. This lowers the detection threshold by 0.5 mb units (O. Dahlman, et al, *Nuclear Test Ban,* Springer 2009, pg. 167).

that uses radar satellite images and other technologies. The North Korean, Indian and Pakistani test sites were located with commercial satellite images.

4) Practically all the radioactive gases and particles must be trapped. The sensitivity of radioxenon detectors has greatly surpassed specifications. Detectors on airplanes can fly into radionuclide plumes.

5) Cheaters must avoid detection of weak seismic signals by closer stations and arrays. The P/S (pressure to transverse wave) ratio above 6 Hz has very successfully discriminated earthquakes from explosions.[4]

THE 1964 SALMON EVENT, A FIVE KT DETONATION CONDUCTED 280 METRES DEEP IN A MISSISSIPPI SALT DOME, CONFIRMED THE THEORY OF DECOUPLING AS A MEANS OF CONCEALING CLANDESTINE NUCLEAR EXPLOSIONS. IN THIS PHOTO, EXPERIMENTERS ARE LOWERING A CANISTER CONTAINING THE NUCLEAR EXPLOSIVE FOR THE SALMON EVENT.

6) Cheaters must prevent detection by national technical means, which are more powerful than the IMS when directed at suspicious areas. Human intelligence provided the locations of Iran's centrifuges and other clandestine sites.

What kind of cheating would matter?

The principal risk that needs to be avoided is that a country could alter the strategic balance or significantly disadvantage national security. The 2002 NAS report concluded that: *"Countries with lesser prior test experience and/or design sophistication would also lack the sophisticated test-related expertise to extract much value from such very-low-yield tests as they might be able to conceal."* The NAS panel judged that: *"States with extensive prior test experience are the ones most likely to be able to get away with any substantial degree of clandestine testing."* Low yield tests by nuclear weapon States should not, by themselves, materially change the strategic balance. Moreover, several clandestine tests are needed to change design parameters, improving the chance of detection.

Military significance of violations

The CTBT provides a strong deterrent against nuclear testing since it strengthens the global norm against testing. This is evidenced by the 2008 United Nations General Assembly resolution on the CTBT (175 in favour with only the U.S. voting against), the few tests that have been conducted since 1996, and the CTBT's 181 Member States. Furthermore, there have been consensus declarations at all of the Conferences on Facilitating the Entry into Force of the CTBT, including by those States that have not yet ratified. The *possibility* of avoiding seismic detection with a cavity should not be confused with the *probability* of detection during the six steps outlined above.

Finally, we need to consider the military significance of violations. The U.S. standard for *effective verification* of an arms control treaty was defined in 1988 by Ambassador Paul Nitze during the Foreign Relations Committee's consideration of the Intermediate Nuclear Forces (INF) Treaty, as follows:
"....if the other side moves beyond the limits of the treaty in any militarily significant way, we would be able to detect such violation in time to respond effectively and thereby deny the other side the benefit of the violation."

Thus, cheating that could threaten national security in a militarily significant way must be detected in sufficient time. In the case of a nation that already has nuclear weapons, effective verification is determined by the military significance of the additional nuclear weapons capabilities it might obtain by cheating, beyond those it had before the treaty was in place.

A worst–case analysis was carried out by the Senate Foreign Relations Committee for START I and START II ratifications. The Executive Reports issued by the Committee on the START Treaties in 1992 and 1995 concluded that potential treaty violations were not militarily significant, namely the Soviets (and then the Russians) would gain little with massive cheating in their ability to hurt U.S. strategic forces beyond what they could achieve without resorting to this.

These results allowed the Senate to determine that the two START Treaties were effectively verifiable. By the same standard, the CTBT is effectively verifiable. Evasive cheating in cavities is possible, but not probable and data extraction is more complicated. Without a CTBT the probability of a nuclear test would be considerably higher because of reduced monitoring without the IMS and a diminished global norm against testing without a CTBT.

[4] K. Walter, "Sleuthing Seismic Signals," *Science and Technology Review*, March 2009, pp. 5–12

Net benefit analysis

General John Shalikashvili, former chairman of the U.S. Joint Chiefs of Staff, concluded in *Findings and Recommendations Concerning the Comprehensive Nuclear Test Ban Treaty* in 2001:
"I believe that it is very much in our national interest to secure these benefits through entry into force of the Test Ban Treaty. If this opportunity is lost, the United States' ability to lead an effective global campaign against nuclear proliferation will be severely damaged."

Shalikashvili commented on evasions with these conclusions:

- There will always be some gap between zero-yield and the lower limit of remote sensing capability to detect, identify, and locate an explosion. With on-site inspections and other sources of information, though, it is more likely that very low-yield testing would be detected or deterred with the Test Ban Treaty than without it.

- Experienced nuclear weapon States such as Russia, and to a lesser extent China, could engage in some evasive testing. However, tests that are small and infrequent enough to avoid detection would not permit them to develop new weapon systems that would undermine the U.S. nuclear deterrent, and eventually even such violations are likely to be caught.

- The verification regime established under the Treaty will enhance the United States' own very capable nuclear test monitoring system and foster new techniques to improve verification. ■

Biographical note

Professor David Hafemeister of the USA was the lead staff on technical matters for the ratification of START, the Treaty on Conventional Forces in Europe (CFE) and the Threshold Test-Ban Treaty (TTBT) while serving at the Senate Committees on Foreign Relations and Governmental Affairs from 1990 to 1993. He has also worked on non-proliferation issues for the State Department, the Arms Control and Disarmament Agency and the National Academy of Sciences. In 1996 Hafemeister received the Leó Szilárd Award. Over recent years, he has authored several books and papers on CTBT verifiability. ■

New publication coming in October 2009

Science for Security: Verifying the Comprehensive Nuclear-Test-Ban Treaty

The publication is dedicated to the International Scientific Studies Conference (ISS09), which took place in Vienna, Austria, from 10 to 12 June 2009. ISS09 was attended by around 500 scientists and 100 diplomats from 100 countries who came together to present and discuss results from the ISS project, which has engaged the scientific community since early 2008.

The purpose of the ISS is twofold: to conduct independent assessments of the capabilities and readiness of the Comprehensive Nuclear-Test-Ban Treaty's (CTBT) verification regime; and to identify scientific and technological developments that might enhance these capabilities as well as improve the cost-effectiveness of the products and services of the Preparatory Commission for the Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO).

During ISS09, scientists presented more than 200 posters covering all of the areas relevant to CTBT verification. This was the first time ever that such a comprehensive collection of scientific work related to the CTBT has been submitted.

Many of the scientists closely involved in the ISS project have contributed articles to the publication, offering their summaries and analyses of the issues presented and discussed at ISS09, including world-renowned seismologists Paul Richards and Lynn Sykes.

Verification science

The announced nuclear test in the DPRK on 25 May 2009

by Robert G. Pearce, Andreas Becker, Tim Hampton and Matthias Zähringer

In Issues 9 and 10 of *Spectrum* we reported on signals recorded by the International Monitoring System (IMS) relating to the first announced nuclear test in the Democratic People's Republic of Korea (DPRK) on 9 October 2006. When the DPRK announced a second nuclear test on 25 May this year, it was natural that Member States would again focus on IMS performance. Since 2006 the IMS has grown much closer to its eventual 321 monitoring stations, with an additional 65 stations having been certified by May 2009. The capabilities of the International Data Centre (IDC) have also been further enhanced. Moreover, the IMS seismic signals showed that this event was larger. These factors conspired to provide us with high quality signals at many more IMS seismic stations. However, this time the IMS does not appear to have recorded relevant signals at its radioactive noble gas stations, which has come as a surprise to some.

So what can we then conclude from the IMS data?

IMS seismic recordings of the 25 May 2009 DPRK event

On 25 May 2009, the IDC's initial list of events compiled automatically from IMS waveform data (Standard Event List 1, SEL1) contained an event recorded in the DPRK, referred to here as DPRK2. It was located (Figure 1) using 23 IMS primary seismic stations. The location had an 'uncertainty ellipse' of 860 square kilometres (km^2), most of which overlapped with that of the announced DPRK nuclear test of 9 October 2006, referred to here as DPRK1. SEL1 is issued within two hours, which means that a location estimate for this event was made available to Member States within that time without any human intervention.

The IDC issues three SELs with different time delays, in order to provide progressively more accurate and reliable event location estimates as more data become available. Currently the IDC issues SEL1 within two hours of 'real time', SEL2 after about four hours and SEL3 after six hours, in accordance with the timeline envisaged after Entry into Force (EIF) of the Treaty. The lists are dominated by large and small earthquakes; there are typically between 120 and 160 events in each SEL every day. The DPRK2 event in SEL2 and SEL3 incorporated observations from 16 auxiliary seismic stations, which reduced the uncertainty ellipse to an area of 582 km^2.

Events are examined by IDC analysts in order to prepare a Reviewed Event Bulletin (REB) for each day, which contains all events meeting specific criteria. Following guidance from the Member States, IDC typically issues the REB for any day within ten days. In view of the considerable interest generated among Member States by this event, an 'expedited' REB containing all the events for 25 May 2009 was issued on 27 May, in accordance with the envisaged post-EIF timeline. This was made possible by delaying the REBs for other days.

During interactive analysis, signals from this event were found from some additional IMS stations, bringing the total to 31 primary and 30 auxiliary seismic stations in the REB, 59 of which

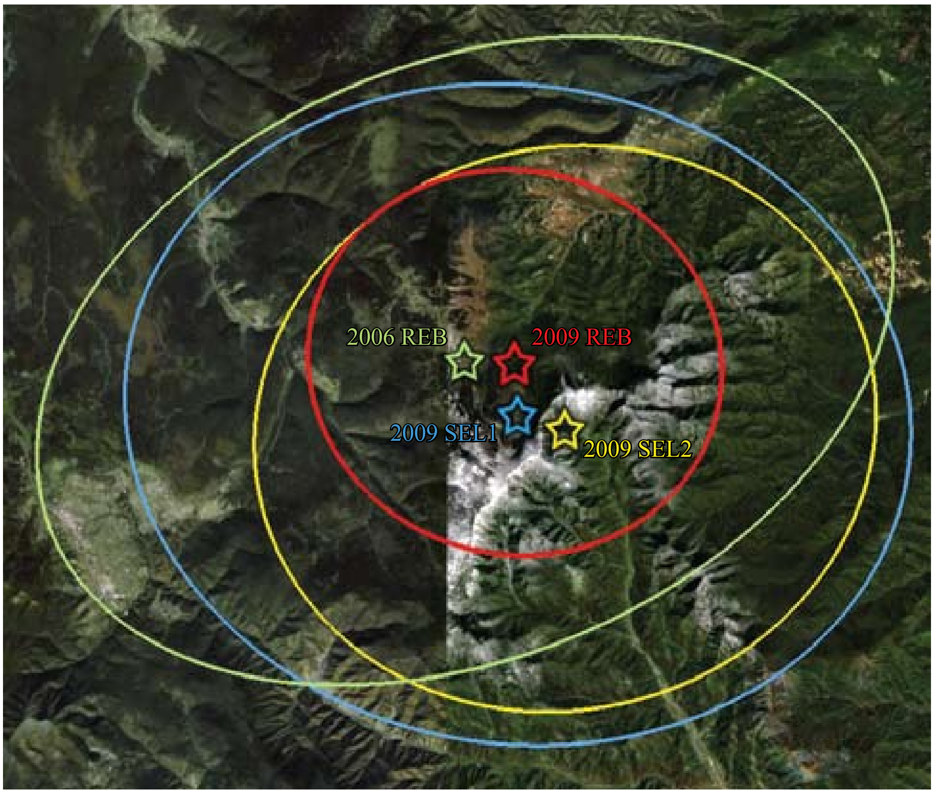


FIGURE 1: LOCATION AND UNCERTAINTY ELLIPSES FOR THE 2006 AND 2009 DPRK EVENTS DETERMINED USING IMS SEISMIC DATA. FOR THE 2009 EVENT, THE FIRST ESTIMATE (SEL1) WAS ISSUED WITHIN TWO HOURS USING IMS PRIMARY SEISMIC STATIONS ONLY, FOLLOWED BY SEL2 WHICH INCLUDED AUXILIARY SEISMIC STATIONS. THE FINAL ESTIMATE OBTAINED FOLLOWING ANALYST REVIEW OF ALL DATA WAS ISSUED IN THE REVIEWED EVENT BULLETIN (REB) WITHIN TWO DAYS. AS EXPECTED, THE UNCERTAINTY ELLIPSES GET PROGRESSIVELY SMALLER AS MORE DATA BECOME AVAILABLE; THAT FOR THE 2006 EVENT IS LARGER THAN THAT FOR 2009 BECAUSE THERE WERE FEWER SEISMIC OBSERVATIONS.

contributed to the location. The location uncertainty was reduced even further, to an area of 264 km^2 (Figure 1).

The Treaty specifies that the IDC should apply an automatic ‘event screening’ procedure to events in the REB, in order to exclude events which are ‘consistent with natural phenomena or non-nuclear man-made phenomena’. Accordingly, experimental event screening criteria are applied to qualifying events in the REB. This leads to a Standard Screened Event Bulletin (SSEB) which is issued about two hours after the REB, and from which some events have been ‘screened out’. The SSEB for 25 May 2009 included 36 events which were ‘screened out’ from a total of 79; DPRK2 was not screened out, and exhibited some clear characteristics of an explosion. Nevertheless, it is important to bear in mind that while the Preparatory Commission for the Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO) makes available IMS data and IDC products to Member States, under the Treaty it remains the responsibility of the States to pass final judgment on their origin.

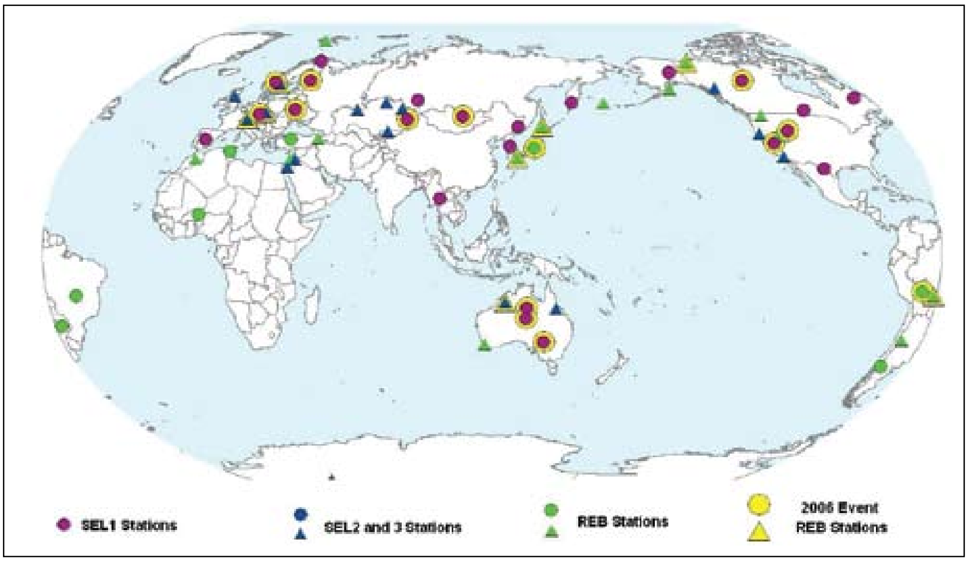


FIGURE 2: IMS SEISMIC STATIONS WHICH RECORDED SIGNALS FROM THE DPRK EVENT OF 25 MAY 2009. THOSE IN RED WERE USED IN THE SEL1 LOCATION ESTIMATE. THE ESTIMATE IN SEL2 INCLUDED ALSO THOSE IN BLUE, AND THOSE IN GREEN WERE MANUALLY ADDED BY ANALYSTS FOR THE REB. STATIONS WITH A YELLOW BORDER WERE USED IN THE 2006 DPRK EVENT. CIRCLES AND TRIANGLES REFER TO ARRAY AND THREE-COMPONENT SEISMIC STATIONS RESPECTIVELY.

Comparison of Seismic Observations for the DPRK events in 2006 and 2009

The REB locations for DPRK1 and DPRK2 differ by less than three km, with the uncertainty ellipse of DPRK2 completely inside that of DPRK1; bearing in mind the sizes of the uncertainty ellipses, this difference in location is hardly significant. Of the 59 stations used to locate DPRK2 (see Figure 2), 17 were certified after DPRK1, meaning that they meet IMS defined requirements and specifications. These 17 stations included four auxiliary seismic stations which were also used in DPRK1, but were subsequently upgraded and certified. It is noteworthy that three of the five seismic arrays closest to the event are new or have been upgraded since DPRK1. This reflects positively on the continuing build-up of the IMS network over the last few years, particularly in Asia.

Radionuclide observations and atmospheric transport modelling

A large part of the radioactive debris from an underground explosion is normally contained within the cavity created by the explosion. However, small traces of radioactive release may be measured at highly sensitive detectors under favourable conditions, even hundreds or thousands of kilometres away. Radioactive noble gases, including xenon, may escape immediately after the explosion by ‘venting’, or at a later time by ‘seepage’. The IMS is designed such that releases from a nuclear test should be detectable at one or more stations in the global network. Radioactive xenon has a half life of a few days, and so offers the best chance of being detected remotely in the IMS network within about three weeks of an event.

At the time of DPRK2, several IMS noble gas stations in the region were operational (see Figure 3), of which only one was operating at the time of DPRK1. This gives an indication of the progressive build-up of the IMS. Noble gas detectors at three of these stations (RN22, RN38 and RN58), were operating continuously at full performance. Their overall detection capability (minimum detectable concentration or MDC) was 0.2 millibecquerel[1] per cubic metre (mBq/m^3) or better throughout the relevant time period.

Although seismic signals originating from a putative underground nuclear explosion travel from the test site to IMS stations along well-defined paths through the Earth in a few minutes, any radionuclide particulates or gas which may reach the Earth’s surface above an underground nuclear explosion travel much more slowly. They then spread out through the atmosphere along

[1] The Becquerel is a measure of the strength of radioactivity.

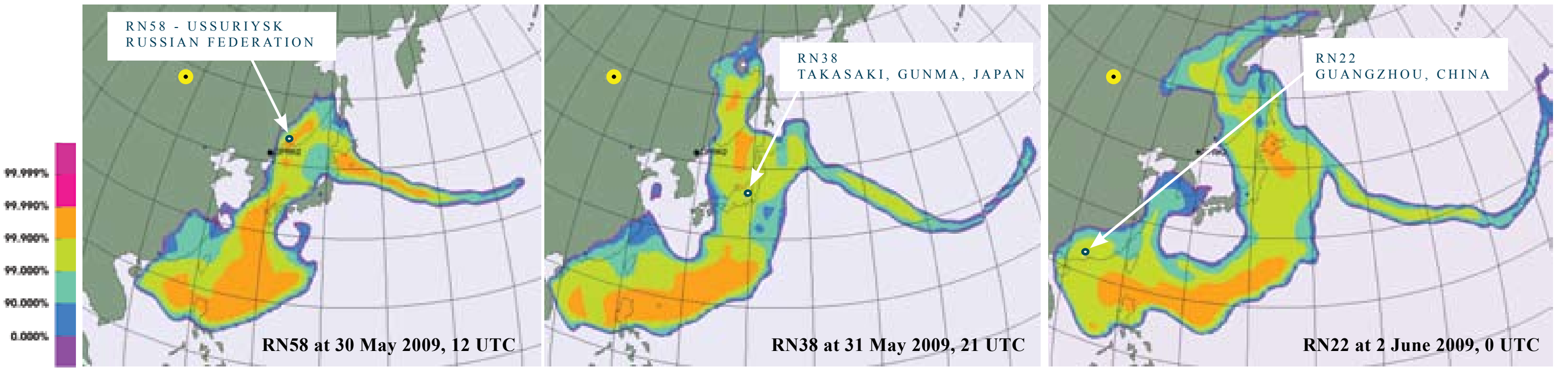


FIGURE 3: EVOLUTION OF THE DETECTABLE RADIOACTIVE PLUME AS CALCULATED FOR AN IMMEDIATE VENTING SCENARIO, PLOTTED AT THE TIMES OF THE STRONGEST ARRIVALS AT (1) RN58, RUSSIAN FEDERATION, (2) RN38, JAPAN AND (3) RN22, CHINA. FOR EXPLANATION SEE TEXT. IMS NOBLE GAS STATIONS OPERATING AT THE TIME OF DPRK2 ARE SHOWN; THE ONLY ONE OPERATING IN THIS REGION AT THE TIME OF DPRK1 IS HIGHLIGHTED BY A YELLOW CIRCLE - RN45, MONGOLIA.

paths which are dictated by the prevailing air movements (in other words, the weather). Atmospheric transport calculations based on millions of daily weather observations are therefore essential to interpret the radionuclide observations (or non-observations) made at IMS stations after days or weeks.

A comprehensive simulation study of atmospheric transport and dilution showed that several IMS stations were in a position to detect a release at the time and place of DPRK2; in other words, air was indeed transported to IMS stations from the site of the event. However, the simulation together with the observations showed that none of these stations detected a visible signal that could be attributed to DPRK2.

Figure 3 illustrates the distribution of a hypothetical radioactive xenon plume at the time of its highest concentration at the above-mentioned three stations. Only those parts of the plume which are above the minimum detectable concentration are shown. The plume was calculated under the assumption of immediate venting at the time and place of DPRK2, and under the assumption that zero containment corresponds to the full release of the radioactive xenon (^{133}Xe) generated by a four kiloton (kt) TNT equivalent explosion, (4×10^{16} Becquerel). For a containment of 90 percent, the detectable plume would cover the area shaded in green and yellow and orange. For a containment of 99.9 percent the detectable plume would cover only the areas in orange. As the stations in this region did not record signals at the corresponding times, it is concluded that the containment of any generated xenon (under the hypothesis that this was a nuclear test) was above 99.9 percent.

These maps of a hypothesized migrating plume are derived from a large body of observed meteorological data, and this demonstrates the crucial importance of meteorological information acquired in connection with the Cooperation Agreement between the CTBTO and the World Meteorological Organization (WMO). The meteorological conditions, and hence the pattern of atmospheric transport, were substantially different at the times of DPRK1 and DPRK2, and this reminds us of the fundamental importance of atmospheric transport modelling (ATM) in the interpretation of IMS radionuclide observations or non-observations.

The above simulation is called ‘forward modelling’ because a release is postulated, and the ATM is stepped forward in time to generate the evolving plume as it would develop under the observed meteorological conditions. The results are confirmed by performing ‘backtracking’ calculations (not shown here). These calculations begin with a notional sample of air at an IMS station at a given time, and trace it backwards in time and space (again using the prevailing meteorological conditions) in order to determine what regions of the globe it could have originated from, and at what sensitivity these regions were monitored, at any past time. These so-called ‘Fields of Regard’ are computed routinely for all radioactive xenon and particulate samples. For the latter, they are also appended to every Reviewed Radionuclide Report (RRR) issued as a standard product by the IDC.

All the above calculations refer to a hypothesized release at the time of DPRK2 (‘venting’). The CTBTO has also investigated how sensitive the IMS network is for detecting seepage that may have occurred at a later time, again under the hypothesis that this was a nuclear test. The maximum possible daily seepage consistent with the observed non-detection of radioactivity is shown in Figure 4, on a logarithmic scale, for each day of the three-week period following the event. The sensitivity of the network varies during this period due to variations in the meteorological transport conditions relevant for each sample from each station, and is accessible from the relevant ATM backtracking (Field-of-Regard) calculations. On all days, the network sensitivity to the DPRK2 event location was sufficiently high to still detect a xenon-133 release of 100 Tera-Becquerel (TBq), a global reference value that corresponds to a 90 percent contained one kt underground nuclear explosion. On all but three days the network’s daily threshold source strength at the DPRK2 event location was even one to three orders of magnitude below (thus better than) the 100 TBq baseline.

The non-detection of radioactivity after DPRK2 may be seen as somewhat surprising in view of the fact that DPRK1, though evidently smaller, was associated with relevant radioactive noble gas observations. The probability of detecting radioactive xenon traces from an underground explosion depends mainly on three factors. Firstly the degree of containment of the radioactive noble gases must be taken into consideration: if this were to be 100 percent then there is nothing to be detected. Secondly, detectability is affected adversely by the decay of radioactive xenon and the dilution of any release during its dispersion by atmospheric transport away from the release site towards IMS stations. Thirdly, the detection systems must be sufficiently sensitive to detect a relevant release that reaches them. This sensitivity may be compromised by a 'background' arising out of releases from nuclear reactors or radiopharmaceutical production unconnected with the possible release of interest.

Of the above factors, station detection capability is under our control, and ATM calculations enable us to diagnose the transport and dilution of any release as it spreads. However, the extent of containment of radioactive material below the surface remains largely unknown. From sensitivity studies (Figure 4) it is concluded that, under the hypothesis that this was a nuclear test, containment was well above 99.9 percent. However, whether planned or unintentional, it is extremely difficult to guarantee such a level of containment in advance. Similarly, the ATM calculations have been well-determined after an event, but different (unforeseeable) meteorological conditions can result in predicted detectabilities at different IMS stations that vary by many orders of magnitude. These two factors make it virtually impossible for a potential Treaty violator to predict the detectability of a nuclear test by IMS radionuclide stations in advance.

Conclusions

DPRK2 provided a tangible reminder that the IMS network has developed substantially since 2006, and it provided a further demonstration that the IMS network and the IDC processing systems are capable of detecting and locating an event of special interest, and making a preliminary location available to Member States automatically within two hours. In this case even the SEL1 location had an area of uncertainty smaller than the 1000 km^2 maximum area permissible for an on-site inspection after EIF, and satisfied the requirement that it should not exceed 50 km in any direction. Moreover, the IMS seismic data showed clear characteristics of an explosive source, and was not 'screened out' as an event consistent with a natural origin. The newly installed IMS noble gas stations, together with ATM calculations based on observed meteorological data, have allowed the CTBTO to determine with good precision the maximum release of radioactive xenon that could have occurred under various release scenarios, under the hypothesis that the event was indeed a nuclear test. In arriving at a conclusion on the nature of any suspicious event, the Member States will have the opportunity to integrate the results from all IMS monitoring technologies, and other sources of data, in order to arrive at their final judgement as to the nature of the event, while after EIF there would additionally be the potential for conducting an on-site inspection under the Treaty. ■

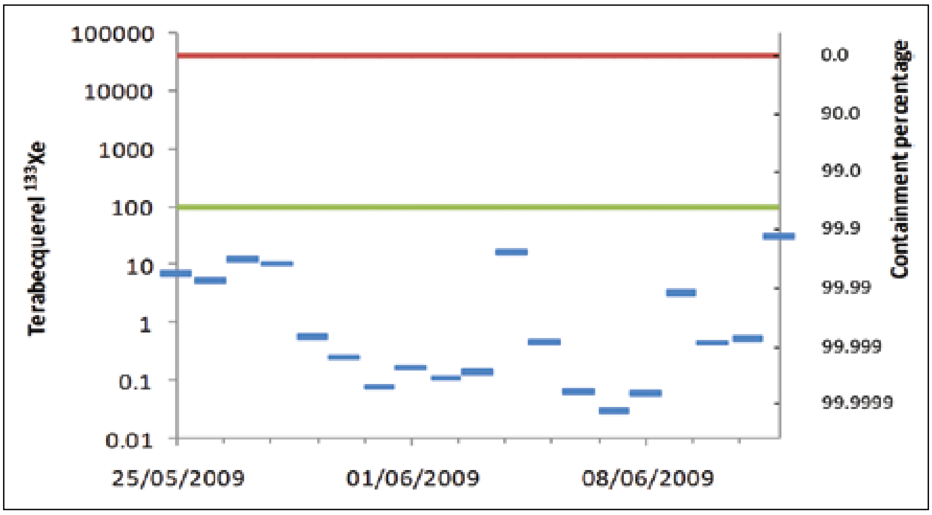


FIGURE 4: MAXIMUM POSSIBLE DAILY RELEASE OF RADIOACTIVE XENON AT THE LOCATION OF THE DPRK2 EVENT WHICH WOULD BE CONSISTENT WITH NON-DETECTION AT THE IMS STATIONS RN22, RN38 AND RN58 (BLUE BARS). THE RED LINE DENOTES THE TOTAL AMOUNT OF ^{133}XE PRODUCED BY A NUCLEAR DEVICE WITH AN EQUIVALENT YIELD OF FOUR KT OF TNT. THE GREEN LINE DENOTES THE MINIMUM REQUIRED RELEASE SENSITIVITY (BASELINE) AGAINST WHICH THE IMS GLOBAL COVERAGE IS EVALUATED.

Biographical note

Dr. Robert G. Pearce worked at the CTBTO International Data Centre for ten years until April 2009, latterly as Chief of the Monitoring and Data Analysis Section. Prior to this, he held appointments at three universities. He has also worked at the UK Government's Blacknest research group.

Dr. Andreas Becker joined the CTBTO as an Atmospheric Sciences Officer in 2001 and is in charge of atmospheric transport modelling (ATM) software development at the IDC. Before this he worked in Germany as a senior scientist developing ATM systems for environmental measurement campaigns.

Tim Hampton joined the CTBTO in 1998 and is part of the team maintaining and operating the IDC application software to generate and distribute products and services. Prior to that, he worked in the UK for 10 years on test-ban monitoring issues.

Dr. Matthias Zähringer is a physicist who joined the CTBTO in 2007 as the Senior Radionuclide Officer at the IDC. Prior to that, he worked at the German Federal Office for Radiation Protection mainly on issues of environmental radioactivity monitoring and emergency preparedness. ■

Potential civil applications

The Utilization of International Monitoring System Seismic Data by the Northwest Pacific Tsunami Advisory Center

by Yohei Hasegawa, Japan Meteorological Agency

Japan has a long history of suffering the effects from a number of local tsunamis due to its geographical and geological environment. In order to mitigate tsunami disasters, the Japan Meteorological Agency (JMA) started a national Tsunami Warning Service that covered the whole region of Japan in 1952, expanding on the local tsunami warning service that was already operating in some areas.

The JMA has made continuous and earnest efforts to improve the Tsunami Warning Service since its inception, through the development of seismological observation networks, earthquake analysis systems and data communication systems. One of the epoch-making achievements of the last decade was the JMA's introduction of the world's first tsunami warning service in 1999, which uses a numerical simulation technique. This technique has produced greater accuracy and a quicker issuance of tsunami warnings than the previous empirical method.

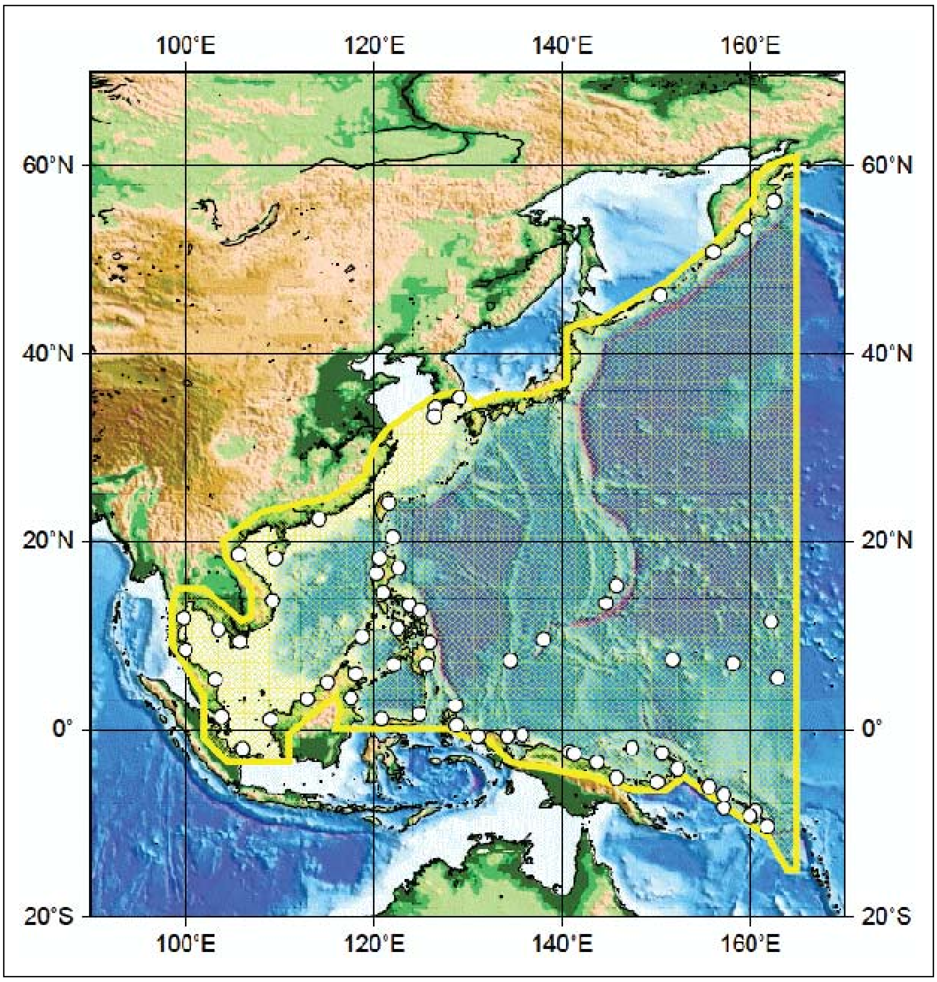


FIG.1 THE GEOGRAPHICAL COVERAGE (SHADED AREA) AND THE FORECAST POINTS (OPEN CIRCLES) OF THE ADVISORY

Massive tsunami highlights importance of international cooperation

During the early developmental stages of the Tsunami Warning Service in Japan, an event occurred that stressed the importance of international cooperation in the area of tsunami mitigation. On 22 May 1960, a magnitude 9.5 earthquake off the coast of Chile generated a massive tsunami that caused serious damage to countries in the Pacific Ocean region. The tsunami killed more than 60 people in Hawaii after travelling halfway across the Pacific and killed over 140 people in Japan after crossing the entire Ocean in less than one day. It was claimed the loss could have been avoided had a proper data and information exchange system for countries in the region been in existence.

This disaster marked a turning point: in 1965 the International Coordination Group for the Tsunami Warning System in the Pacific, now reorganized as the Intergovernmental Coordination Group for the Pacific Tsunami Warning and Mitigation System (ICG/PTWS), was established under the Intergovernmental Oceanographic Commission (IOC) of the United Nations Educational Scientific and Cultural Organization (UNESCO). The group's aim is to prevent tsunami disasters through the exchange of seismological and tsunami observation data among the member states.

Establishment of the Northwest Pacific Tsunami Advisory Center

The ICG/PTWS has implemented various activities through the cooperation of its member states, including the ocean-wide tsunami warning provision by the Pacific Tsunami Warning Center based in Hawaii. As a contribution to the

activities of the group, Japan established the Northwest Pacific Tsunami Advisory Center (NWPTAC) within the JMA. The NWPTAC started its service in March 2005 by providing countries in the region with detailed forecast information about tsunamis generated in the Northwest Pacific using the same numerical simulation technology as the domestic system described earlier.

The NWPTAC monitors and analyses seismic data on a 24/7 basis from the domestic observation network in Japan, the United States Geological Survey Live Internet Seismic Server (LISS), and the Incorporated Research Institutions of Seismology (IRIS). It then issues a Northwest Pacific Tsunami Advisory (NWPTA) when a large earthquake occurs in the region. A NWPTA, hereafter referred to as an Advisory, is provided via the Global Telecommunication System of the World Meteorological Organization, e-mail, and facsimile when the NWPTAC detects a big earthquake of magnitude 6.5 or greater in its coverage (Fig.1). After issuing an Advisory, the NWPTAC monitors sea level data from the global network of tide gauges, and subsequently issues further Advisories, including the tsunami observation data, when it actually detects a tsunami wave.

An Advisory contains the following information:

1) Earthquake parameters;

2) Tsunamigenic potential;

3) Estimated tsunami amplitude and arrival time at coastal points; and

4) Tsunami observational data.

The outline of the system is as follows:

The first step in building the system involves setting a number of possible earthquake fault models and calculating the propagation of the tsunami generated by each fault model. Then the results of the tsunami's arrival time and maximum amplitude at certain places for each case are stored onto the tsunami forecast database. Those processes are conducted and completed in advance. When an actual earthquake occurs, the tsunami's arrival time and amplitude at principal coastal locations (Fig.1) are retrieved from the database according to the determined hypocenter and magnitude, and an Advisory including the above-mentioned information is issued.

Using high-quality seismic data for accurate forecasts

Though the numerical simulation technique has enabled a prediction with a high spatial and amplitude resolution, eventual forecast accuracy greatly depends on hypocenter and magnitude determination accuracy. That means that the acquisition of stable high-quality seismic data is a prerequisite for ensuring high forecast accuracy. While the JMA was able to use such high-quality seismic data from its domestic network along with those of LISS and IRIS, it also recognized the importance of obtaining additional high-quality data to complement those data for overseas locations.

The Preparatory Commission for the Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO) is tasked to set up the International Monitoring System (IMS), which is a network comprised of 321 stations to monitor the globe for any sign of a nuclear explosion. Included in this network are 170 seismic stations (50 primary stations and 120 auxiliary stations). Prior to 2004, there had been discussions about making use of the IMS seismic data for other purposes than the original aim of detecting nuclear explosions; the potential civil and scientific applications of the data generated even greater interest after the Indian Ocean tsunami disaster in December 2004. JMA therefore decided to conduct research on the effectiveness and

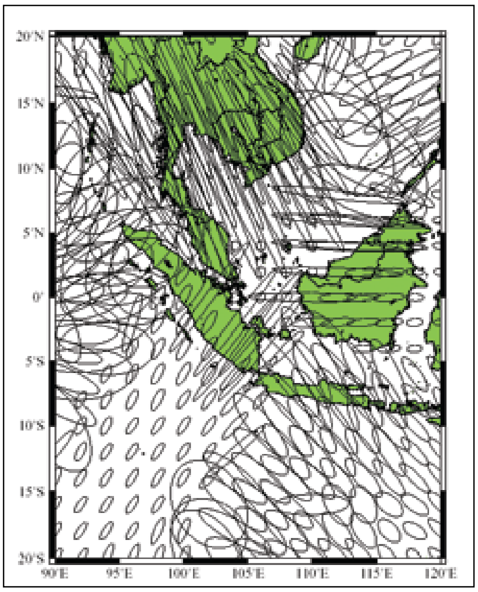


FIG.2 HORIZONTAL ERRORS OF ESTIMATING EARTHQUAKE LOCATION USING ONLY LISS AND IRIS DATA.

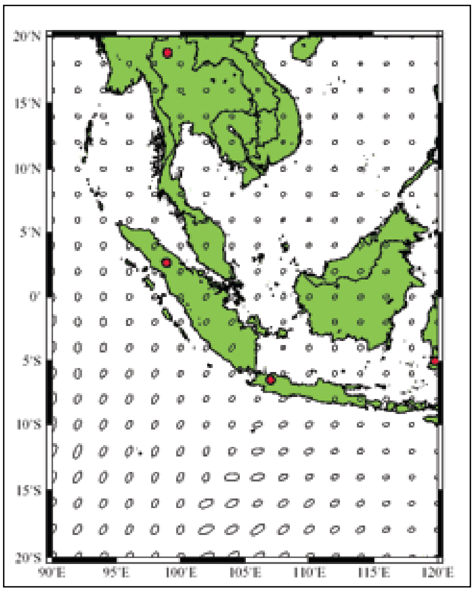


FIG.3 HORIZONTAL ERRORS OF ESTIMATING EARTHQUAKE LOCATION USING IMS DATA (RED CIRCLES) IN ADDITION TO LISS AND IRIS DATA.

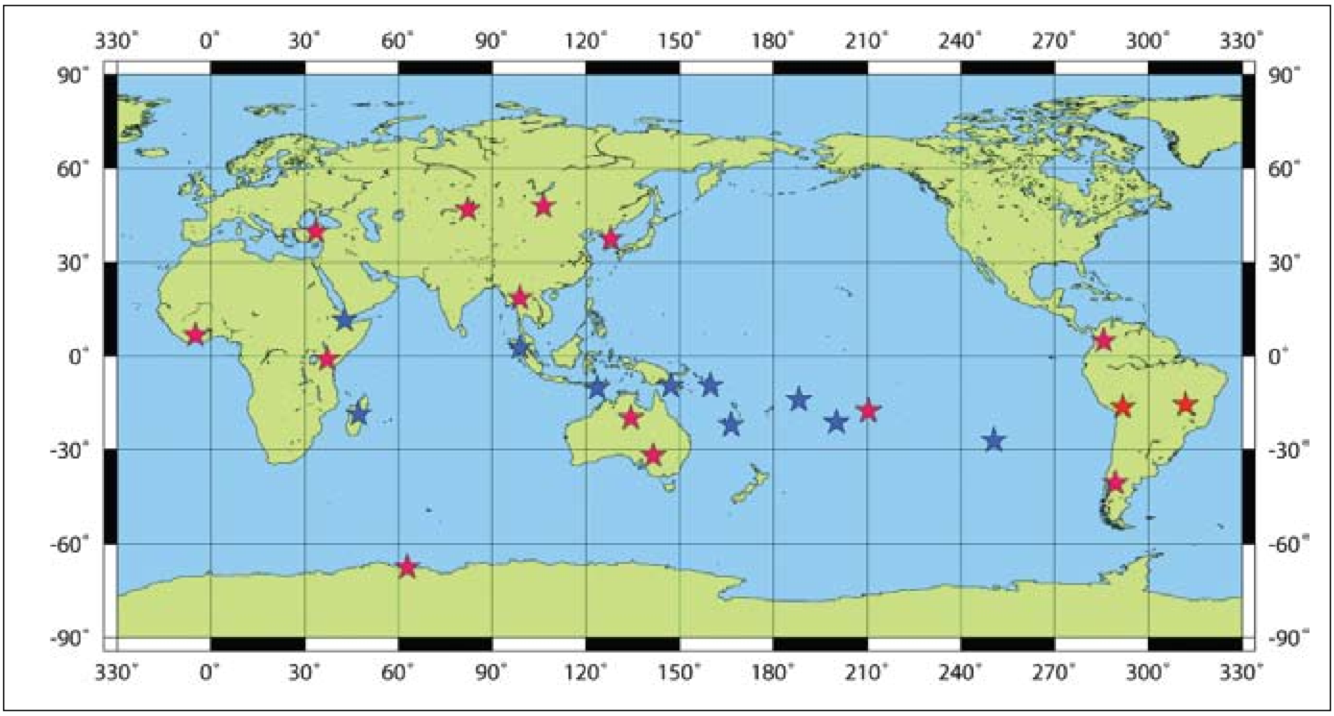


FIG.4 CTBT/IMS SEISMIC OBSERVATION STATIONS USED BY JMA : RED STARS: PRIMARY SEISMIC STATION (15 STATIONS) BLUE STARS: AUXILIARY SEISMIC STATION (10 STATIONS)

transmission reliability of IMS seismic data for tsunami warning services.

Figures 2 and 3 show horizontal error ellipses for earthquake locations around Sumatra, Indonesia. Fig2 shows the situation when only using LISS and IRIS data, while Fig.3 shows the case when using IMS data in addition to LISS and IRIS data. Error ellipses in Fig.2 are quite large and some of them extend to both land areas and the ocean. In this case we cannot even distinguish between an inland earthquake and one that occurred in an ocean region, which is inappropriate for the purpose of issuing of tsunami warnings. On the other hand, error ellipses in Fig.3 are considerably smaller, so that we can acquire a precise earthquake location. In regard to data latency and transmission reliability, research by the JMA indicated that IMS seismic data have advantages over data sources currently available through the Internet.

Tsunami warning arrangement signed with the CTBTO

After IMS seismic data availability had been verified by the research mentioned above and through subsequent meetings between the CTBTO and UNESCO/IOC, an agreement was reached whereby the CTBTO would provide its seismic data for tsunami warning centres with the formal approval of UNESCO/IOC. In August 2008, the signing of the Tsunami Warning Arrangement took place in Vienna between Ambassador Yukiya Amano, the Permanent Representative of Japan to the International Organizations in Vienna, and Ambassador Tibor Tóth, Executive Secretary of the CTBTO. This arrangement was the first of its kind and of great significance, allowing Japan to receive data from the CTBTO for its Tsunami Warning Service. At present, JMA receives data from the observation stations shown in Fig.4.

As mentioned above, IMS seismic data have great potential to contribute to the Tsunami Warning Service. The JMA highly appreciates the fact that the CTBTO, together with its Member States, decided to provide its seismic data to mitigate the loss of life caused by tsunami disasters in the world, and we would like to express our sincere gratitude to them. The JMA hopes that further cooperation and coordination be enhanced between CTBTO, UNESCO/IOC and relevant tsunami warning organizations of any region and country in the world to save lives from future tsunami disasters. ■

Biographical note

Yohei Hasegawa has been the Senior Coordinator for International Earthquake and Tsunami Information of the Earthquake and Tsunami Observation Division, Seismological and Volcanological Department of the Japan Meteorological Agency (JMA) since 2007. He has also served as a Vice-Chair of the Intergovernmental Coordination Group for the Pacific Tsunami Warning and Mitigation System (ICG/PTWS) since 2007. ■

Editor-in-Chief:
Annika Thunborg, Spokesperson, Chief of Public Information

Prepared, coordinated and edited by: Denise Brettschneider

CTBTO staff contributors:
Ola Dahlman, Luis Gain, Jeff Given, Kirsten Haupt, Dina Ismail, Zachary Johnson, Alexander Kmentt, Thomas Muetzelburg, Dasanti Wimalaratne

Layout and design: Todd Vincent

Distribution: Christian Evertz

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Public Information
Preparatory Commission for the Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO)

Vienna International Centre
P.O. Box 1200
1400 Vienna, Austria
T +43 1 26030 6200
F +43 1 26030 5823
E info@ctbto.org
I www.ctbto.org

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