CHAPTER 1

SETTING THE POLITICAL STAGE

1.1 Introduction

Calls for the cessation of nuclear testing can be traced back to the beginning of the nuclear age. Over the years a number of attempts to negotiate an end to testing failed, usually because of an inability to agree on verification provisions, in particular on-site inspections. However, in 1963, the United States, United Kingdom, and Soviet Union negotiated the Treaty Banning Nuclear Weapon Tests in the Atmosphere, Outer Space and Under Water, known as the Partial Test Ban Treaty (PTBT), a precursor to the Comprehensive Nuclear-Test-Ban Treaty (CTBT). Because underground testing was excluded from the ban, on-site inspections were not called for. However, the PTBT did include in its Preamble and Article I a commitment to negotiate "the permanent banning of all nuclear test explosions" (PTBT 1963). In 1974 the United States and the Soviet Union signed the Threshold Test Ban Treaty (TTBT), which prohibited tests having a yield exceeding a threshold of 150 kilotons (equivalent to 150,000 tons of TNT). Although the treaty did not enter into force until the two countries completed a verification protocol in 1990, both parties to the TTBT also undertook an obligation in the Preamble and Article I to continue negotiations toward the cessation of all underground nuclear weapon tests (TTBT 1974/1990).

Following negotiations at the Conference on Disarmament (CD) in Geneva from 1994 to 1996 (Figure 1.1), the United Nations General

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Fig. 1.1 The Council Chamber of the Palais des Nations, venue for the League of Nations; the 1955 Four Power Conference on the reunification of Germany; and negotiations of the NPT, the Chemical Weapons Convention, and the CTBT.

Assembly adopted the CTBT (CTBT 1996) in September 1996 by a vote of 158 to 3 (Bhutan, India, and Libya), with five abstentions (Cuba, Lebanon, Mauritius, Syria, and Tanzania) (UN 1996). Since the conclusion of the negotiations (Figure 1.2), there has been a moratorium on nuclear testing among the five nuclear weapon states recognized by the Treaty on the Non-Proliferation of Nuclear Weapons (NPT). The five include China, France, the Russian Federation, the United Kingdom and the United States. India and Pakistan both conducted a number of nuclear weapon tests in May 1998, and the Democratic People's Republic of Korea (DPRK) conducted two nuclear weapon tests, in 2006 and 2009. Following the tests by those three countries, the United Nations Security Council unanimously adopted resolutions condemning them. In the case of the DPRK, the Council acted under Chapter VII of the UN Charter and imposed a range of strict sanctions in both instances (UNSC 2006, UNSC 2009a). In the case of India and Pakistan, the resolution (UNSC 1998) led to sanctions by the United States, and 14 countries suspended bilateral aid programs to both countries.

Why is a ban on nuclear testing desirable? While a country could develop a basic bomb like the one used in Hiroshima without testing, and the nuclear weapon states sustain their weapon arsenals by means other than testing, a treaty such as the CTBT makes it difficult for a state to develop advanced nuclear weapons (Perry and Scowcroft 2009). This impedes a nuclear arms race and is seen as a measure to strengthen the NPT, which calls for nuclear disarmament in Article VI. The Preamble of the CTBT also notes that the treaty could contribute to the protection of the environment.

As of June 2011, 153 countries have ratified the CTBT, including each of the European Union (EU) countries, three of the five recognized nuclear weapon states, and 82 of the 118 members of the Non-Aligned Movement (NAM); all but seven of the 114 signatories of the nuclear-weapon-free zone treaties have signed the CTBT. Yet nine more countries specified in the treaty must ratify the CTBT for it to enter into force, as will be discussed below: China, the DPRK, Egypt, India, Indonesia, Iran, Israel, Pakistan, and the United States (Mackby 2011).

1.2 Provisions of the CTBT

The basic obligations of the CTBT are contained in Article I of the treaty:

1. Each State Party undertakes not to carry out any nuclear weapon test explosion or any other nuclear explosion, and to prohibit and prevent any such nuclear explosion at any place under its jurisdiction or control.

2. Each State Party undertakes, furthermore, to refrain from causing, encouraging, or in any way participating in the carrying out of any nuclear weapon test explosion or any other nuclear explosion.

The treaty provides for the establishment of a Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO) in Vienna to implement the treaty's provisions and support countries in their efforts to verify compliance with the treaty. The CTBTO will include a Conference of the States Parties, the principal decision-making organ, which will meet annually, and an Executive Council to promote implementation of and compliance with

Fig. 1.2 Between meetings of the negotiations of the CTBT in 1996 (left to right): Ambassador Munir Akram of Pakistan and Ambassador Sha Zukang of China; Indian Ambassador Arundhati Ghose and U.S. Ambassador Stephen Ledogar.

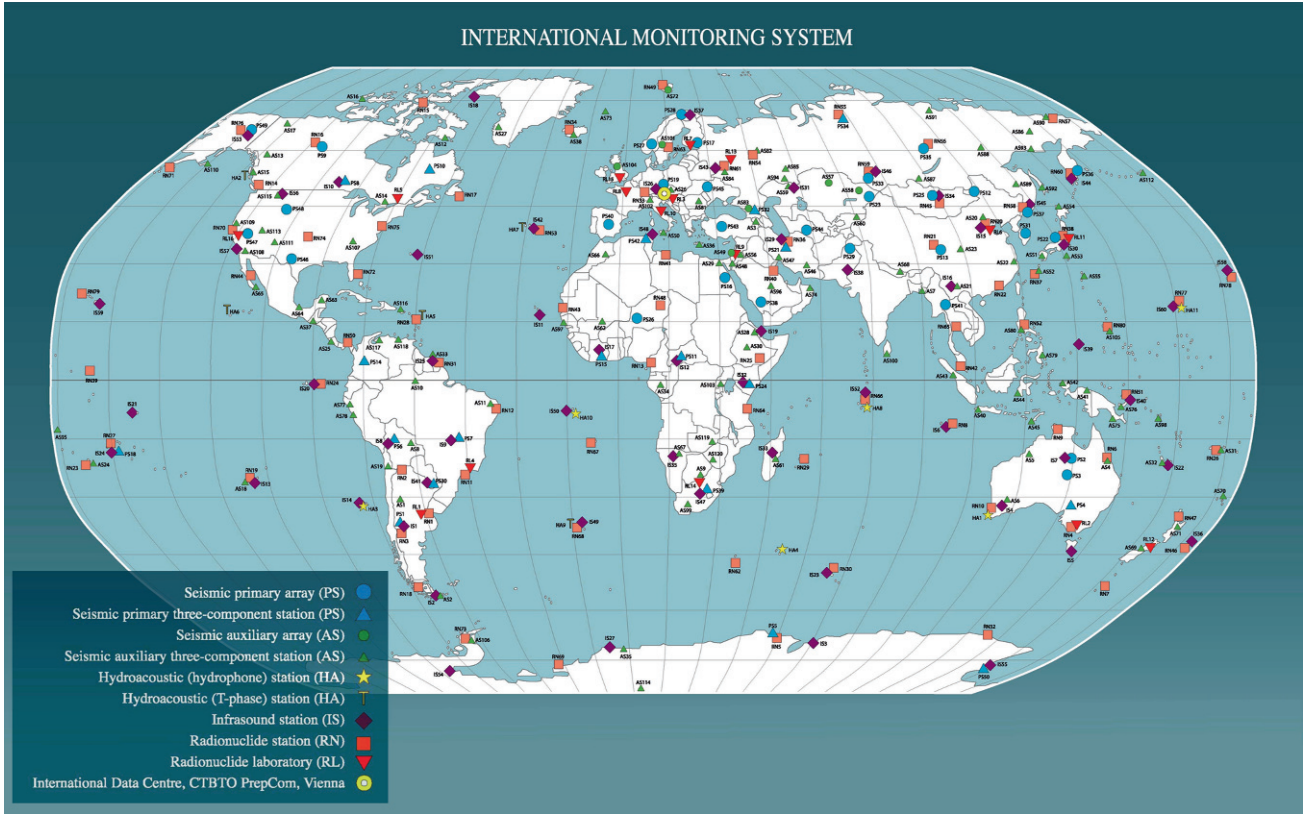

Fig. 1.3 The 321 seismic, radionuclide, hydroacoustic, and infrasound stations of the International Monitoring System are distributed around the globe. In addition, 16 radionuclide laboratories analyze the samples of particular interest.

the treaty, including approving requests for on-site inspections (OSI). A Technical Secretariat will assist the states parties, the Conference, and the Executive Council in the implementation of the treaty, in particular in regard to the verification regime. A Preparatory Commission (PrepCom) for the CTBTO with a Provisional Technical Secretariat (PTS) was established in 1997 to carry out the necessary preparations to implement the operation of the treaty's verification regime. The aim is to make a seamless transition to the CTBTO upon entry into force.

The verification provisions of the CTBT are more far-reaching than those of other treaties. The CTBT provides for an International Monitoring System (IMS)—comprised of 337 high-quality stations and laboratories in 89 countries—to monitor for compliance (Figure 1.3). The IMS includes 50 primary and 120 auxiliary seismological stations to detect seismic events. The IMS radionuclide network is the first global network, comprising 80 radionuclide stations, 40 of which will be capable of detecting noble gases upon entry into force of the treaty; 16 radionuclide laboratories analyze samples of filters from the stations. In addition, a unique network of 60 infrasound stations are designed to detect nuclear explosions conducted

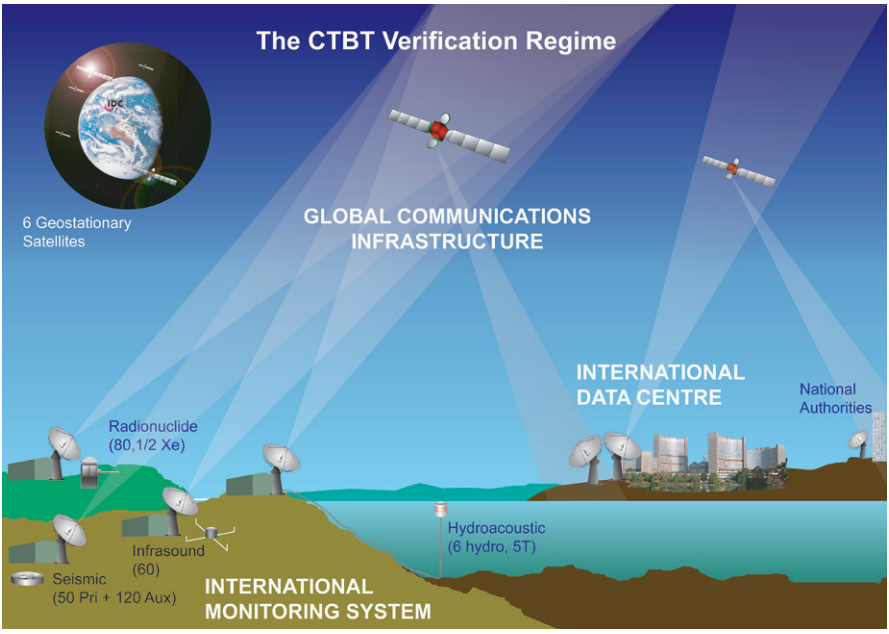

Fig. 1.4 A schematic depiction of CTBT monitoring illustrates sensors of the International Monitoring System providing data via a global communications infrastructure to the International Data Center (IDC) in Vienna. The IDC then transmits results of its analysis to the national authorities.

in the atmosphere, and 11 hydroacoustic stations are to detect such explosions in the oceans (Figure 1.4).

The IMS stations are to be certified according to specifications agreed upon by the PrepCom. More than 85 percent of the IMS stations have been installed, and almost 80 percent were certified by the end of 2010. Under the treaty, data from these stations of the IMS are transmitted in real time via a global communications infrastructure to an International Data Center (IDC) in Vienna, and the data from the individual stations are authenticated to ensure they are not manipulated. The IDC is to receive, process, and analyze the data in a standardized way to produce bulletins containing information about, *inter alia*, the origin time, location, and strength of detected events. These bulletins are then sent to states parties. The IDC has been operating and sending bulletins provisionally since September 1999. How countries can verify compliance with the treaty is more thoroughly examined in Chapters 2 through 7 of this book.

In addition to data provided by the IMS, countries are able to use data from thousands of other stations located around the world that are not part of the IMS. Countries can also use information from other technologies, such as satellites and other intelligence assets, as part of their national technical means of verification.

If there is a concern about possible non-compliance with the treaty, countries may first request a process of consultation and clarification, in which the Director-General and the Executive Council are to assist by providing relevant information. In addition, countries will be able to request an OSI to clarify if a nuclear weapon test explosion was carried out. Such a request would be based on information from the IMS or derive from national technical means of verification. The area of an OSI will not exceed 1,000 square kilometers, and the duration will not exceed 60 days, unless the Executive Council authorizes an extension of a maximum of 70 more days. The decision to conduct an OSI will require at least 30 affirmative votes of the 51 members of the Executive Council. These and other issues regarding OSI are further examined in Chapter 5.

In respect to verification, the CTBT stands in contrast to a number of other international treaties that control the spread of weapons of mass destruction (WMDs) and contain limited or no provisions for verification. This is true for the PTBT, considered the predecessor of the CTBT, which prohibited the testing of nuclear weapons in all environments except underground (Figure 1.5). Efforts to develop a verification protocol for the Biological Weapons Convention (BWC 1972) were rejected in 2001 after six years of negotiations (Bolton 2002, Findlay 2006). Other agreements, including the Antarctic Treaty (of 1959), the Outer Space Treaty (of 1967), and the Seabed Treaty (of 1971) denuclearize and demilitarize specific

Fig. 1.5 President John F. Kennedy signs the Partial Test Ban Treaty in 1963, flanked by Vice President Lyndon B. Johnson, Secretary of State Dean Rusk, and U.S. senators.

areas of the globe as well as outer space, but do not include provisions for verification, although the Antarctic Treaty contains provisions for inspections without an administrative institution to implement them. The five treaties establishing nuclear-weapon-free zones in Latin America, the South Pacific, South East Asia, Africa, and Central Asia contain no specific provisions regarding verification beyond the safeguards put in place by the International Atomic Energy Agency (IAEA), though they prohibit the testing of nuclear weapons.

The NPT includes a provision for safeguards in an agreement between each non-nuclear state party and the IAEA. An Additional Protocol, which grants the Agency broader information and access rights, has been adopted by more than 100 countries (IAEA 2011). If routine inspections are not sufficient, the IAEA may request a special inspection; however, this has rarely been exercised, as examined in Chapter 5. Verification of the Chemical Weapons Convention (CWC), which entered into force in 1997, relies primarily on routine on-site inspections. The right to request a challenge inspection of a state party has never been exercised under the CWC.

A number of treaties between the United States and the Soviet Union or the Russian Federation have extensive verification provisions. The TTBT, which entered into force in 1990, the Intermediate-Range Nuclear Forces Treaty (INF), which entered into force in 1988, the Strategic Arms Reduction Treaty (START), which entered into force in 1994, and New START, which entered into force in 2011, include detailed inspection and counting provisions. However, the Strategic Offensive Reductions Treaty (also known as the Moscow Treaty), which entered into force in 2003, contains no specific verification provisions.

1.2.1 Preparatory Commission Phase

The CTBTO PrepCom is meant to be a temporary organization that will present a final report on the operational readiness of the regime to the first session of the Conference of the States Parties upon entry into force of the CTBT. The PrepCom is to carry out the progressive commissioning, technical testing, and provisional operation of the IMS and IDC; assure support of certified laboratories and means of communications; prepare for the conduct of OSIs; and, if requested by States Signatories, provide legal and technical advice to facilitate ratification. It is also entrusted with the development of operational manuals for the seismological, radionuclide, hydroacoustic, and infrasound monitoring, as well as manuals for the operation of the IDC and the carrying out of OSIs; these manuals are to be adopted by the first session of the Conference of the States Parties. The PrepCom thus oversees the implementation of the verification regime, adopts an annual program and budget, and has developed administrative and financial regulations.

As noted, the PrepCom established a PTS and appointed an Executive Secretary to assist with its activities at the Vienna International Center in Vienna, where states members meet twice a year. There members consider questions in two Working Groups, one related to legal and administrative matters (Working Group A) and the other to establishing the verification regime (Working Group B), which meet in extended sessions to determine working plans and consider the progress made toward implementation of the treaty. The Working Groups' recommendations, once approved by the PrepCom, delegate responsibilities to the PTS. The PTS provisionally operates the IMS and the IDC, maintains a global communications infrastructure, assists states members with the installation and operation of monitoring facilities, and reports back to the PrepCom on its progress in implementing the verification regime.

Pursuant to Article XIV of the CTBT, a biannual conference (called the Article XIV Conference) has been held since 1999 to consider measures that countries can undertake to accelerate the ratification process and the treaty's entry into force. Because of the difficulties involved in ratification in certain countries, the CTBT has taken longer than anticipated to enter into force, and the PrepCom has been in existence longer than expected. The capabilities of the verification regime and issues related to sustaining it until entry into force are examined in greater detail in the rest of this book.

1.2.2 Entry into Force

To enter into force, the CTBT requires the ratification of 44 specific countries. The 44 include those which participated in the negotiations in the CD and which had nuclear power and research reactors in 1996, as listed in Annex 2 of the CTBT (Figure 1.6). Of the nine previously mentioned countries that are still required to ratify before the treaty will enter into force, all but three have signed the CTBT: the DPRK, India, and Pakistan.

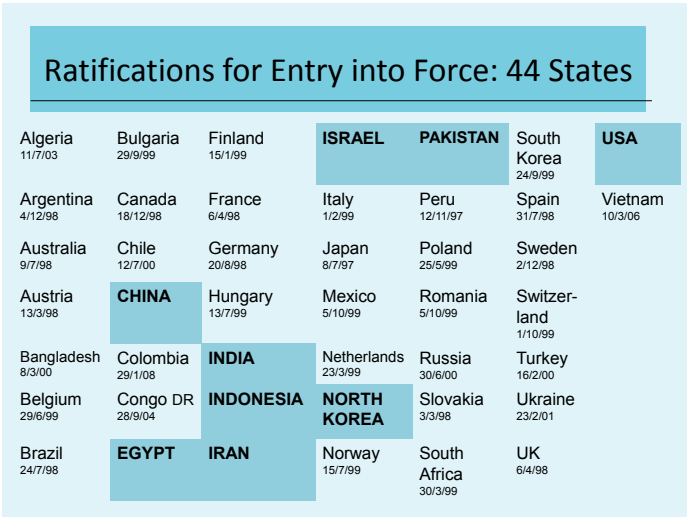

Fig. 1.6 Ratifications required for entry into force of the CTBT, pursuant to Article XIV.

China

China signed the CTBT the day it opened for signature in September 1996. The treaty has been in the National People's Congress for the process of ratification since 2000. Although China has not yet ratified the treaty, the representative said at the UN General Assembly in 2008, "China commits itself to the early ratification of the CTBT. ... Before the entry into force of the CTBT, China will honor its commitment of moratorium on nuclear test[ing]" (Kang 2008). China has expressed its desire for early entry into force at numerous international conferences, including the 2010 NPT Review Conference (Li 2010). When Chinese President Hu Jintao met U.S. President Barack Obama in Washington in January 2011, they issued a Joint Statement in which "both sides support early entry into force of the CTBT" and they agreed to work together to reach this goal (Joint Statement 2011).

China contributed actively to the negotiations in Geneva and has also been participating in the work of the PrepCom. It has been especially engaged in the efforts on OSI, on mobile noble gas detectors and the preparation of procedures to guide inspectors.

Democratic People's Republic of Korea (DPRK)

Although the DPRK (North Korea) is considered an isolated country, the delegation at the CD participated in the negotiations on the treaty. The country's representatives also voted yes on the United Nations resolution that adopted it; however, it did not sign the treaty. After withdrawing from the NPT in 2003, the DPRK conducted a nuclear weapon test in 2006 and again in 2009. It is under sanctions for violating UN resolutions on its nuclear activities. In November 2010 North Korea showed a new modern uranium enrichment facility to U.S. scientific experts, resulting in further debate about its nuclear activities. The DPRK has not spoken officially about the CTBT for a number of years. The six-party talks (involving the DPRK, South Korea, China, the United States, Russia, and Japan) could possibly become a venue where the issue of CTBT ratification might be discussed; however, these talks have not taken place for several years.

Egypt

Egypt was also active in the CTBT negotiations; one of its representatives served as Chair of the Working Group on legal issues and Friend of the Chair on the Preamble and Review of the Treaty. The country plays a key role in the Middle East as well as among the NAM, which it chairs from 2009 to 2012. It has steadfastly contended that it has been in good standing with the NPT and will not support further arms control agreements, including the CTBT, the Chemical Weapons Convention, the African Nuclear-Weapon-Free Zone Treaty, or the IAEA Additional Protocol until Israel ratifies the NPT. This condition is meant to address what Egypt sees as the regional considerations associated with the Middle East and the universal adherence to related treaties, commencing with the NPT (Mubarak 2001). The decision made in 1995 to indefinitely extend the NPT included a provision to establish a Middle East zone free of nuclear weapons and other weapons of mass destruction, as well as to conclude the negotiations on the CTBT.

Egypt stated at the 2009 Article XIV Conference to Facilitate Entry into Force of the CTBT that the decision about ratification of the CTBT would be linked to the positive outcome of the May 2010 NPT Review Conference, particularly regarding the issue of a zone in the Middle East. The 2010 NPT Review Conference decided that a conference should be held in 2012 on a

Middle East zone free of nuclear weapons and all other weapons of mass destruction, and, in Egypt's view, a certain amount will depend on what can be achieved there. However, it remains to be seen whether uprisings in the Middle East in the spring of 2011 will have an impact on the 2012 Conference.

On a regional level, if progress is made toward establishing a zone free of weapons of mass destruction in the Middle East, Egypt, Israel, and Iran may look at ratification of the CTBT in a different light. In addition, the DPRK, Egypt, India, Indonesia, Iran, and Pakistan are all members of the NAM, which stressed achieving universal adherence to the CTBT at its 2009 summit (NAM 2009).

India

India holds a historic role on the issue of nuclear testing, as Prime Minister Jawaharlal Nehru called for a nuclear test ban as early as 1954 (Figure 1.7). In 1978 India took the initiative at the 33rd session of the UN General Assembly to secure a resolution calling upon all states, in particular all nuclear weapon states, to refrain from testing, pending the conclusion of a comprehensive test ban treaty.

Although India has not joined the NPT, it did sign the PTBT. The country's representatives actively participated in the negotiations on the CTBT in Geneva, serving as Friend of the Chair on seismic techniques and on the future organization to implement the treaty. One of the aspirations of India was to include in the treaty a time-bound framework for nuclear disarmament, and this was not forthcoming. In addition, when the negotiators placed India on the list of those required for entry into force, the Indian ambassador said that the country would not accept any language in the treaty that would affect its sovereign right to decide, in the light of its supreme national interest, whether it should accede to a treaty.

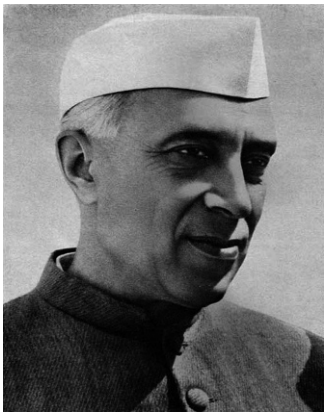

Fig. 1.7 Prime Minister Jawaharlal Nehru of India first called for the end to nuclear testing in 1954.

India would not sign "not now, not ever" (Frontline 2009). In June 1996 it also removed its four monitoring stations (primary and auxiliary seismic, radionuclide, and infrasound) from the list of the IMS in the protocol to the treaty. As a result, there are four monitoring stations currently listed in the protocol as "To be determined." India continued to attend the negotiations but did not join consensus on the treaty in the CD.

Since the nuclear weapon tests of India and Pakistan in 1998 they have been observing a moratorium. Prime Minister Atal Behari Vajpayee told the UN General Assembly in October 1999 that India "would not stand in the way" of the treaty coming into force. This sentiment was echoed a decade later, in December 2009, by Prime Minister Manmohan Singh when he told visiting Japanese President Yukio Hatoyama that if the United States and China ratify the CTBT it "would create a new situation" (Singh 2009). The joint statement from Prime Minister Singh and President George W. Bush issued at the beginning of the India civil nuclear cooperation agreement process on 18 July 2005 included a commitment from India to continue its unilateral moratorium on nuclear testing. This is a condition of the United States for full cooperation. However, in a subsequent response to domestic queries, Singh stated that India had the sovereign right to test (Gill 2009).

Indonesia

Indonesia, speaking in 2009 on behalf of the NAM at the third session of the 2010 NPT Preparatory Committee, said, "We support the objective of the CTBT, which is intended to enforce a comprehensive ban on all forms of nuclear tests without exception and to stop the development of nuclear weapons, in the direction of the total elimination of nuclear weapons" (Indonesia 2009). Indonesia said in June 2009 that it would ratify the CTBT right after the United States; however, it announced at the NPT Review Conference on 3 May 2010 that it was proceeding to initiate the process of ratification. Foreign Minister R.M. Marty M. Natalegawa stated that Indonesia shared the vision of a world free of nuclear weapons and expressed the hope that "this further demonstration of our commitment to the nuclear disarmament and nonproliferation agenda will encourage other countries that have not ratified to do so" (Natalegawa 2010).

Subsequently, the foreign minister said that Indonesia was planning to play a more central role in nuclear disarmament and expected to ratify the CTBT in 2011. "God willing, Indonesia will complete the ratification process in 2011 and encourage various parties to support the implementation of the CTBT," he said (Natalegawa 2011). As a state party to the Treaty on the Southeast Asia Nuclear-Weapon-Free Zone, Indonesia has undertaken under Article 3 not to test or use nuclear weapons.

Iran

Iran participated very actively in the negotiations on the CTBT, serving as Friend of the Chair on on-site inspections report writing, follow-up action, and sanctions. Although it did not join the final consensus on the treaty in the CD, it signed the treaty on the first day it opened for signature at the United Nations. Iran voted in favor of the CTBT resolution at the 2009 General Assembly, and the country has been a strong advocate of the treaty in the PrepCom. Given the contentious situation in the UN Security Council and the IAEA surrounding Iran's nuclear activities, Iran has not voiced its views on CTBT ratification. In 2012 Iran will become the next chair of the NAM, which has voiced its support of the CTBT on a number of occasions.

Israel

Israel has been actively engaged in both the negotiations and the PrepCom in Vienna. As an Observer in the CD negotiations, it was not allowed to break consensus, but it could contribute papers and thereby make its contributions felt in the treaty, in particular on the issue of OSI. Israel's considerations for ratification have been expressed on a number of occasions and include the non-abusive nature of the on-site inspection regime; equal status in the policy-making organs of the organization, in particular the Executive Council; and adherence to the treaty by other Middle Eastern countries.

The treaty stipulates that the Executive Council will make the decision about whether an OSI will take place, and this body will be composed of six geographical regions, the composition of which is enumerated in the annex to the treaty. Israel is in the Middle East and South Asia regional group on the Executive Council. The equal status of Israel in the policy-making organs of the treaty was a strong requirement in the end game of the CTBT negotiations in 1996 and it remains so today. Due to the political situation in the area, countries in that group have been unable to meet, although this issue has been addressed in a number of conferences.

During the PrepCom phase, as during the negotiations, Israel has been especially interested in conditions for on-site inspections, indicating that it was concerned that a frivolous charge might lead to an OSI and might be used to gain access to sensitive information (Ramaker et al. 2003). This said, it was among the first to sign the treaty. In the deliberations in the PrepCom in Vienna it has also focused on the IMS and IDC build-up.

Pakistan

Pakistan was also actively involved in the CTBT negotiations. Like India, Pakistan wanted the goal of nuclear disarmament to be included in the treaty. It strongly endorsed provisions for entry into force that would include the eight nuclear-capable states, as did a number of others in the negotiations. As Ambassador Munir Akram said at the time, "To those who live in the real world, it is clear that if one of those states is out of the treaty, all of them will be out.… Those who sincerely desire an early entry into force with or without these eight states ignore fundamental strategic and political realities" (Ramaker et al. 2003). Contrary to India, Pakistan voted in favor of the CTBT at the United Nations. Not long thereafter, in May 1998, India carried out a number of nuclear weapon tests, and Pakistan followed suit.

After the 1998 tests of both countries, Prime Minister Nawaz Sharif told the UN General Assembly, "Pakistan has consistently supported the conclusion of a CTBT for over 30 years. ... There is no reason why the two countries cannot adhere to the CTBT. In a nuclearized South Asia, CTBT would have relevance if Pakistan and India are both parties to the Treaty" (Sharif 1998). Pakistan repeated at the United Nations in 2005 and 2007 that it would not sign the treaty unilaterally.

Nevertheless, since the U.S.-India civil nuclear deal, the linkage of actions by Pakistan to those of India may not be a foregone conclusion. "The conclusion of the U.S.-India nuclear agreement, which fails to extract any favorable commitment from India about its intentions towards the CTBT, has not created optimism in Islamabad about its prospects," said former Ambassador Shahbaz of the Permanent Observer Mission of Pakistan to the PrepCom. "The deal upset our threat perception by aggravating the imbalance in our capabilities" (Personal communication 2010).

Pakistan is following the developments regarding the prospects of the CTBT entry into force, and when it sees movement it will review its policy in the interest of regional peace and security, Shahbaz added. Pakistan is maintaining a unilateral moratorium on nuclear testing and has said that it will not be the first to resume testing. Since the establishment of the CTBTO PrepCom, Pakistan has attended a number of the meetings of the Working Group on Verification as an observer and participated as observer at the 1999, 2007, and 2009 Article XIV Conferences.

United States

When the treaty opened for signature at the United Nations in September 1996, President Bill Clinton was the first to sign it. However, when the U.S.

Senate declined to provide its advice and consent to ratification in 1999, the treaty lost a sense of urgency in the United States as well as in much of the international community. Subsequently, the George W. Bush administration stated its opposition to the treaty. In the following administration, President Barack Obama, in a benchmark speech in Prague in April 2009, called for the elimination of nuclear weapons and said that he would "immediately and aggressively" pursue U.S. ratification of the CTBT (Obama 2009).

An examination of the issues surrounding the ratification and entry into force of the CTBT revolves around a number of key questions, most of which are captured in the 2009 report of the Congressional Commission on the Strategic Posture of the United States, a bipartisan, congressionally appointed group chaired by former Secretary of Defense William J. Perry (Congressional Commission 2009). The CTBT is the only item on which the Commission did not reach a consensus view, and thus the arguments presented by both sides illustrate the debate in other circles, in particular the U.S. Senate, regarding the ratification of the treaty. For example, commissioners opposing the treaty believed that a CTBT would diminish the confidence in the reliability of the U.S. nuclear weapons stockpile, thereby reducing the credibility of America's nuclear deterrent. Proponents argue that the Stockpile Stewardship Program (SSP) has ensured that the United States can maintain a safe, secure, and reliable stockpile without testing. Opponents further believe that a zero-yield ban is unverifiable and that countries could conduct tests without being detected. Treaty supporters maintain that the CTBT is effectively verifiable and that potential violators could extract little, if any, military value from clandestine testing at levels that are undetectable. In this regard, the 2010 Department of State report on compliance with arms control agreements said that there were no indications during the reporting period, 2004–2008, that any of the NPT nuclear weapon states "engaged in activities inconsistent with its declared moratorium" (State Department 2010).

In spite of the lack of agreement on the CTBT, the Congressional Commission recommended a number of actions to prepare the way for a new Senate review of the CTBT, including securing agreement among the five nuclear weapon states recognized by the NPT on a definition of the activities that are banned and permitted under the treaty and defining a diplomatic strategy for securing entry into force. "Many of the members of the commission would strongly support the CTBT if there were clarification," Vice Chair James Schlesinger said (Grossman 2009). In another approach, former Los Alamos National Laboratory director Sigfried Hecker said, "The single most important reason to ratify the CTBT is to stop other countries from improving their arsenals. … [W]e gain substantially more from limiting other countries than we lose by giving up testing" (Weeks 2009).

As for concerns about the lifetime of nuclear stockpiles, a 2007 report by the JASON Group, a leading independent scientific advisory group established in 1960 to provide consulting services to the U.S. government on defense science and technology matters, states that "the primaries of most weapons system types in the stockpile have credible minimum lifetimes in excess of 100 years and that the intrinsic lifetime of Pu in the pits is greater than a century" (JASON 2007). The SSP, life extension programs (LEP), and computer simulations have extended the reliability of the weapons. The administrator of the National Nuclear Security Administration (NNSA), Tom D'Agostino, said, "The SSP over the past decade has provided improved scientific and analytic tools, including advanced supercomputer simulation and sophisticated experimental capabilities, which were not available to the previous generation of designers/engineers. ... We know more about the complex issues of nuclear weapons performance today than we ever did during the period of nuclear testing" (D'Agostino 2008).

A technical analysis of the treaty by the U.S. National Academy of Sciences in 2002 stated, "The worst-case scenario under a no-CTBT regime poses far bigger threats to U.S. security interests-sophisticated nuclear weapons in the hands of many more adversaries-than the worst-case scenario of clandestine testing in a CTBT regime, within the constraints posed by the monitoring system" (NAS 2002a). The Department of State, the NNSA, and the National Academy of Sciences sponsored a project (NAS 2010) to review and update the 2002 report on technical issues related to the treaty, to be published in 2011.

More recently, on 6 April 2010, the United States released the third Nuclear Posture Review, a comprehensive review of U.S. nuclear weapons strategy and policy for the next five to 10 years. As regards the CTBT, the review stated that ratification of the CTBT "is central to leading other nuclear weapons states toward a world of diminished reliance on nuclear weapons, reduced nuclear competition and eventual nuclear disarmament" (DOD 2010a).

Precedents

It is worth noting that there are precedents for late arrivals in the arms control arena. The landmark nuclear arms control treaty, the NPT, did not obtain the ratification of certain key countries, most notably China and France, until 1992, more than 20 years after it opened for signature and well after most other countries had ratified. This is significant because the central NPT tenet not to transfer nuclear weapons is directed at the five acknowledged nuclear weapon states, which include China and France. Neither China nor France participated in the NPT negotiations. The same

two countries did not join the PTBT of 1963 (China became a nuclear weapon state in 1964). Yet both countries were among the first to sign the CTBT, and France ratified it in April 1998. The NPT entered into force in 1970, upon ratification of 40 countries in addition to the depositories—the United States, United Kingdom, and Soviet Union. Although the TTBT was signed in 1974, it did not enter into force until 1990, following additional negotiations on the verification protocol. As noted, all of the nine countries that still need to ratify the CTBT for it to enter into force participated actively in the negotiations. With a moratorium on nuclear testing among the five for more than 14 years, and the subsequent moratorium by India and Pakistan, there is an established norm of non-testing in effect, with the exception of the DPRK.

1.2.3 Scope — Zero Yield

In the negotiations on the CTBT from 1994 to 1996, delegates recalled that in the NPT and the PTBT negotiations of the 1960s it was not possible to define a nuclear weapon test explosion. There are no definitions in those treaties, and this absence of definitions was not questioned over the years. As for the CTBT, there was concern that to define a nuclear weapon test in technical terms in a treaty could expose sensitive information and would ultimately prove unnecessary because it would take so much negotiating time and effort. The decision was made early in the negotiations in the Conference on Disarmament not to define nuclear weapon test explosion (Ramaker et al. 2003).

The lack of such a definition in the CTBT has become a contentious issue in the United States (Kyl 2009), although the U.S. State Department's article-by-article analysis of the treaty says, "The U.S. decided at the outset of negotiations that it was unnecessary, and probably would be problematic, to seek to include a definition in the Treaty text of a 'nuclear weapon test explosion or any other nuclear explosion' for the purpose of specifying in technical terms what is prohibited by the Treaty" (U.S. Government 1997).

During the negotiations, the five nuclear weapon states consulted often among themselves on the scope of the treaty. Although these consultations were shrouded in secrecy, the general parameters of the discussions became well known: desires ranged from allowing four pounds of nuclear yield to several hundred tons (Ramaker et al. 2003). However, they finally agreed that the language in Article I of the treaty should mean that no tests that produced a nuclear yield should be allowed to anyone under the treaty, i.e., there should be a zero yield. The five announced this decision to all 60 Members plus Observers sitting in the Conference on Disarmament

on different dates, as follows: France on 10 August 1995, the United States on 11 August 1995, the United Kingdom on 14 September 1995, the Russian Federation on 23 October 1995, and China on 21 March 1996 (Ramaker et al. 2003).

On 7 October 1999 Ambassador Stephen Ledogar, Chief U.S. negotiator for the CTBT, testified before the Senate Foreign Relations Committee that Russia and China had committed themselves to a zero-yield ban. He said that fact was "substantiated by the record of the negotiations at almost any level of technicality (and national security classification) that is desired and permitted. A ban should be a ban. The answer to this dilemma should be no threshold for anybody, i.e., zero means zero. … If what you did produced any yield whatsoever, it was not allowed. If it didn't, it was allowed" (U.S. Senate 1999). In the same hearing Secretary of State Madeleine Albright expressed the same view.

Russian negotiator in the Conference on Disarmament, Victor Slipchenko, recently suggested that ratification by the United States corresponds to Russia's interests. He said that it might be possible to confirm at a high level the official position from the ratification of the treaty in the State Duma in 2000 by Foreign Ministry official Yuri Kapralov that "in accordance with the CTBT, all test explosions of nuclear weapons are banned, including hydro-nuclear experiments, whatever the level of energy release" (Slipchenko 2009). Russian President Dmitry Medvedev noted that "Under the global ban on nuclear tests, we can only use computer-assisted simulations to ensure the reliability of Russia's nuclear deterrent" (Global Security Newswire 2009).

The chief negotiator of Australia, Ambassador Richard Starr, who played a leading role in the formulation of the language on scope, said, "I had no doubt whatsoever that what we were promoting meant zero yield, and we understood this was accepted by each of the nuclear weapon states when they announced their intention to adhere to this formula. Our work in Geneva was backed up by talks in the major capitals, including each of the nuclear weapon states" (Personal communication 2010).

Despite the clear political declaration by all five nuclear weapon countries, there has been a great deal of discussion about nuclear weapon–related experiments. It is important not to lose track of what the treaty does and does not prohibit. In simple terms, as one ambassador in the negotiations put it, "We're banning the bang, not the bomb." A number of experiments are carried out with the stated purpose of securing the safety and reliability of existing weapons and weapon designs. These subcritical, hydrodynamic and other experiments are discussed in Chapter 2.

1.3 Testing as Part of Nuclear Weapon Development

During a period spanning more than five decades, 2,052 nuclear explosions were carried out in the atmosphere, under ground, under water, and in outer space. Some 1,500 of these took place under ground. There are slight inconsistencies regarding the numbers of explosions reported in different publications, however, the overall picture is much the same. The United States and the former Soviet Union conducted most of them, with the United States conducting 1,030 tests and the Soviet Union 715. France conducted 210 tests, and the United Kingdom and China each carried out 45 tests. India announced it had conducted a nuclear explosion for peaceful purposes in 1974. In May 1998 it announced two tests involving five nuclear devices, and in the same month Pakistan announced that it had conducted two tests involving a total of six nuclear devices (a test may involve two or more nuclear devices detonated simultaneously).

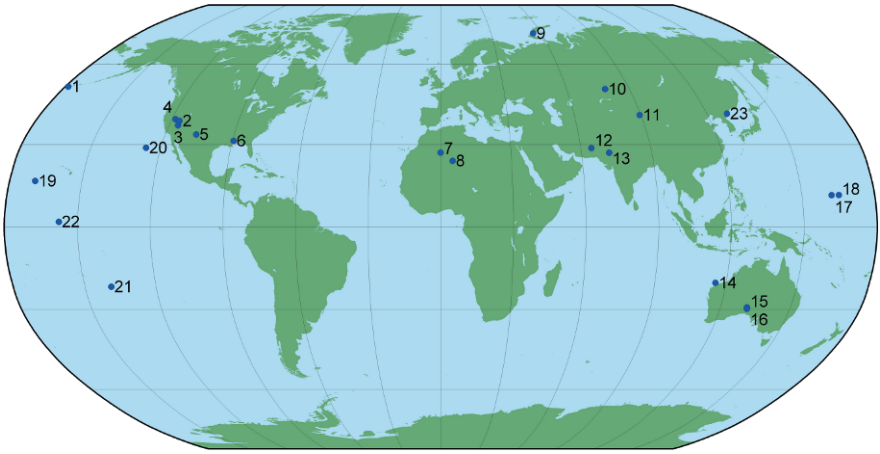

Fig. 1.8 Test sites of the world: 1. Amchitka Island, Alaska (U.S.), 2. Central Nevada Test Area (U.S.), 3. Nevada Test Site (U.S.), 4. Fallon, Nevada (U.S.), 5. Trinity Site, New Mexico (U.S.), 6. Hattiesburg, Mississippi (U.S.), 7. Reggan, Sahara Desert, Algeria (France), 8. In Ekker, Algeria (France), 9. Novya Zemlya (USSR), 10. Semipalatinsk (USSR), 11. Lop Nor, Western China (China), 12. Chagain Hills, Baluchistan (Pakistan), 13. Pokharan, Rajastan Desert (India), 14. Monte Bello Islands, Australia (UK), 15. Emu Field, Australia (UK), 16. Maralinga and Woomera Test Sites, Australia (UK), 17. Eniwetok Atoll, Marshall Islands (U.S.), 18. Bikini Atoll, Marshall Islands (U.S.), 19. Johnston Island (U.S.), 20. Eastern Pacific Ocean (U.S.), 21. CEP, Mururoa and Fangataufa Atolls, French Polynesia (France), 22. Christmas Island, Kiribati (U.K. and U.S.), 23. P'unggye (North Korea). The U.S. carried out three atmospheric tests in the South Atlantic Ocean (Operation Argus). The Soviet Union conducted peaceful nuclear explosions at more than 46 sites on its territory and the U.S. did so in five locations in the United States.

North Korea has announced two tests, and Israel is not believed to have tested (Dahlman et al. 2009). Some 517 nuclear tests were conducted in the atmosphere by the nuclear weapon states recognized under the NPT. The PTBT of 1963 prohibited nuclear weapon testing in the atmosphere, although, as mentioned, not all countries signed it. Nuclear weapon testing was conducted in more than 20 locations around the world (Figure 1.8).

Subsequently, tests were confined to sites in the United States, Soviet Union, China, and French Polynesia; India, Pakistan, and the DPRK tested within their territories. The purpose of most tests was to research and refine new nuclear weapons or to study weapons effects (DOE 2000). The non-nuclear components can be tested and replaced without detonating a warhead (Garwin 2011).

The Soviet Union and the United States carried out what are called peaceful nuclear explosions (PNEs) for various purposes: to create dams, stimulate oil and gas recovery, study the Earth's structure, and produce underground storage space, among others. From 1965 to 1988 the Soviet Union conducted 124 PNEs, some of which involved multiple devices, at more than 46 sites (Mikhailov 1996, Nordyke 2000). The United States conducted 27 such explosions, three of which involved multiple nuclear devices, from 1961 until 1973. All but four of these were conducted at the Nevada Test Site (renamed the Nevada National Security Site in 2010).

Since the Cold War, the number of nuclear warheads has been greatly reduced. In 1986, the Soviet Union held some 45,000 nuclear weapons and the United States had 24,400; as of 2011, the estimated numbers were 12,000 and 9,400, respectively (Kristensen 2010). In May 2010 the United States revealed the number of nuclear weapons it held available for use in war: 5,113 as of 30 September 2009 (DOD 2010b). The New START treaty signed by the United States and Russian Federation in Prague on 8 April 2010 limits their numbers of deployed warheads to 1,550 and deployed intercontinental ballistic missiles (ICBMs) and submarine launched ballistic missiles (SLBMs) to 700, with a combined limit of 800 deployed and non-deployed ICBM launchers, SLBM launchers, and heavy bombers equipped for nuclear armaments. They also declared their intention to follow this agreement with further reductions. France announced that it holds 300 operationally deployed warheads. The United Kingdom announced in its Strategic Defence and Security Review of October 2010 that it will reduce its stockpile of operationally deployed warheads from fewer than 160 to no more than 120 and the overall nuclear warhead stockpile from not more than 225 to not more than 180 by the mid-2020s (U.K. Government 2010). China has an estimated 240 warheads: about 175 active nuclear warheads and 65 warheads in reserve (Norris and Kristensen 2010). The nuclear arsenals of Israel, Pakistan, and India are unknown but

Fig. 1.9 About 50 B61 nuclear bombs stored under ground in the United States.

are estimated at about 80 each. North Korea is estimated to possess fewer than 10 nuclear devices. Figure 1.9 shows arsenals in underground storage.

1.4 Political Development

There has been significant political development and a number of activities on nuclear-related issues. As mentioned, in his Prague speech President Obama called for the elimination of nuclear weapons and said that he would "immediately and aggressively" pursue U.S. ratification of the CTBT. Subsequently, he presided over the UN Security Council Summit in September 2009 that unanimously adopted Resolution 1887, which covered a number of actions to strengthen the NPT (UNSC 2009b). The resolution calls on states to "refrain from conducting a nuclear test explosion and to sign and ratify the Comprehensive Nuclear-Test-Ban Treaty (CTBT), thereby bringing the treaty into force at an early date" (UNSC 2009c).

Also pursuant to the resolution, President Obama hosted a Global Nuclear Security Summit in April 2010 to focus on securing nuclear materials worldwide and combating nuclear terrorism. The summit brought together 49 world leaders—an unprecedented number—in Washington to spotlight the goal of securing all vulnerable nuclear material within four years and examine how to prevent terrorist groups from gaining nuclear materials. The danger that weapons-grade nuclear material and the technology needed to develop nuclear weapons may spread to terrorists and non-state actors has largely replaced the concerns of the Cold War. It is possible that terrorists could make a low-yield nuclear explosive device using weapons-grade or reactor-grade plutonium (NAS 2002b). Former Director-General of the IAEA Mohamed El Baradei reported in 2009, "We still have 200 cases of illicit trafficking of nuclear material a

year reported to us. ... Pretty soon you will have nine weapons states and probably another 10 or 20 virtual weapons states" (El Baradei 2009).

The possible confluence of terrorism, nuclear material, and upheavals in international security has made many question the relevance of nuclear weapons in today's security environment, and a new movement has evolved calling for the elimination of nuclear weapons. This was triggered by an op-ed in *The Wall Street Journal* in January 2007 by former U.S. Secretaries of State George Shultz and Henry Kissinger, former Secretary of Defense William Perry, and former Chairman of the Senate Armed Services Committee Sam Nunn. They called for eight urgent steps that would provide the basis for a world free of the nuclear threat. One of these was "to achieve ratification of the Comprehensive Test Ban Treaty, taking advantage of recent technical advances, and working to secure ratification by other key states" (Shultz et al. 2007).

This was followed a year later with another *Wall Street Journal* op-ed, in which the same senior statesmen noted the interest and support for urgent action generated around the world by their first article. They went on to call for bringing the CTBT into effect, which would strengthen the NPT (Shultz et al. 2008). This was followed by articles in *The Times* by former U.K. foreign and defense secretaries, in *Le Monde* by four French statesmen, and in the *Frankfurter Allgemeine Zeitung* by four German statesmen, as well as articles by senior statesmen of Australia, Belgium, Italy, Japan, the Netherlands, Norway, Poland, the Russian Federation, and South Korea, along with many organizations around the world associated with this movement (e.g., Nuclear Security Project 2010, Global Zero 2010). The CTBT figures prominently among most of these articles and organizations.

Countries may have a different perspective than the senior statesmen about the elimination of nuclear weapons. Under the NPT, states parties are committed to pursue nuclear disarmament, and at the NPT Review Conferences nuclear weapon states describe the activities that they have undertaken to reduce the size of their nuclear arsenals. Nevertheless, debate continues over the conditions under which the elimination of nuclear weapons will take place. As noted, President Obama endorsed the abolition of nuclear weapons, though he added, "This goal will not be achieved quickly—perhaps not in my lifetime" (Obama 2009). At the signing ceremony of the New START agreement (Figure 1.10), Russian President Dmitry Medvedev acknowledged about the two countries, "Yes, we have 90 percent of all the stockpiles which is the heritage of the Cold War legacy and we'll do all that we have agreed upon. ... [W]e do care about what is going on with nuclear arms in other countries of the world, and we can't imagine a situation when the Russian Federation and the

United States take efforts to disarm and the world would move towards a principled different direction away" (Medvedev 2010).

China, along with the United Kingdom and France, has indicated that when the two countries with the largest numbers of nuclear weapons reduce to their levels, it will join the debate. "China has consistently stood for the complete prohibition and thorough destruction of nuclear weapons," said the representative to the 2010 United Nations First Committee (PRC 2010). France has said that the common goal is to create the conditions that will make nuclear weapons ultimately unnecessary (France Diplomatie 2010). "Nuclear deterrence remains an essential concept of national security," stated the 2008 French White Paper. "The sole purpose of the nuclear deterrent is to prevent any State-originating aggression against the vital interests of the nation..." (French White Paper 2008). The 2010 Strategic Defence and Security Review of the U.K. said, "It is right that the United Kingdom should retain a credible, continuous and effective minimum nuclear deterrent for as long as the global security situation makes that necessary." It also said that as a party to the NPT, it remains committed to the long term goal of nuclear disarmament (U.K. Government 2010).

1.5 CTBT in the Context of Nuclear Non-Proliferation and Disarmament

The CTBT has been linked to the NPT since the latter was negotiated in 1968. The NPT is considered the cornerstone of the international non-proliferation regime and has 189 states parties, more than any other arms control treaty. Under the NPT, the non-nuclear weapon states are obliged not to acquire nuclear weapons, while the nuclear weapon states are obliged in Article VI to "pursue negotiations in good faith on effective measures relating to cessation of the nuclear arms race at an early date and to nuclear disarmament, and on a treaty on general and complete disarmament under strict and effective international control." The non-nuclear weapon states see the CTBT as a benchmark in that provision, a tangible goal that will constitute a good faith effort by the nuclear weapon states to work toward nuclear disarmament. The nuclear weapon states believe that the CTBT will contribute to non-proliferation. The CTBT notes both objectives in the Preamble, which says that the cessation of nuclear weapon test explosions, by constraining the development and qualitative improvement of nuclear weapons, "constitutes an effective measure of nuclear disarmament and non-proliferation."

As mentioned, at its 2009 summit, the NAM stressed the significance of universal adherence to the CTBT (NAM 2009). The CTBT has figured prominently in most Review Conferences of the NPT, and the absence of agreement on the CTBT was considered a prime reason for the failure of

the 1990 and 2005 Conferences to adopt a Final Document. The call for a CTBT also figured prominently in the 1995 decision to extend the NPT indefinitely. The five nuclear weapon states wrote a letter to the 1995 NPT Review Conference in which they pledged their support for the conclusion of the CTBT and, at the same time, called upon all states parties to the NPT to make the NPT permanent. "This will be crucial for the full realization of the goals set out in article VI," the letter said (NPT 1995).

The CTBT was included in the "13 Steps" to implement Article VI of the NPT encompassed in the final document of the 2000 Review Conference. The first step was the "urgency of signatures and ratifications, without delay and without conditions," to achieve the early entry into force of the CTBT.

The May 2010 Review Conference of the NPT heard more than 60 states parties note in their opening statements that the CTBT was key to non-proliferation. In the consensus final document the conference resolved that all nuclear weapon states "undertake to ratify the CTBT with all expediency," noting that this would have a positive effect on others, and that they should encourage Annex 2 countries in particular to ratify. The Final Document stated, "The Conference calls on all States to refrain from any action that would defeat the object and purpose of the Comprehensive Nuclear Test-Ban Treaty pending its entry into force" (NPT 2010).

Fig. 1.10 U.S. President Barack Obama and Russian President Dmitry Medvedev sign the New START treaty at Prague Castle on 8 April 2010. The treaty limits the number of nuclear warheads to 1,550 for each country.

CHAPTER 2

MONITORING UNDERGROUND NUCLEAR EXPLOSIONS

2.1 Underground Nuclear Explosions and Weapon-Related Experiments

The first underground nuclear tests were carried out in 1957 by the United States and the Soviet Union. As discussed in Chapter 1, in 1963 the Soviet Union, United Kingdom, and United States signed the Partial Test Ban Treaty (PTBT), which prohibited testing in the atmosphere, outer space, and under water, and since 1980 all nuclear explosions have been conducted under ground. Of the 2,052 nuclear explosions that have been carried out, 1,501 have been conducted under ground, though as noted in Chapter 1, there are minor divergences in the number of reported explosions. Most of the explosions involved the development and testing of nuclear weapons, although about 150 were part of programs for so-called peaceful nuclear explosions (PNEs) (Nordyke 2000).

2.1.1 Characteristics of an Underground Nuclear Explosion

Underground testing is a well-established technique, with the explosive device placed in either a tunnel or a shaft built into a hill or mountainside or in a wide and deep borehole drilled into the ground. Explosions have been conducted both in hard rock, such as that found at the former Soviet test site at Semipalatinsk, and in softer rock, such as that found at the

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Nevada Test Site (NTS) in the United States. An underground explosion creates a cavity the size of which is dependent on explosion yield, bedrock, and placement depth. A 1 kiloton explosion will form a melted cavity with a radius of 4 to 12 meters, depending on the structure and lithology (strength, compressibility, and sound speed) of the bedrock. The volume of the cavity increases in proportion to the energy release, or "yield," of the explosion. The cavity, which initially is well sealed by melted rock, is surrounded by crushed and cracked rock that extends to about 10 times the cavity radius (Hawkins and Wohletz 1996). In many cases the cavity collapses, and a chimney is formed with a height several times the cavity radius. The source effects are further discussed in relation to on-site inspections in Chapter 5.

Two main features of an underground explosion that are detectable at a distance are seismic signals and radionuclide gases, in particular xenon. In strength, the seismic signals are approximately proportional to the explosion yield. The strength of the signals also depends on the coupling of the shock wave to the surrounding bedrock, which in turn relates to the composition and the physical properties of the bedrock. Because of the melted rock in the walls of the cavity, radionuclide material is to a great degree trapped, if the cavity stays intact. If the cavity cracks or collapses, radioactive gases may leak out. Noble gases, like xenon, that do not easily react chemically with surrounding materials are more likely to escape from the cavity compared to other gases such as iodine. Leakages of noble gases have been observed from underground nuclear test sites in both the former Soviet Union and the United States (Dubasov 2010). A major leakage might occur if an unknown geological feature happens to be located close to the explosion, as in the case of the United States test Baneberry (Figure 2.1).

In addition to observing signals generated by the explosion, satellite measurements, either photographic or by radar, can be used to observe the extensive logistic activities prior to detonation that are associated with preparations for a nuclear test. Observations by satellite may also reveal effects on the Earth's surface above the explosion.

2.1.2 Nuclear Weapon–Related Experiments

As explained in Chapter 1, there has been a great deal of discussion about the fact that there is no definition of a "nuclear explosion" in the Comprehensive Nuclear-Test-Ban Treaty (CTBT). This discussion has also addressed what nuclear weapon–related experiments the treaty does and does not prohibit. Such experiments all relate to the "physics package" that contains the nuclear material. The many non-nuclear parts of a nuclear weapon, numbering 4,000 to 6,000 (Shalikashvili 2001), can be tested without the nuclear material. The three types of nuclear-related tests

Fig. 2.1 Underground nuclear explosion Baneberry, with a yield of 10 kilotons, conducted at the Nevada Test Site on 18 December 1970. The device was exploded at a depth of about 270 meters beneath the surface. The event released radioactivity into the atmosphere, resulting in a cloud of radioactive dust that reached an altitude of 3 kilometers.

discussed below aim at increasing the understanding of the behavior of nuclear material in an explosion process. Are these tests prohibited under the CTBT?

Subcritical experiments (SCE), which are conducted as part of the Stockpile Stewardship Program in the United States, Russia, and China, aim at studying the material properties and the equation of state of fissile material at high pressure. In an SCE, a small amount of fissile material is exposed to a strong shock wave generated by conventional explosives. The experiments are material-related and can be conducted in different ways using materials in a configuration with no resemblance to nuclear warheads (JASON 1997). From 1997 until 2006, 23 SCEs were reported in the United States (Medalia 2008). Two of those experiments were conducted jointly with the United Kingdom. The U.S. SCEs have all been conducted in a tunnel complex 300 meters underground at the Nevada Test Site (NTS). On 15 September 2010, the first subcritical experiment in a new U.S. series was conducted at the NTS. During a visit to the Russian test site at Novaya Zemlya on 28 June 2002, the Russian Defense Minister Sergey Ivanov announced that Russia intended to maintain that test site and continue conducting subcritical experiments at a rate of four to six

a year (NTI 2002). It has also been reported that China conducted four subcritical experiments at the Lop Nor test site in 2001 (Lewis 2009). As subcritical tests are designed not to release any fission energy, they are not banned under the CTBT.

The second type of nuclear weapon–related experiment is the hydrodynamic experiment, or test. This type of experiment also explores the behaviour of material under high pressure and high temperature. A mock-up of the nuclear part of a weapon, with the fissile material replaced by a non-fissile material possessing similar material properties, can be used. The detonating high explosive sends a strong shock wave through the non-fissile nuclear material, and its behaviour is studied (Global Security 2005). As hydrodynamic experiments do not involve any fissile material, they are not banned under the CTBT.

The third type of experiments, hydronuclear, involve fissile material that could result in a "very slight degree of super criticality" and the release of a small amount of fission energy (Thorn and Westervelt 1987). In 1960 and 1961, during the nuclear test moratorium, 35 such hydronuclear experiments were reported at Los Alamos and a smaller number at the NTS. The Los Alamos experiments released nuclear explosion yields ranging from less than a few grams to 100 grams of equivalent conventional explosives, compared to billions or trillions of grams or kilotons or megatons in nuclear weapons. The tests were conducted to address nuclear weapon safety issues and gain data on the behavior of the fissile materials involved. Reports indicate that hydronuclear experiments can address only a limited range of questions. A similar program of thermonuclear experiments with "no considerable nuclear energy release" was conducted by the Soviet Union at the Semipalatinsk test site from 1958 to 1989 (Mikhailov 1998). Under the CTBT, these hydronuclear and thermonuclear experiments are prohibited.

Thus there is agreement among the nuclear weapon states on these nuclear material–related tests; the CTBT does not prohibit subcritical tests in which no chain reaction occurs or hydrodynamic tests in which the fissile materials are replaced by non-fissile materials. The treaty does not allow hydronuclear tests.

2.2 Seismological Monitoring

Seismology is a well-established science on a global scale, and CTBT verification is only one of many applications. Seismological verification is a discipline in its own right that has been pursued for more than 50 years as part of the preparations for test ban negotiations. The Group of Scientific Experts of the Conference on Disarmament (CD) in Geneva developed