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## NUCLEAR TESTING AND PROLIFERATION – AN INEXTRICABLE CONNECTION

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*To achieve a global ban on nuclear testing, my Administration will immediately and aggressively pursue US 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, Prague, Czech Republic, 5 April, 2009.

*I will begin working to build the necessary bipartisan support for US ratification of the Comprehensive Nuclear Test Ban Treaty ... success would be the single greatest arms control accomplishment for the new Senate and it would reestablish America's traditional leadership role on nonproliferation.*

Senator John Kerry, Chair, Senate Foreign Relations Committee, *Boston Globe*, 13 January, 2009.

President Obama's call in Prague to complete the Comprehensive Nuclear Test Ban Treaty (CTBT) was widely praised on the global stage. But what will be entailed for the United States to ratify the CTBT and reinvigorate international efforts to secure the remaining signatures and ratifications so that the Treaty can at last enter into force?

When deciding whether to vote for or against international treaties and agreements, Senators need to consider the *net benefit* of that treaty for the United States. In other words, considering all aspects, on balance is the United States' national security increased by ratifying the treaty or is it diminished? Senators should evaluate the totality of the treaty and assess the answers to a range of questions, such as the following: If US nuclear testing was followed by Chinese and Russian nuclear tests, would this likely diminish US security? Are US nuclear forces diminished by relying on the Stockpile Stewardship Program as compared to nuclear testing? If so, is it significant for the different warhead types in the enduring stockpile? What are the missions for US nuclear warheads and which of these have extremely high demands for weapons reliability? How much are US monitoring capabilities enhanced with the CTBT International Monitoring System (IMS) in place? Can the US obtain on-site inspection access without a CTBT? Is the nuclear nonproliferation regime stronger and better off with or without the CTBT?

This article addresses these important questions and provides an up-to-date political and technical analysis of the CTBT and its role in US security and nuclear nonproliferation policy.

First we need to recall what happened last time

the CTBT came before the Senate, and consider the consequences of the Senate vote against CTBT ratification on 13 October, 1999. Ratification was defeated by 48 votes to 51, falling far short of the necessary two-thirds Senate majority. This vote was forced prematurely after a curtailed debate by Senator Jesse Helms (Republican, North Carolina), then Chair of the Senate Foreign Relations Committee, citing procedural grounds. This was most unfortunate, as the treaty fell victim to partisan politics in the Senate which was bitterly divided along party lines at the time over issues unrelated to the CTBT's subject matter and content. Before the vote, 62 Senators (24 Republicans and 38 Democrats) had circulated a letter sponsored by Senators John Warner (Republican, Virginia) and Daniel Patrick Moynihan (Democrat, New York), calling on Majority Leader Trent Lott (Republican, Mississippi) and Minority Leader Tom Daschle (Democrat, South Dakota) to halt the vote, since they feared that the CTBT would not be considered on its own merits.

Describing the 1999 ratification debacle in detail in *Foreign Affairs*, Terry Deibel concludes: "Looking back, the Senate's defeat of the CTBT may well have been a turning point in American statecraft if not in world politics, marking at least a setback for efforts to regulate weapons through detailed arms control treaties, and possibly their end. The Senate's action also may have been a watershed in the politics of American foreign policy, for the treaty's failure was an important triumph for unilateralism – a conservative strain of Republican thought that now struggles for control of George W. Bush's foreign policy against the cooperative internationalism that

was the hallmark of his father's administration."<sup>1</sup>

A decade has lapsed since that defeat. In the United States – and elsewhere – we are now seeing the CTBT rise from its long coma because it makes such good sense for nuclear safety and stability. This multilateral treaty bans all nuclear explosions of any yield in all places for all time. The CTBT is an *arms control measure* that constrains the nuclear weapon states (NWS) from testing new or old types of nuclear weapons. It stops new big weapons, such as thermonuclear weapons and it stops the development of most small battle-field weapons. The CTBT is also a *nonproliferation measure* that constrains non nuclear weapon states (NNWS) by raising an almost universally-adopted barrier to stop nuclear testing and to support the fundamental security regime based around the Nuclear Non-Proliferation Treaty (NPT).

Such a barrier would not completely prevent the development of simple weapons, such as uranium gun-type weapons and primitive plutonium-implosion weapons, but the CTBT makes it more difficult to design warheads for more sophisticated weapons and delivery systems and sets a global norm against developing new nuclear weapons. The United States has considerable experience and data from its 1,039 tests, more than Russia at 718 tests, France (198), China (45), United Kingdom (45), India (6), Pakistan (6) and North Korea (2).<sup>2</sup> At the time of writing, the CTBT has 181 signatories, of which 149 have ratified; and 35 of the 44 nuclear capable states listed in Treaty Annex 2, required for entry into force have ratified. The principal outliers among nuclear weapon capable states are the United States, China, Israel, India, Pakistan and North Korea. In addition, Iran, Egypt and Indonesia have signed but not yet ratified.

China and Israel are waiting for the United States. India was ready to ratify in 1999 before the US Senate voted against the CTBT and let them off the hook. If India acts, Pakistan will follow. And surely diplomacy can find a way with North Korea. For comparison sake, the United Nations has 191 members, the NPT has 189 states parties, and the International Atomic Energy Agency (IAEA) has 146 members (February 2009) with some 155 states under safeguards.

### **CTBT and NPT inextricably linked**

The international commitment to end nuclear testing has been enshrined in the NPT since its conclusion in 1968. The most important treaty for international peace and security that exists, the NPT was built on a basic bargain. The overwhelming majority of countries agreed to join the treaty as non nuclear weapon states, not to acquire nuclear weapons and to allow inspections of their nuclear facilities. In return, the five states that possessed

nuclear weapons at the time of treaty signing in 1968 were allowed to join the NPT as recognized nuclear weapon states, but in return they pledged to negotiate the elimination of their nuclear arsenals and promised not to impede the sharing of peaceful nuclear technology with the NNWS. Interim steps toward nuclear disarmament in the nearer future were also to be negotiated. When the NPT was signed in 1968, these interim steps were understood to include: a permanent ban on all nuclear explosive tests, a treaty halting the further production of nuclear weapon explosive material, deep reductions in nuclear weapons, and legally binding commitments never to use nuclear weapons against NPT non nuclear weapon states. Upon this basic bargain was the NPT built. Observing the bargain is essential to the health of the treaty regime. But the most important element of the NPT bargain was and is the commitment to ban all nuclear testing.

It was recognized at the time of the signing of the NPT that the total elimination of all the nuclear weapon arsenals was likely to be far in the future. But the NPT was a strategic bargain; it was not a gift from the non nuclear weapon states. Thus, if they were going to give up the possession of this ultimate weapon, at least, they agreed, the NWS could in the nearer future take the step of halting nuclear weapon tests. From the earliest of days the NNWS saw the test ban as the litmus test of NWS compliance with this basic bargain of the treaty. The test ban is the only interim measure explicitly mentioned in the Treaty. The discontinuance of nuclear weapon tests is called for in preambular paragraph 10 of the NPT. Without the CTBT, the NPT is not seen by most of the world as a treaty of balanced obligations. A one-sided NPT will not survive forever.

The NPT is currently under severe stress as a result of diverse problems, including: North Korea's nuclear weapon and missile programmes; Iran's uranium enrichment programme; Pakistan's A.Q. Kahn's nuclear Wal-Mart; the Indian and Pakistani nuclear weapon programmes and tests; the large Israeli nuclear arsenal outside the treaty; the nuclear flirtations by Syria and others; and concerns by states living in troubled neighbourhoods that proliferation might cascade. The NPT doesn't solve everything; it cannot constrain the potential misuse of nuclear fuel cycles for energy production, for example, but without the NPT this issue cannot even be addressed. It is obvious that the United States does not have the ability to address these issues by itself. Unilateral US efforts to stem global proliferation are bound to fail; only with the expanded clout of nations working together is there a chance to succeed.

Because of its contribution to the prevention of future nuclear arms races and its importance to the NPT regime, there is no significant international

issue today with greater consensus than the CTBT. In December 2008 the United Nations General Assembly voted a laudatory CTBT resolution by 175 in favour, versus one in opposition (the United States) with three abstentions (India, Mauritius and Syria). If one totalled up the numerous votes in the UN regarding the test ban over the past six years, the total vote count would be 1,045 in favour to 8 against (6 US votes, 1 North Korea, 1 Palau).<sup>3</sup> This is not where the United States should be. Since President Obama favours the CTBT, it is generally assumed there will be no negative vote by the US next December when the UN addresses this issue again. *Thus, CTBT has gone from near death to a hopeful resurrection.*

The near-death of the CTBT is perplexing when one considers its importance to the global nonproliferation regime. What the constitution is to the United States, the NPT is to proliferation prevention. The NPT is the best that we have, with nothing on the horizon to replace it. It entered into force in 1970 with a then lifetime of 25 years.

In the late 1960s when the NPT was negotiated in Geneva, most delegations intended to provide that the NPT would be a permanent treaty as is the custom with multilateral arms control treaties. However, three delegations – Sweden, Germany and Italy – opposed this, on the grounds that the treaty's future was uncertain and the commercial impact of the safeguards could not be determined. The compromise reached was set out in the NPT's Article X: that the initial period of the Treaty would be for 25 years and after this period there would be a conference of the states parties at which, by majority vote, they would decide whether to make the treaty permanent or extend it for a fixed period or periods. This decision was delegated to the 1995 Review Conference by the treaty text and, thus, on a one-time basis an extension of the Treaty could be agreed and become effective without reference to national legislatures. Any subsequent extension would have had to be made by Treaty amendment. This would have been an impossibility given the arduous amendment process provided by the Treaty and the very large number of national legislatures that would have to approve it. In effect, therefore, the 1995 Conference was the only opportunity to make the NPT permanent.

In advance of the 1995 decision, the United States, the United Kingdom, France and Russia, all NPT nuclear weapon states, plus Germany and greatly assisted by allies such as Japan and Australia, worked mightily to renew the NPT without a time-limit, in perpetuity, for forever. The other NPT nuclear weapon state, China, took a moderately supportive position. However, many of the then 173 (now 184) NPT non-nuclear weapon states had other

ideas in mind. They were concerned that if the Treaty were made permanent, they would lose all leverage over the NWS to fulfil the disarmament obligations in the NPT basic bargain, as reflected in Article VI of the treaty. In 1995, Article VI lay largely unimplemented with the absence of a test ban as the most important example.

One of the authors of this article (Thomas Graham) represented the United States as the Ambassador for Nonproliferation and Arms Control, and during 1993-1995 travelled to the capitals of 47 NPT parties, returning to some of them many times (seven trips to Egypt, for example), to remind other governments of the importance of the NPT for their particular neighbourhoods and for global stability, and to urge that they support indefinite extension of the NPT without conditions.

Many of the non-nuclear treaty parties believed that the nuclear weapon states had not met their NPT arms control obligations. Of overwhelming importance was the long failure to achieve a CTBT. The NPT Review Conferences of 1980 and 1990 had failed over this issue and the 1975 and 1985 Review Conferences essentially papered over profound differences on the necessity for a CTBT. However, in the run-up to the 1995 Conference, the United States abandoned its long held opposition. In October 1993, the United States spoke during the United Nations' consideration of its annual resolution calling for a CTBT and voted in favour for the first time, and in 1994 joined other members of the Conference on Disarmament (CD) in negotiating a CTBT in earnest.

The US change of policy gave credibility to Ambassador Graham's assurances to the leaderships of countries around the world, such as South Africa, Indonesia, Colombia, Mexico, the Philippines, Egypt, Morocco, the South Pacific Nations and many others important to NPT extension, when he told them that "you don't need to have leverage on the nuclear weapon states to meet their obligations, you don't need to adopt the proposal of some who want to place restrictive conditions on the continuing life of the Treaty, the world community can give itself the security of a permanent NPT without crippling conditions. The United States is committed to the CTBT and its other obligations under Article VI." It was on this basis, as reflected in the Principles and Objectives on Non-Proliferation and Disarmament, adopted prior to the decision on indefinite extension, that an overwhelming majority of the NPT parties supported making the NPT permanent, a great step forward for US interests and for world security. The long failure of the United States to ratify the CTBT is a serious breach of faith with this decision, gravely undermining the viability of the NPT. Thus, it is most important that the United States ratify the

CTBT in the near future, if at all possible before the 2010 Review Conference.

The 2005 NPT Review Conference was a disaster: for the first time ever the NPT parties were unable to agree on anything. The United States was largely responsible for this by, among other things, being unwilling to recognize the commitments made by the nuclear weapon states in 1995 to secure indefinite NPT extension, in particular the CTBT. A US failure to ratify the CTBT by the time of the 2010 Review Conference could lead to another “lost” Review Conference, seriously jeopardizing the future of the NPT. By contrast a US ratification would be viewed as highly positive by NPT parties and would put the nonproliferation regime back on the road toward viability after many reverses in recent years.

CTBT entry into force requires more than the United States, however. Of the further eight states necessary for entry into force, China and Israel are waiting for Washington to act and would likely follow suit reasonably soon. India agreed to join the CTBT after its 1998 tests but was let off the hook by the 1999 action of the US Senate. US and India relations are better now than in 1998, so there should be renewed impetus to obtain India’s signature and ratification after US ratification. Action by India to ratify probably would be followed by Pakistan. With the US, Israel and China in the CTBT there would no longer be a reason for Egypt and Indonesia to stay out. So that would leave Iran and North Korea. Iran might be willing to join if only because a failure to ratify would appear to give the lie to their claim that Iran does not seek nuclear weapons but only peaceful nuclear power. Any other reason Iran might put forward for staying out would have been removed. That would leave North Korea, and the outcome would likely depend on how much pressure China would be willing to bring to bear. But entry into force would be in sight.

Post 1995, many NPT non nuclear weapon states are still uncomfortable that they gave away the sovereign right to possess a potent weapon to defend themselves. Moreover, the NNWS for the most part comply with IAEA inspections, while the NPT nuclear weapon states are barely inspected. This tradeoff makes sense to NNWS because they want to live in nuclear-free neighbourhoods and on a stable earth, but they are nevertheless angry that the NWS have not fulfilled their obligations under Article VI to disarm and reduce the threat of nuclear weapons. The NNWS asked themselves if they should extend the NPT without a time limit without obtaining a quid pro quo constraint on NPT nuclear weapon states. As the 1995 NPT renewal stood in the balance on Article VI, the NNWS decided that preventing nuclear weapon modernization by halting nuclear tests and preventing new states from

becoming nuclear weapon states was their most immediate objective, and so they prioritized holding the NWS to their commitment to conclude the CTBT negotiations underway in the CD.

In a letter dated 19 April 1995 from France, Russia, the United Kingdom and the United States (China agreed later) to the 1995 NPT Review and Extension Conference, the NWS coupled a determination to complete the CTBT with a request to the NNWS that the NPT provisions be made permanent (the quid pro quo):

*“We reaffirm our determination to continue to negotiate intensively, as a high priority, a universal and multilaterally and effectively verifiable comprehensive nuclear test-ban treaty, and we pledge our support for its conclusion without delay... We call upon all States parties to the [NPT] to make the treaty provisions permanent. This will be crucial for the full realization of the goals set out in Article VI.”*<sup>4</sup>

As in 1968, the NNWS in 1995 chose to back having a strong, durable NPT and thereby gave up the leverage of holding the treaty hostage over its extension. In the Statement of Principles and Objectives on Nuclear Non-Proliferation and Disarmament that accompanied the resolution indefinitely extending the NPT, all NPT parties agreed to conclude a CTBT in one year. The 1995 NPT Review and Extension Conference agreed on the following objective:

*“The completion by the Conference on Disarmament of the negotiations on a universal and internationally and effectively verifiable Comprehensive Nuclear-Test Ban Treaty no later than 1996. Pending the entry into force of a Comprehensive Test Ban Treaty, the nuclear – weapon States should exercise utmost restraint.”*<sup>5</sup>

After this was agreed, the NNWS fulfilled their part of the bargain and renewed the NPT without a time limit. Without the CTBT promise, it might have been necessary to settle for a fixed renewal of the NPT, with proposals ranging from 10 to 25 years. A ten year NPT would have expired in 2005, when the Review Conference failed completely. If the NPT had been renewed for 25 years, the NPT would be nearing its expiration in 2020.

By way of comparison: if the US Constitution was nearing expiration and had to be renegotiated by the 50 states, there would likely be chaos and instability in the United States. Large states like California might insist on having more power in the Senate than smaller states like Wyoming or Rhode Island. Such arguments could foreseeably wreck the careful balances and, once undone, it would be difficult if not impossible to renegotiate and achieve a better US Constitution than the one we have.

## Verification of the CTBT

Critics of the CTBT have suggested that the Treaty would not be verifiable below levels of about one kiloton, as this was the baseline agreed at the time that states negotiated to get the most reasonable and cost-effective monitoring architecture. As anticipated at the time, verification capabilities have continued to get better as the system has expanded and improved. Seismography can now distinguish the characteristic signature from a nuclear explosion and discriminate between that and the signatures from earthquakes, mine-collapses, mini-meteorites, and ripple-fired chemical explosions.<sup>6</sup>

In addition to advances in the IMS monitoring technologies, verification is also enhanced by improvements in the capabilities of civilian seismic networks and national technical monitoring systems. The National Academy of Sciences (NAS) study, *Technical Issues Related to the Comprehensive Nuclear Test Ban Treaty* concluded that “underground nuclear explosions can be reliably detected and can be identified as explosions, using IMS data down to a yield of 0.1 kilotons (100 tons) in hard rock if conducted anywhere in Europe, Asia, North Africa and North America.”<sup>7</sup> Advances in regional seismology provide additional confidence. For some locations (such as Russia’s nuclear test site at Novaya Zemlya) the use of seismic arrays and nearby seismic stations have lowered the detection threshold to below 0.01 kilotons. The NAS results were obtained under criteria that three or more primary IMS stations must detect the event with a success probability of 90%. This ignores the contribution of the 120 IMS auxiliary stations, which, according to the NAS would lower the detection threshold by an additional 0.25 to 0.5 magnitude units. This could greatly increase detection of explosions in hard rock, making it a risky proposition for a potential violator to conduct an illegal nuclear explosion from 50 tons on upwards. See Table I for a summary of monitoring capabilities for eight types of technologies.

As an example, take the 0.6 kiloton, North-Korean explosion (essentially a failed test) on 9 October 2006.<sup>8</sup> This explosion was promptly detected and identified from signals recorded at 31 seismic stations in Australia, Europe, North America and Asia, including 22 IMS stations (10 primary and 12 auxiliary, when only 60% of IMS seismic stations were certified) established by the Preparatory Commission for the Comprehensive Test Ban Organization (CTBTO). The US Geological Survey posted a good estimate of the test location five hours after the explosion occurred. The location was narrowed to a few square kilometres by David Albright and Paul Brannon, using commercial imagery.<sup>9</sup> The 25 May 2009 North Korean

explosion of 2 to 3 kilotons was observed by 61 IMS seismic stations when 76% were certified (130 of 170).

Seismic data from underground chemical explosions show that far lower yield explosions would have been detected in the Korean region – in fact as low as 0.002 kilotons, a factor of 50 below the 0.1 kiloton NAS monitoring threshold and a factor of 500 below the nominal one kiloton baseline.<sup>10</sup> A 0.005 kiloton (5 ton) threshold is not applicable everywhere, but it is evidence that considerably lower limits can be obtained than previously assumed, particularly if there is a sufficient density of regional seismic stations. Similarly, the 4 ton blast that shattered the US embassy in Kenya and also the 4 ton blast that destroyed the *Kursk* submarine in 2000 were recorded by 20 seismic stations.<sup>11</sup>

Much of this progress is due to the availability of more data at closer distances. Regional monitoring is based on signals that travel via the earth’s crust and upper mantle, and have been recorded at distances up to about 1,500 kilometre (km). Better results are obtained with regional monitoring than with longer-range or teleseismic stations, which measure body waves that travel below the earth’s mantle. New algorithms, closer access, and more detailed seismic models enhance the ability to improve location estimates and better discriminate between nuclear tests, earthquakes, chemical explosions for mining, or other phenomena. For example, analysis of Soviet-era data from seismographs located at a distance of 500 - 1,500 km from the Semipalatinsk site in Kazakhstan provided information **on all but two of the 340 tests over one ton** (0.001 kilotons).<sup>12</sup> This achievement took place with seismographs employing old technology. Newer broad-band, digital seismographs are much better.

As of July 2009, 247 of the total 337 IMS facilities were certified (73%), 28 were being tested but not yet certified (8%), 29 were under construction (9%), and 33 are in the planning stage (10%). Since over 90% of the IMS facilities are now certified, operational or under construction, it is expected that 95% of the IMS network will be completed in five years. Additional data can be retrieved quickly from the 120-station auxiliary IMS network and from the vast Global Seismic Network and the International Seismological Centre.

The major nuclear weapon states are well monitored with 32 sites in Russia, 12 in China and 39 in the United States. The South American cone is well covered with 23 sites in Argentina, Brazil and Chile. The coverage of North Korea is excellent as well, with 23 sites in China, Japan and South Korea. The Middle East is covered with 17 sites. India and Pakistan are surrounded with over 40 sites in

Australia, Bangladesh, China, Sri Lanka and Thailand. To these assets must be added the many seismographs not part of the IMS and additional capability from national intelligence capabilities.

### **Evasion Scenarios using Cavities**

The NAS panel examined 10 evasion scenarios suggested by the US intelligence community.<sup>13</sup> The panel concluded that “the only evasion scenarios that need to be taken seriously at this time are cavity decoupling and mine masking.” On the latter issue, member states are requested to notify the CTBTO (on a voluntary basis) of chemical explosions over 0.3 kiloton. Seismic patterns from ripple-fired explosions and infrasound detection can discriminate between explosions and earthquakes. The most commonly cited concern during the Senate debate was cavity decoupling, which is the use of a cave, underground cavern or other form of cavity to muffle the seismic wave from a nuclear explosion.<sup>14</sup> No country is known to have fully decoupled a nuclear explosion in a cavity that was created for that purpose. An explosion is “fully” decoupled if the cavity is large enough to reduce the nuclear blast pressure on the cavity wall below a critical level (the cavity radius to do this must be larger than 25 meters times the yield in kilotons to the 1/3 power). The only “fully” decoupled nuclear test had a small yield of 0.4 kiloton that was reduced by a factor of 70 at 1 Hz. The decoupling factor is reduced at higher frequencies, for example 10 at 10 Hz, which is more accessible to regional seismographs.

During the 1999 Senate debate, then Senate Majority Leader Trent Lott mistakenly claimed that a 70 kiloton explosion in a cavity could be hidden from IMS monitoring. To do this would require a deep cavity with a 200 meter diameter (equivalent to a 50 storey building) with an area of 0.13 square km at a depth of one km. No such cavity has ever been constructed and it would be essentially impossible to construct one or to find and use a hypothetical cavity of this kind with sufficient secrecy to hide a test. The NAS panel determined that an explosion in a cavity “cannot be confidently hidden if its yield is larger than 1 or 2 kiloton”.<sup>15</sup> The prospect that a country could cheat undetected fails to take into account that nowadays arrays of seismographs and other seismic capabilities can detect and identify many events that take place more than 2,000 km away with yields considerably less than one kiloton. And such claims ignore the advances in regional seismology and the venting of radionuclides, which would be detected by other monitoring technologies linked into the IMS. The panel noted that if an inexperienced state wanted to reduce the risk of detection, “it would probably try to limit test yields to 0.1 kiloton or less”.<sup>16</sup>

### **Military Significance, or What Could be Gained by Cheating?**

The principal risk that needs to be avoided is that a country under the CTBT could alter the strategic balance between it and the United States. The NAS study concluded that it would be very difficult for states with less nuclear testing experience, such as *India, Pakistan, North Korea, Iran and Iraq*, to meet the required conditions to avoid detection by testing in a cavity at one kiloton or less. It is far easier to test in the 10 kiloton region without a specific yield, than to test at a specific 1 kiloton yield or less. The NAS study concluded that “Countries with lesser prior test experience and/or design sophistication” would also lack the sophisticated test-related expertise to obtain “limited improvement of efficiency and weight of unboosted fission weapons compared to first-generation weapons not needing testing” from tests at levels of 0.01 kiloton to 1–2 kilotons.<sup>17</sup>

The NAS panel also judged that “States with extensive prior test experience [Russia and China] are the ones most likely to be able to get away with any substantial degree of clandestine testing.” Such states could, with difficulty, potentially validate designs for unboosted one kiloton fission weapons in a cavity. At the same time, it must be taken into account that very low yield tests by such nuclear weapon states would not, by themselves, materially change the strategic balance. A 1995 JASON panel concluded that testing at 0.5 kilotons would provide only minimal gains in developing a new weapon design. Moreover, at a minimum, several clandestine tests are needed to change design parameters, improving the chance of detection.

### **Effective Verification**

The US standard for *effective verification* of an arms control treaty was defined during Senate ratification of the 1988 Intermediate-range Nuclear Forces (INF) Treaty and the 1991 Strategic Arms Reduction Treaty (START). During INF Treaty ratification hearings, Ambassador Paul Nitze defined effective verification 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”.<sup>18</sup> *Effective verification* is determined by the military significance of the *additional* nuclear-weapons capabilities obtained by cheating, beyond those it had before the treaty was in place.

It is clearly recognized that treaty violations that might threaten US national security in a militarily significant way must be detected in sufficient time. Undetected cheating at extremely low yields under the CTBT would, at most, provide only limited benefits for Russia and China and would not

adversely affect the strategic balance. By contrast, it is much more difficult for states with limited testing experience to gain significant information at very low yield levels.

A worst-case analysis on the consequences of a treaty breakout was carried out by the Senate Foreign Relations Committee for the Senate ratification for START I (under Senator Pell, Democrat, Rhode Island), an approach that was repeated for START II ratification (under Senator Helms, Republican, North Carolina).<sup>19</sup> Those reports concluded that potential violations to the START treaties were not militarily significant, since even if they cheated, the Soviets (and then the Russians) would gain little in their ability to hurt US strategic forces beyond what they could do without violating the treaties. These results allowed the Senate Foreign Relations Committee to determine that the two START treaties were effectively verifiable, which has been borne out with time.

Over the past decade, despite missing some of the ratifications necessary for the treaty to enter into force, the CTBT Organization in Vienna has been far from idle. The International Monitoring System, with stations all round the world, is now 90% complete (73% of the 337 facilities are certified, 8% are in testing, 9% are under construction, with the remaining 10% in the planning phase). Moreover, the effective nuclear explosion detection limit is far better than the one-kiloton limit that some of the Treaty's opponent's claimed for it at the time of the ratification vote, by a factor of 10 at 0.1 kilotons.

By any reasonable standards – and certainly, in accordance with the standards applied by the Senate Foreign Relations Committee when it ratified START I – the CTBT is effectively verifiable.

### **Stockpile Stewardship Program**

The 2006 JASON group concluded that aging of plutonium is not a significant issue, noting:

*“Most primary types have credible minimum lifetimes in excess of 100 years as regards aging of plutonium; those with assessed minimum lifetime of 100 years or less have clear mitigation paths that are proposed and/or being implemented...There is no evidence for void swelling in naturally aged or artificially aged plutonium samples over the actual and accelerated times scales examined to date, and good reason to believe it will not occur on times scales of interest, if at all. Systems with large margins will remain so for greater than 100 years with respect to plutonium aging. Thus, the issue of plutonium aging is secondary to the issue of managing margins.”<sup>20</sup>*

The JASONS recommended measures to increase performance margins of weapons, such as increasing tritium content in warheads.<sup>21</sup> The NAS panel

continually asked weapon designers during classified briefings on the enduring stockpile whether testing was needed to resolve the issue under discussion. US weapon scientists always responded that testing was not needed to solve the issue under discussion. The NAS panel concluded that a properly run stockpile stewardship programme is far more important than nuclear testing to maintain the reliability of warheads:

*“It seems to us that the argument to the contrary – that is, the argument that improvements in the capabilities that underpin confidence in the absence of nuclear testing will inevitably lose the race with the growing needs from an aging stockpile – underestimates the current capability for stockpile stewardship, underestimates the effects of current and likely future rates of progress in improving these capabilities, and overestimates the role that nuclear testing ever played (or would be ever likely to play) in ensuring stockpile reliability.”<sup>22</sup>*

These conclusions are consistent with the fact that the United States has not needed to test in the 17 years since it undertook a testing moratorium in 1992.<sup>23</sup> Each year the US government has stated that it is “confident that the stockpile is safe and reliable, and there is no requirement at this time for nuclear tests.” The annual certification on stockpile readiness requires the Secretary of Defense (after advice from Strategic Command and the military services) and the Secretary of Energy (after advice from the three weapon laboratory directors and the National Nuclear Security Administration (NNSA) administrator) to determine whether all safety and reliability requirements are being met without the need for nuclear testing. These reports have always certified that the stockpile does not need testing for reasons of safety or reliability. The NAS panel concluded that testing is not needed in future years, with these caveats: (i) a robust stockpile stewardship programme, (ii) no new weapon designs, and (iii) the right of the United States to withdraw from the CTBT if US leaders decide that nuclear testing is necessary for defending US national security.

### **Enduring Stockpile and Safety Issues**

The enduring stockpile is currently projected to consist of about 5000 warheads (about 50% operational and 50% in reserve) with seven different types. The warheads in the enduring stockpile have been tested 150 - 200 times. The yield on the target is usually much larger than what is needed for particular missions, so the only important issues are does the weapon explode and is missile accuracy sufficient. The United States has not tested each warhead type enough times to determine reliability with high confidence statistics. For example, if we assume ten reliability tests were performed and all were successful, the reliability evaluation is not

100% with 100% confidence, but is framed as a 30% chance that reliability is less than 90% and a 10% chance that reliability is less than 80%.<sup>24</sup> In other words, when a few successful tests give the design yield, the reliability of a warhead type is defined as 1.0, but *without* a confidence level. If problems arise, the reliability evaluation is reduced somewhat arbitrarily.

Since the weapons have been extremely reliable, the DOE only dedicated one test per year to examine the reliability of the ten different types of weapons already deployed. Thus, nuclear testing has not played a large role in determining our confidence in the reliability of the weapons in the nuclear arsenal; it is non-explosive monitoring that has played the dominant role in maintaining our confidence in the reliability of nuclear weapons. The NAS panel concluded the following on future needs for nuclear testing:

*“The question of whether nuclear testing might ever be needed to correct problems discovered in weapons certification and deployment generated some controversy in the 1980s. However it was shown that almost all of the problems cited in support of this proposition were either of a kind not requiring nuclear testing or represented cases where testing had been inadequate during development. In relating these experiences to the current situation it is also important to note that the observed failures all occurred within three years after entry into the stockpile. The weapons in today’s active stockpile have long passed the age where anomalies in initial production units are a significant problem. Furthermore, they are all based on tested designs that have taken advantage of lessons learned from other vintages.”*<sup>25</sup>

The main threat to warhead reliability is caused by non-nuclear components, which are examined without nuclear-explosive testing. Problem areas that have been uncovered are the following: insufficient tritium, faulty tritium bottles, corrosion of fissile material, degradation of high explosives, low-temperature performance, vulnerability to fratricide neutrons, radar, batteries, fuse switches, neutron generators, faulty cables, trajectory sensors, control systems, rocket motors, gas transfer valves, firing sets, and pilot parachutes.

Experience demonstrates that nuclear weapon safety is more reliant on avoiding human error than on weapon design or testing. Only one serious US nuclear weapon accident has taken place since 1968. This took place in 1980 when a wrench fell 80 feet, fracturing the first stage of a liquid-fuelled Titan missile in a silo in Arkansas. Nine hours later it exploded, propelling the 9-megaton, W-53 warhead 100 feet onto a neighbouring field. This accident did not spread radioactivity and could not happen now

since all liquid-fuelled missiles have been decommissioned. Over the nuclear weapon era, only two accidents spread considerable radioactivity, and both of these were the result of aeroplane accidents: at Palomares, Spain (1966) and Thule, Greenland (1968). Practically all (29 of 32) nuclear weapon accidents have resulted from aircraft accidents. Accidents with aircraft are much less relevant since aeroplanes no longer routinely carry or fly nuclear weapons, unless they are on special alert. The nuclear armed cruise missiles accidentally flown across the U.S. in 2007 were not supposed to be on the bomber that carried them, this was an on the ground error. The least safe nuclear weapons (liquid-fuelled ICBMs, nuclear artillery and short-range attack missiles) have been decommissioned. The safety procedures for submarine weapons have been modified to increase safety. There is a DoD consensus that there are no significant safety problems requiring modifications that need nuclear testing.

### **The National Security Value of a CTBT**

The CTBT has important security value for both the United States and the international community. France, Russia and the United Kingdom ratified the CTBT promptly, despite the failure of the US Senate to ratify the treaty to date. China has practically completed its ratification procedures but appears to be waiting for the US to ratify.

Without a CTBT, China could, for example, test miniaturized hydrogen bombs for a MIRVed ICBM, and so start a new nuclear arms race. Without a CTBT, Russia’s military would push to renew nuclear testing. Without a CTBT, the political-legal barrier to weaponization would be much smaller. Without a CTBT there would be greater disharmony among the family of nations, and less capability to unite against the dangers of proliferation, making it even more difficult to prevent nuclear weapons programmes in Iran, North Korea and other nations. For these reasons, the CTBT is a national security issue for the US and the now 188 other NPT parties. The CTBT will make the world safer and this includes nations under the US nuclear umbrella, such as Japan, South Korea and Germany.

The National Academy panel examined three scenarios regarding the future of the CTBT, with emphasis on seven nations: Russia, China, India, Pakistan, North Korea, Iraq and Iran. The scenarios were: a fully implemented CTBT with compliance; a CTBT where one or more states sought to violate their obligations and conduct clandestine tests using evasion techniques to avoid IMS detection; and no CTBT. The NAS panel concluded the following: “The worse-case scenario under a no-CTBT regime poses far bigger threats to US 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.”<sup>26</sup>

General John Shalikashvili, former Chair of the Joint Chiefs of Staff, examined the *net benefit* of the CTBT by examining all aspects, including political ramifications for two worlds, with and without a CTBT, concluding the following:

*“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.”*<sup>27</sup>

General Shalikashvili’s report suggested a mechanism for CTBT ratification in which the United States would “commit to conducting an intensive joint review of the Test Ban Treaty’s net value for national security ten years after US ratification, and at ten-year intervals thereafter... If, after these steps, grave doubts remain about the Treaty’s net value for US national security, the President, in consultation with Congress, would be prepared to withdraw from the Test Ban Treaty under the ‘supreme national interests’ clause.”<sup>28</sup>

## Conclusion

It is widely believed that the United States will not test a nuclear weapon because both China and Russia would quickly respond with multiple nuclear tests, leading to a new arms race. In addition, the prevailing wisdom in Washington is that US efforts to halt nuclear proliferation would be greatly damaged if the US tested. Thus, the United States is already operating under CTBT-like constraints, while not gaining the full benefits that would follow from the CTBT being in force. It would be in US interests to ratify the CTBT for many reasons. In the unlikely case that the US found itself needing to test for serious reasons, then we have the option to withdraw from the CTBT for national security reasons.

As discussed above, without a CTBT, China could test miniaturized hydrogen bombs for a MIRVed ICBM, starting a new nuclear arms race. Some nuclear weaponeers in Russia would be keen to renew nuclear testing if not constrained by the CTBT, which Russia has ratified but could ditch if US ratification were to be subject to further significant delays. As long as the nuclear test ban holds, could-be nuclear-armed nations such as Iran would not be able to proof test the more advanced, smaller nuclear warheads designs that are needed in order to deliver nuclear weapons by missile. The CTBT helps block new nuclear threats from emerging, thereby enhancing US and global security. Without a CTBT, there would be less unity among

nations to address nuclear programs in Iran, North Korea and other nations. Without a CTBT, there would be a smaller political-legal barrier to weaponization. Without a CTBT there would be disharmony among the family of nations, and less capability to unite against the dangers of proliferation. US ratification for the CTBT will restore US global leadership and strengthen international support for the Nuclear Non-proliferation Treaty, the bedrock of all efforts to stop the spread of nuclear weapons. For these reasons, the CTBT is a national security issue for the US and the 188 other NPT parties. A one-sided NPT will not survive forever. The security of the United States and global non-proliferation would be enhanced by the ratification of the Comprehensive Test Ban Treaty and it is now being degraded by a failure to ratify.

## Notes

<sup>1</sup> Terry Deibel, ‘The Death of a Treaty’, *Foreign Affairs* 81 (Sept./Oct. 2002), pp 142-161.

<sup>2</sup> CTBT Organization, [www.ctbto.org](http://www.ctbto.org).

<sup>3</sup> In six annual votes in 2003 to 2008, members of the UN General Assembly cumulatively gave 1045 votes in favor of the treaty and only eight against (North Korea and Palau once each, and the United States six times). See the following UN General Assembly Resolution votes: 2008(175/1/3: UNGA 63/87, 2007(176/1/4: UNGA 62/59), 2006 (172/2/4: UNGA 61/104), 2005 (172/1/4: UNGA 60/95), 2004 (177/2/4: 59/109), 2003 (173/1/4: UNGA 58/71). The eighteen abstentions resulted from six votes each by Colombia, India, Mauritius and Syria. Since Colombia’s abstention was procedural, not political, and they cleared the way to ratify the CTBT on 29 January, 2008, we have ignored their previous abstentions.

<sup>4</sup> Letter to the 1995 NPT Review and Extension Conference by France, Russia, UK and US (China agreed later), 19 April, 1995, NPT/Conf.1995/20.

<sup>5</sup> Principles and Objectives for Nuclear Non-Proliferation and Disarmament, <http://disarmament.un.org/wmd/npt/1995dec2.htm>

<sup>6</sup> Discrimination uses the following information: Ratio of body waves to surface waves, ratio of pressure waves to shear waves, first motion, depth of event, frequency spectra (explosions have more higher frequency components), regional coda envelopes, source location (ocean events ruled out), waveform correlations (with past tests and with earthquakes) and other data from radionuclides, infrasound, interferometric synthetic aperture radar, space monitoring and NTM.

<sup>7</sup> National Academy of Sciences, *Technical Issues Related to the Comprehensive Nuclear-Test-Ban Treaty* (Washington: National Academy Press, 2002), p 5. For thresholds in soft rock, see Paul Richards and Won-Young Kim, ‘Monitoring for Nuclear Explosions’, *Scientific American*, March 2009, pp 70-77.

<sup>8</sup> Paul Richards and Won-Young Kim, ‘Seismic Signature’, *Nature Physics* 3, (January 2007), pp 4-6, and ‘North Korean Nuclear Test: Seismic Discrimination at Low Yield’, *EOS* 88(14) (3 April, 2007), pp 157-161.

<sup>9</sup> Ramond Jeanloz, ‘Comprehensive Nuclear-Test Ban Treaty and US Security’, p 384 in G. Schultz, S. Andreasen, S. Drell and J. Goodby (eds.), *Reykjavik Revisited: Steps Toward a World Free of Nuclear Weapons*, (Palo Alto: Hoover Press, 2008) and [http://www.isis-online.org/publications/dprk/NorthKoreaTest\\_27May2009.pdf](http://www.isis-online.org/publications/dprk/NorthKoreaTest_27May2009.pdf).

<sup>10</sup> Paul Richards and Won-Young Kim, ‘Seismic Signature’, *Nature Physics* 3 (January 2007), pp 4-6.

<sup>11</sup> Raymond Jeanloz, pp 379-380.

<sup>12</sup> Vitaly Khalturin, Tatyana Rautian and Paul Richards, ‘A Study of Small Magnitude Seismic Events during 1961-1989 on and near the Semipalatinsk Test Site, Kazakhstan’, *Pure and Applied Geophysics* 158 (2001), pp 143-171.

<sup>13</sup> NAS-CTBT study, pp 46-49.

<sup>14</sup> Lynn Sykes, ‘Dealing with Decoupled Nuclear Explosions Under a Comprehensive Test Ban Treaty’, pp 247-293 in Eystein Husebye and Anton Dainty (eds.), *Monitoring a Comprehensive Test Ban Treaty*, NATO ASI Series (Boston: Kluwer, 1996).

<sup>15</sup> NAS-CTBT study, p 7.

<sup>16</sup> NAS-CTBT study, p 75.

<sup>17</sup> NAS-CTBT study, pp 68-78.

<sup>18</sup> US Senate Foreign Relations Committee, *The START Treaty*, Senate Executive Report, 102-53, September 1992, p. 27.

<sup>19</sup> US Senate Foreign Relations Committee, *The START Treaty*, pp 49-64 and the *START II Treaty*, Executive Report 104-10, pp 29-37. The SFRC ratification reports to the Senate concluded that, because of the resilience of the US nuclear triad, the surviving US strategic forces would not be greatly affected by massive Russian cheating in yields or numbers of strategic weapons.

<sup>20</sup> JASON, *Pit Lifetime* (McLean, VA: MITRE Corporation, 20 November, 2006), pp 1, 16.

<sup>21</sup> JASON, *Primary Performance Margins* (McLean, VA: Mitre Corporation, 1999).

<sup>22</sup> NAS-CTBT study, p 34.

<sup>23</sup> NAS-CTBT study, pp 19-34, and (LLNL)

[/asc.llnl.gov/publications/SSPContributions.pdf](http://asc.llnl.gov/publications/SSPContributions.pdf), and (LANL)

**Table 1. CTBT monitoring capabilities**

Method	Description	IMS Assets (when complete)
Seismic	NAS concluded that explosions above 0.1 kt in hard rock can be detected in Asia, Europe, North America and North Africa. Tests in cavities can be detected above 1-2 kt for advanced nuclear weapon states, with risk of venting and excursion yields. This limit is perhaps 0.1 kt for new nuclear nations.	IMS will use 50 primary and 120 auxiliary seismic stations. Arrays of seismographs and regional seismographs can obtain lower threshold yields. In addition, thousands of non-IMS stations have data that could trigger an on-site inspection.
Hydroacoustic	NAS concluded that explosions above a few kg can be detected in Southern Hemisphere, and above 1 ton for all oceans.	IMS will use six hydrophone arrays and five T-phase monitoring stations.
Infrasound	NAS concluded that explosions above 1 kt in the atmosphere can be detected, and above 0.5 kt over continents.	IMS will use 60 infrasound monitoring stations.
Radionuclide	NAS concludes that explosions above 0.1–1 kt can be detected to identify the event as a nuclear explosion. The 0.6 kt North Korean test was detected at 7,000 km distance.	IMS will use 80 particulate monitoring stations, and 40 of these will also detect radionuclides. NTM sensors can be placed on airplanes for close approaches to suspected test sites.
InSAR (Interferometric Synthetic Aperture Radar)	InSAR can measure subsidence as low as 0.2–0.5 cm in many locations, with yields above 1 kt at 500 m depth. InSAR can determine locations to 100 m.	United States has four classified SAR satellites. Europe, Canada and Japan sell unclassified SAR data for as low as \$1,000 each.
On-Site Inspections (OSI)	Any CTBT party can request an OSI, which needs 30 of 51 votes in the Executive Council.	Photos and radioactivity obtained by air and ground. Mini seismic arrays can observe aftershocks. Magnetic anomalies, SAR, soil data obtained with GPS locations.
Confidence-Building Measures	After CTBT enters into force, nuclear weapon states could locate more sensors at test sites to lower thresholds further.	Close-in sensors could detect seismic, infrasound, electromagnetic pulse, radionuclide and other data indicative of a test.
National Technical Means	US NTM technologies have considerable reach and precision.	NTM sensors are located in space, in the atmosphere, on the ground, in the oceans and underground.

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