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Working Toward a World Without Nuclear Weapons
Max von Laue Lecture
Bonn, Germany
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I am very honored to have been invited to give the Max von Laue Lecture. To all physicists, von Laue is greatly admired for his major scientific achievements in discovering x-ray diffraction by crystals, which was recognized by the Nobel Prize in 1914. This field that he created remains a powerful scientific tool in the study of matter in many fields of science to this very day, 50 years after his death. Von Laue is also universally admired for acting with honor and speaking out with courage against Nazi policies of racial discrimination and in support of scientific integrity during the darkest and most dangerous days of the Hitler regime.

Von Laue and his contemporary Albert Einstein, both born in the same year, 1879, were members of the generation of physicists whose revolutionary discoveries early in the 20th century led civilization across a one-way bridge into today's new era. It is the era in which, for the first time in history, we can now literally destroy, not just damage, but destroy the civilization built by mankind over the past 3000 years. This is the danger we have created with the building of thermonuclear weapons with the potential to release explosive energy of unimaginable destructiveness.

Shortly after the first atom bomb was exploded, Einstein warned us that "The unleashed power of the atom has changed everything save our modes of thinking; we thus drift toward an unparalleled catastrophe." He challenged humanity to change its thinking before it is too late. A few years later, when efforts commenced to turn the primitive atomic bombs that obliterated Hiroshima and Nagasaki into mere triggers of modern thermonuclear weapons hundreds to thousands of times more powerful, the two great physicists Enrico Fermi and I.I. Rabi warned: "It is clear that the use of such a weapon cannot be justified on any ethical ground which gives a human being a certain individuality and dignity even if he happens to be a resident of an enemy country…… It is necessarily an evil thing considered in any light."

And yet today, 65 years after the end of World War II, two decades since the dismantling of the Berlin Wall and dissolution of the Soviet Union into the dust bin of history, we still are living in a world armed with approximately twenty thousand nuclear bombs, and with a growing number of nations seeking to join the nuclear weapon club.

Why? What are these weapons for? What purpose do they serve in the modern world? Do large arsenals of deployed nuclear weapons, many of which are ready for launch within minutes of notice, contribute to our national security, or are they themselves part of the problem? Cannot we do better than living under a continuing danger of a nuclear holocaust?

During the Cold War, the United States and the former Soviet Union relied on nuclear deterrence to navigate successfully through those perilous years. Both nations accepted as a fact that a nuclear attack by one aimed at the other, either directly or at their vital interests, would be an act of suicide. And, against what seemed to be insurmountable odds, not one of the literally tens of thousands of existing nuclear weapons was detonated in military combat, although there were numerous opportunities, and several close calls, to do so. Only recently have we learned how perilously close we came to nuclear war in the 1962 Cuban Missile Crisis.

Today it would be dangerously wrong to draw comfort from that achievement. Relying on nuclear weapons for deterrence is becoming increasingly hazardous and decreasingly effective in a world in which nuclear know-how, materials and weapons are spreading ever further and faster. With the spread of advanced technology, and, furthermore, with a renewed international interest in nuclear technology for civilian power generation, we are facing a growing danger that nuclear weapons may fall into the hands of "rogue states" or terrorist organizations that do not shrink from mass murder on an unprecedented scale.

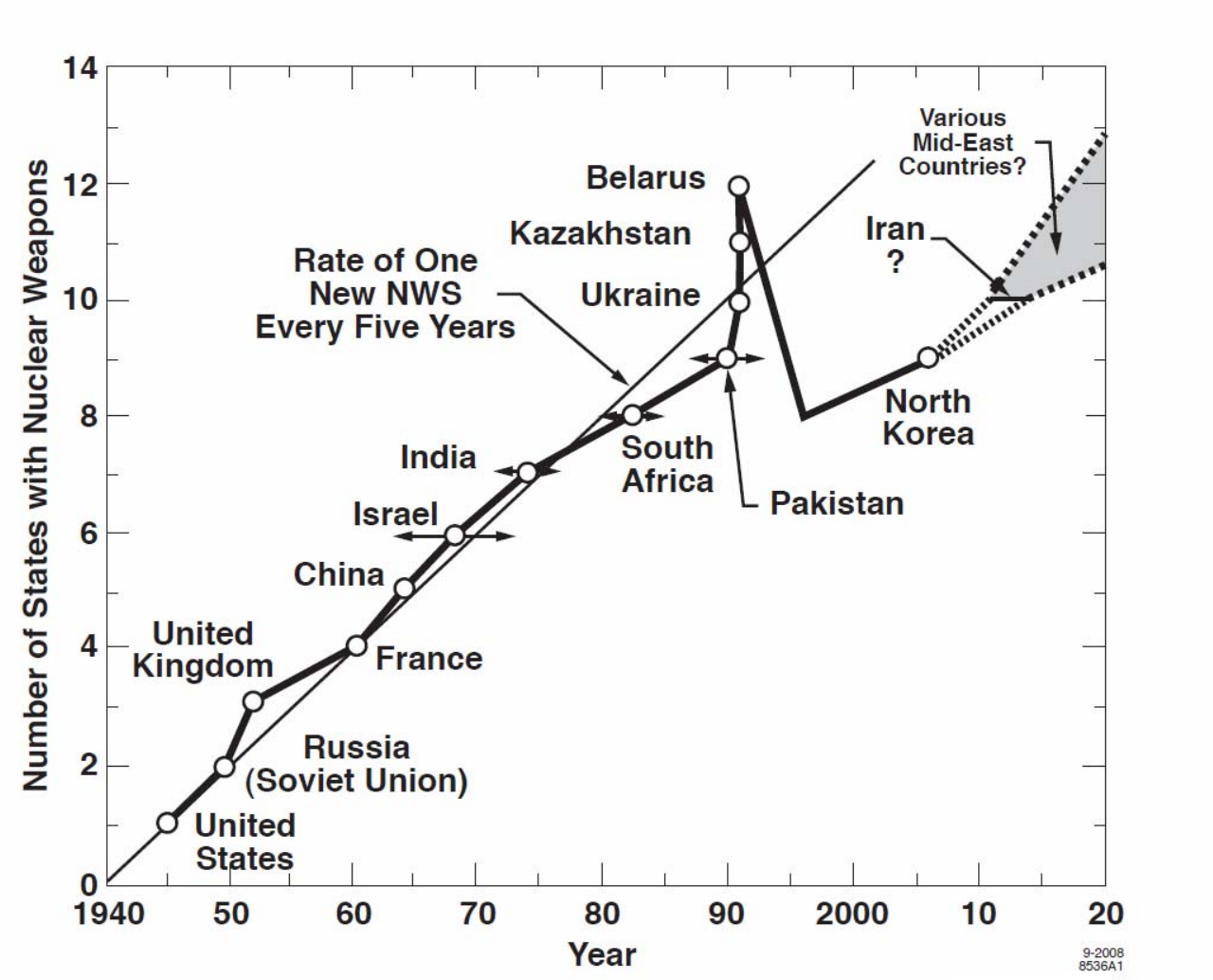

Figure 1

George Shultz, the former U.S. Secretary of State, and a close friend and colleague at Stanford University in California, and I have talked together a lot about arms control and the devastating consequences of nuclear explosions. In recent years we have shared increasing concerns about the growing danger of proliferation and the inadequacy of current efforts to meet the challenge. The world seemed to us to be teetering on the edge of a new and more perilous era, with nuclear proliferation (Figure 1) becoming ever more likely and imminent. The spread of nuclear know-how and technology, as evident in the actions of North Korea and Iran, makes it all too clear that this is not a distant danger. It is on our doorsteps and requires urgent action.

As George Shultz and I probed for more effective ways to stem the rising tide of proliferation, we looked back at the remarkable meeting between American President Ronald Reagan and the Soviet leader General Secretary Mikhail Gorbachev at Reykjavik, Iceland, in 1986. At that summit, still in the midst of the Cold War, Gorbachev and Reagan faced the danger of a nuclear conflict head on. They agreed on the revolutionary goal of eliminating all nuclear weapons. Their effort was a sincere and serious one, but they were unable to complete the deal. Back then it proved impossible to remove all obstacles of the Cold War. Recall the Berlin Wall still stood in 1986 – and there were disagreements on what limits to put on research on ballistic missile defenses that could not be resolved; and so the talks collapsed. The seriousness in the discussions between Reagan and Gorbachev is evident in the official transcript of their anguished final negotiating session, an extra one not originally scheduled for their meeting.

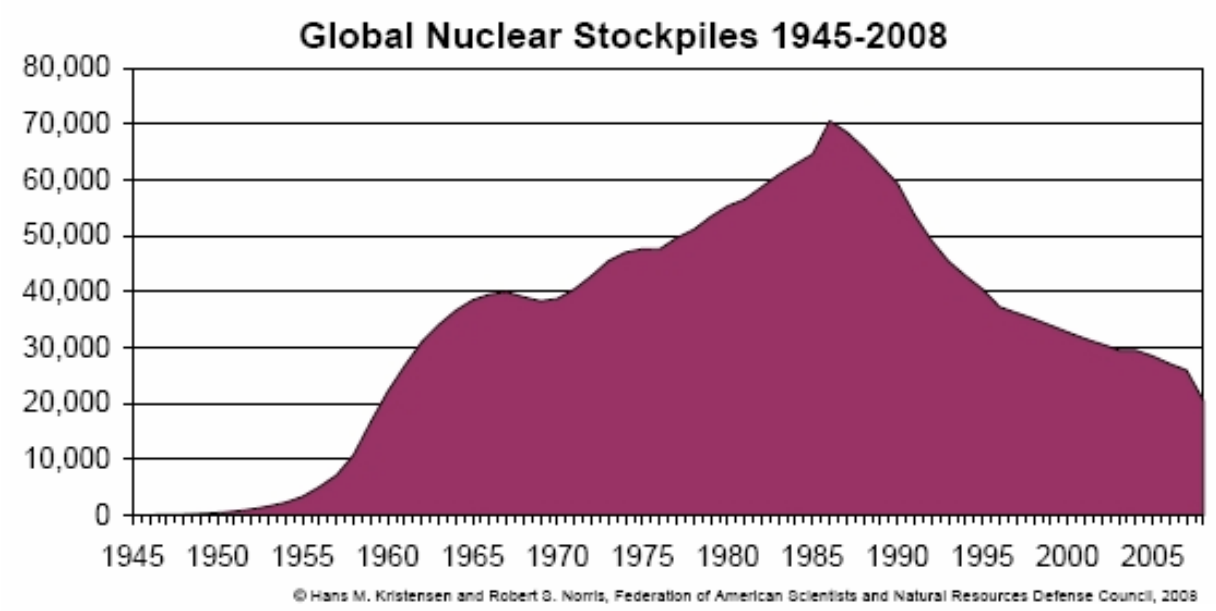

Figure 2

Too bad. On many occasions in his speeches and writings President Reagan, both before and after Reykjavik, called "for the abolition of all nuclear weapons", which he considered to be "totally irrational, totally inhumane, good for nothing but killing, possibly destructive of life on earth and civilization." Both leaders in subsequent writings remarked on the major importance of their Reykjavik discussions. Reagan wrote that "Reykjavik was a major turning point in the quest for a safe and secure world." Gorbachev wrote that Reykjavik "marked a turning point in world history." Figure 2 illustrates the downturn in the sizes of the global nuclear arsenals initiated in 1986 by their efforts at Reykjavik. But their vision to eliminate all nuclear weapons shocked many world leaders, both in and out of office, including in NATO and the United States. Together with so-called policy experts in nuclear deterrence they were dismayed by the fact that the leaders of the two countries with, by far, the largest nuclear arsenals, more than 95% of the world total, had proposed the abolition of their most powerful weapons. Unfortunately no strong leaders succeeded Reagan and Gorbachev to carry their cause forward.

The Reykjavik vision of a world without nuclear weapons inspired George Shultz and me to organize a conference at Stanford, on its 20th anniversary in October, 2006. The idea was not to

rehash the events at Reykjavik – George Shultz had been there – but to analyze the implications, for today, of what happened there. The conference participants – a number of whom had participated directly or indirectly at Reykjavik – expressed concern about the growing dangers of proliferation, and endorsed the goal of a world free of nuclear weapons. We also spelled out an action-oriented agenda consisting of a series of specific steps that we believed were both practical and necessary for achieving a world without nuclear weapons.

These results were presented in an essay that appeared in the Wall Street Journal three years ago in January 2007. It emphasized that current efforts in facing the nuclear dangers, commendable though they may be, did not rise to the level of the challenge; and it concluded that "U.S. leadership will be required to take the world to the next stage – to a solid consensus for reversing the reliance on nuclear weapons globally as a vital contribution to preventing their proliferation into potentially dangerous hands and ultimately ending them as a threat to the world." The fact that such a strong call for ridding the world of nuclear weapons appeared in an op-ed headlined by former secretaries of state George Shultz and Henry Kissinger, former secretary of defense William Perry, and former senator Sam Nunn, two Republicans and two Democrats, a nonpartisan group of former high-level US government officials, all of whom were known throughout the Cold War, and still today, to be strong supporters of military strength, triggered quite a reaction.

That essay had an enormous impact. It received an overwhelming positive response from people and leaders all over the world who agreed strongly with both the vision and the urgent importance of the steps that we had identified. We were amazed by this reaction so very different from 1986. Reagan and Shultz were roundly criticized by the nuclear mandarins of that day including many NATO leaders as well as in the United States. Notably, two-thirds of former top level U.S. government national security officials publicly endorsed our goal and efforts. We were encouraged by this response to convene a second conference, one year later, for which we prepared substantive analyses of the specific steps that we had identified as essential to making progress toward our goal.

This conference further informed and strengthened our convictions. It also led to a second Wall Street Journal article that reaffirmed the importance of achieving a world without nuclear weapons, and of the importance of that vision both as a goal and as a compass to guide thinking in the formulation of nuclear policies. It emphasized that the vision of moving toward zero was necessary to generate global cooperation to implement the steps to pull us back from the precipice of nuclear proliferation and to make progress toward turning the vision into reality. Like its predecessor, the article received major support world-wide. And just as we were thinking about how to carry our message out of country to the international community, to learn from colleagues from other countries what reactions they had, what was their thinking, did we have things right or wrong from their point of view, the Norwegian government made an offer we couldn't refuse. Its Foreign Office invited us to come to Oslo in February 2008 – 2 years ago – for a conference to do just that. We met with about 100 scholars, military, former government folks from 29 countries including all the nuclear powers.

We learned a lot in Oslo. We found strong support for our message and efforts to rekindle and realize the vision of a nuclear free world. Perhaps the most important message was this. That support came with an important condition: the nuclear states had to show their sincerity, their honest commitment to working together toward a world in which there was, in the currently popular phrase, "a level playing field." The days were over, we heard, for a two-tier system of some nations with, and many without, nuclear weapons. And the same holds true for preserving two tiers of nations that can or cannot enrich uranium, a dual-use technology that can provide fuel, both for reactors to produce civilian power and for making nuclear weapons.

Many expressed concerns that the major nuclear powers – U.S., Russia, China, England, and France – were not living up to the commitment in Article VI of the Non-Proliferation Treaty to work toward getting rid of all of these weapons. They viewed continuing efforts to modernize and improve current nuclear forces to be inconsistent with that goal. We heard that they no longer were willing to sit by passively and watch this pattern of behavior continue without advancing their own nuclear capabilities. Yes, they were impressed by the reduction of the numbers of nuclear warheads (Figure 2), but they were deeply concerned with the growing threat of proliferation and also frustrated by the unwillingness of the United States, in particular, to join the large majority of the other nations – both with and without nuclear weapons – who have ratified the Comprehensive Test Ban Treaty.

There is no doubt that we will have to overcome very difficult obstacles to gain the broad international support required to make serious progress forward. In order to prevent proliferation and further reduce existing nuclear forces, the nuclear powers will have to convince the other 180 nations in the world that we embrace, together with them, the bold vision of Reykjavik as an essential part of the process. Otherwise, the individual steps that we identified are unlikely to be perceived as fair or urgent. The vision and the steps are tightly connected. The vision is necessary to accomplish the steps, and these steps in turn must be implemented if the vision is to be perceived as realistic or possible. The good news is that no law of nature stands in the way of ridding the world of nuclear weapons; only political problems that, in principle, can be overcome. The bad news is, as Einstein once said, "Politics is much harder than physics." But it is very encouraging that many current world leaders have now actively embraced, and are willing to cooperate to achieve the vision of Reykjavik.

President Obama has endorsed the need to escape the trap of nuclear deterrence as we have known it for the past half century. As he remarked in his acceptance of the Nobel Peace Prize in Oslo three months ago: "A decade into a new century, this old architecture is buckling under the weight of new threats. The world may no longer shudder at the prospect of war between two nuclear superpowers, but proliferation may increase the risk of catastrophe. Terrorism has long been a tactic, but modern technology allows a few small men with outsized rage to murder innocents on a horrific scale." It is important that this message has broad bipartisan support in the United States, expressed in particular by Senator McCain both during his presidential campaign, and since then.

Both Obama and the Russian President Medvedev, at their first meeting on April 1, 2009, committed their governments to work together toward eliminating nuclear weapons. The leaders of the two largest nuclear weapons states officially committed their countries "to achieving a nuclear free world, while recognizing that this long-term goal will require a new emphasis on arms control and conflict resolution measures, and their full implementation by all concerned nations."

Toward this end the US and Russia have re-engaged in pursuit of new and verifiable reductions in our strategic offensive arsenals in a step-by-step process, beginning by replacing the recently expired Strategic Arms Reduction Treaty with a new, legally binding treaty.

And the UN Security Council, in its first comprehensive action on nuclear issues since the mid-1990s, unanimously adopted Resolution 1887, which begins: "Resolving to seek a safer world for all and to create the conditions for a world without nuclear weapons…"

I am encouraged to believe that the prospects for a global effort directed toward achieving a world with no nuclear weapons are very much enhanced by such expressions of support by senior leaders. But the challenge is daunting. I will illustrate what I mean by this by discussing six specific steps that present challenges that have to be overcome enroute to achieving this goal.

We may have won the rhetorical battle, so far, but now it is necessary to get down to the brass tacks and move ahead.

- **START Follow On**
- **Short Range, Battlefield Nuclear Weapons**
- **Fissile Material Production Cut-Off**
- **International Control of the Nuclear Fuel Cycle**
- **Additional Verification Teeth for the Nuclear Non-Proliferation Treaty (NPT)**
- **Comprehensive Test Ban Treaty (CTBT)**

Figure 3

(Figure 3) Step 1: The US and Russia are currently negotiating an extension of the 1994 START Treaty. (See what has been accomplished by March 16) Beyond that we must proceed with deeper reductions beyond those that are anticipated to emerge, hopefully soon, from the current negotiations on the START extension, which approximate 1500 nuclear warheads and 700 launchers as a ceiling for each side's intercontinental range forces. In order to make such deeper reductions, it will require a formal agreement to extend essential monitoring and verification provisions beyond these contained in the 1994 Treaty, including compliance with limitations on non-deployed or reserve forces in addition to those deployed. We have found through experience in the last several decades that we can agree on counting rules for deployed warheads, or warheads designated as deployed, using established approaches and techniques. However monitoring non-deployed warheads will require an increased level of intrusiveness to verify compliance. Well before the numbers decrease from today's levels into the hundreds, other nations will have to enter into the discussions with us.

Step 2: It will also be necessary to include in the limitations not just strategic or long-range intercontinental delivery systems and warheads, but also shorter range tactical nuclear weapons, many of which currently are deployed in or near the border of Europe. This will require reviewing their role, a subject that has already stirred debate in a number of NATO countries.

Last October 25, Germany's Foreign Minister Guido Westerwelle said the German government would "enter talks with our allies so the last of the nuclear weapons still stationed in Germany, relics of the Cold War, can finally be removed." Turkey, which hosts a handful of U.S. tactical nuclear bombs, officially supports inclusion of all non-strategic nuclear weapons in the disarmament process. This was recently emphasized in a New York Times op-ed published last month by the Polish and Swedish Foreign Ministers Carl Bildt and Radek Sikorski.

Withdrawing all such sub-strategic nuclear weapons from Europe will present even greater challenges, since they will require more transparency and cooperation between all countries involved. This class includes smaller and more portable nuclear weapons designed for forward deployment that are particularly inviting for terrorist groups to attempt to acquire. For as long as they remain, these weapons, together with all nuclear material, should be secured to the highest possible standards.

Step 3: Similarly it will also be important to negotiate a verifiable treaty – the proposed Fissile Material Cut-Off Treaty – that bans the production of more fissionable nuclear material that can be used as fuel for atomic bombs. It may not be simple, but it is not at all impossible for

sub-state units who manage to get their hands on no more than 50 kilograms of highly enriched uranium to assemble a crude nuclear device of the type that was dropped on Hiroshima. The most effective tools for reducing this risk are to reduce the size of the nuclear arsenals, and to provide strong security protection while reducing the large quantity of weapons useable material worldwide.

Step 4: Another urgent step is to establish international control of the nuclear fuel cycle. The growing worldwide demand for energy to meet civilian needs and aspirations, and for limitations of greenhouse gases that contribute to global warming, has led to a resurgence of interest in building nuclear reactors. This will inevitably lead to an increase in the potential for the spread of sensitive nuclear fuel cycle technologies, most directly through enrichment of uranium at the front end of the cycle. Proliferation concerns are also raised by technology to recapture weapons-grade plutonium by reprocessing spent fuel from nuclear reactors; often referred to as the back end of the nuclear fuel cycle. The fundamental point here is this: nations that develop an indigenous infrastructure for civilian nuclear power using today's most prevalent technology of light water reactors, also acquire the technical infrastructure to build a nuclear bomb. This technology has dual uses, military as well as civilian.

Here is the arithmetic for an illustrative example involving uranium enrichment. To power a light water reactor the uranium fuel must be enriched to about 4% of the fissioning isotope 235; to produce 1 gigawatt of electric power annually the reactor will burn up each year about 1,000 kilograms of 235. By way of contrast the uranium to fuel a primitive bomb of the gun-type that destroyed Hiroshima must be enriched to about 90% 235. However gas centrifuges commonly used for the enrichment require only about 40% more work to produce 1 kilogram of bomb fuel compared to reactor fuel that contains 1 kilogram of U235. The most difficult challenge is to master the technology for enrichment, not just the percentage of enrichment. Since the amount of fuel in the bomb is less than $1/20^{th}$ of the 1,000 kilograms that a reactor will burn each year, it is clear that an enrichment plant that can provide fuel for the reactor is a good deal larger than what is needed to fuel one or a few simple bombs during that time.

A country that acquires civilian nuclear power, consistent with Article IV of the NonProliferation Treaty, thus becomes a latent nuclear power. This is the underlying issue we are now facing in the discussions with Iran. The only way to contain and control this danger of proliferation is by establishing a mechanism for international control of the fuel cycle at all stages – enriching the fuel, maintaining control of the fuel during its burning in the reactor, and, if deemed economically desirable, reprocessing spent fuel from the reactor. Furthermore it will be necessary for such a cooperative regime to guarantee availability of the needed supply of fuel to all nations that agree to comply with the non-proliferation treaty. This clearly will be a very difficult problem to work out because it brings into play concerns about sharing economically valuable proprietary information that will be placed under international control. With the growing interest in nuclear power for clean energy and less dependence on Mid-East oil, more than a few countries have expressed new interest in developing such a nuclear power infrastructure, and discussions are in progress. This clearly presents a most difficult and urgent problem to solve.

Step 5: Another aspect of this problem is giving the NonProliferation Treaty sharper verification teeth than it has in its present form. This is evident in the current tensions with Iran's nuclear program, and in the record of North Korea, as it also was in the run up to the Iraq war. At present, nations must declare their nuclear power sites and allow access to them to verify that no fuel is being diverted for military uses. But what about non-declared sites where the IAEA currently lacks authority to make on-site challenge inspections of suspect activities. There are currently efforts in progress to remedy this problem. A number of nations – roughly

one-half of the total – have signed onto Additional Protocols that permit onsite challenge inspections of all suspect activities. Uniform global acceptance of these protocols is being sought but remains to be established. Furthermore for the "verification teeth" to be effective they must be supported by the intention and ability to be enforced. The words must mean something. The recently adopted UNSC Resolution 1987 contains several provisions for strengthening the IAEA.

Step 6: Next comes the task of bringing the Comprehensive Test Ban Treaty into force.

The CTBT bans all explosive tests that produce any nuclear yield as a consequence of initiating a nuclear chain reaction. Such nuclear explosive tests would be required to validate new weapons designs that incorporate more advanced technology than used in the most primitive gun type uranium bomb dropped on Hiroshima.

The United States was the first signatory of the CTBT in September 1996. Since then it has been signed and ratified by 152 countries, i.e. 80% of all nations, including all U.S. NATO allies, plus Russia and Japan. All 44 nations that are identified in the text of the CTBT – the so-called Annex 2 countries designated as nuclear capable – must ratify the Treaty before it enters into force. So far 35, or all but 9, have done so. In addition to the U.S., other countries who have yet to ratify the CTBT are China, a key hold-out waiting for us to act, plus India and Pakistan who have not yet signed the Treaty and are unlikely to do so unless the U.S. acts also. Egypt, Indonesia, Israel, Iran, and North Korea are also holdouts. President Clinton sent the CTBT, which he called the "longest sought, hardest fought prize in the history of arms control negotiations", to the Senate in 1996. When the Senate considered it three years later in 1999 it fell far short of winning the support of a 2/3rds majority that is necessary for the Senate to recommend ratification. In fact the Senate debate preceding this vote was a very cursory one, and the main issues never were adequately discussed.

U.S. unwillingness to ratify the CTBT and take leadership to bring it into force is a cause for growing concern in many nations, and was evident in our meeting in Oslo two years ago. The CTBT has long been seen as a litmus test of the nuclear states' commitment to Article VI of the NonProliferation Treaty which calls for pursuing measures leading toward nuclear disarmament. The U.S. already has taken hard licks on this issue in the last two NonProliferation Treaty review conferences, and can expect strong pressure at the scheduled five-year NPT review conference in May. Ratification of the CTBT by the U.S. is a big deal. As former Secretary of State and Chairman of the Joint Chiefs of the U.S. Military, General Colin Powell, said in Senate testimony in 2002: "It is the centerpiece of the global nonproliferation regime."

This prompts the question: why has the United States been unwilling to ratify this treaty despite growing support worldwide? Technical issues that were raised in the 1999 Senate debate focused on two concerns: our ability to maintain a safe, reliable and secure nuclear deterrent, without underground explosive tests, until we no longer need them; and, secondly, the ability of the International Monitoring System to detect explosive yields down to such low levels that tests evasively performed below that level would be essentially useless to a cheater trying covertly to develop a new threat to our security. I will address these two concerns briefly.

Following the moratorium on underground tests initiated in 1992 by the first President Bush, the United States established a broad science-based Stockpile Stewardship Program (SSP). There is now general agreement in the United States that this program, to date, has achieved remarkable successes. Its accomplishments have enabled the directors of the nuclear weapons laboratories to assert that at present there is no need to conduct nuclear test explosions for them to certify that the deterrent meets the requirements of safety, security, and reliability to function as intended.

The achievements enabling the United States to maintain a safe, secure, and reliable nuclear arsenal, without explosive testing since 1992, have been made possible by important advances in scientific understanding of nuclear explosions. Here are two specific examples:

A thorough study by the Los Alamos and Lawrence Livermore National Laboratories, relying on data mining of previous tests plus new laboratory work, has removed a critical concern about the stability of the plutonium metal in the pits as it ages due to radioactive decay while sitting in the stockpile. We can now confirm that pit lifetimes are longer than 85 to 100 years.

JASON, an independent defense advisory group of senior scientists, who had full access to the pertinent classified information, recently completed a study commissioned by the government that concluded more broadly: the "[l]ifetimes of today's nuclear warheads could be extended for decades, with no anticipated loss in confidence, by using approaches similar to those employed in Life Extension Programs to date." However, looking to the future, the study team also emphasized the need to provide adequate and stable funding for the program in order to ensure the safety, reliability and effectiveness of the shrinking US arsenal. Such an investment will also strengthen trust and confidence in US technical capabilities to take the essential steps needed to reduce nuclear dangers throughout the globe. These capabilities include preventing proliferation and preventing nuclear weapons or weapons-useable material from getting into dangerous hands.

The second technical question raised during the failed ratification debate was the ability to verify compliance with the treaty consistent with the security needs of the United States. A number of technical developments and studies since that Senate debate in 1999 have greatly strengthened the case for answering this question in the positive. First of all, there were detailed studies, one commissioned by President Clinton and led by former Chairman of the Joint Chiefs General John Shalikashvili in 2000-2001, and a second one by the National Academy of Sciences in 2002. Both drew the conclusion that the answer to that question is positive. More recently in the fall of 2006 the North Koreans detonated a nuclear device of very low-yield. Whether this was a fizzle or a deliberate choice is still debated. I believe a fizzle is more likely than a planned yield of only ½ kiloton because of the practical difficulty in attempting to predict so small a yield with precision in an initial test. Nevertheless this low yield – only about 3 percent of the Hiroshima bomb – was clearly detected and identified by many stations, near and not so near to North Korea. This event, and a second one in 2009 of somewhat higher yield, confirmed the impressive sensitivity of the International Monitoring System, which is now largely – about 80% overall – complete. When finished it will consist of more than 300 globally-deployed sensors: seismic (50 primary 100 secondary) hydroacoustic (11), infrasound (60) (0.001-20Hz) and radionuclide (80 for detecting Xe133 that escapes into the atmosphere). Currently it is working very well. Moreover, unlike many reconnaissance systems, it doesn't have to be directed and is constantly on station. It is further enhanced by national research facilities around the world that share their findings and showed their own power beyond the IMS in locating, identifying, and calibrating such events, not to mention individual nations' intelligence systems.

During the coming year I hope the U.S. Senate, after careful preparation, will again consider CTBT ratification. The major achievements made during the past decade in maintaining high confidence in our nuclear arsenal under a test ban, and toward completing the International Monitoring System, have greatly strengthened the technical case for the United States to ratify the CTBT. There are good reasons for legitimate skeptics in 1999 to support ratification now.

So far I have been talking about what Michael Quinlan has called "disarmament mechanics." But once we cross the threshold into the End State of zero nuclear weapons we will encounter

new conceptual issues of great difficulty. You may rightly think it is absurdly premature to be thinking now of what a world without nuclear weapons would be like in a more than a casual way. The path ahead to reach that goal is a long one and already presents major obstacles that we have to surmount. But if we are to generate a serious commitment from nations around the world to join in the effort to implement the steps to reach the End State, we and they must understand what we are working toward well enough to make the goal seem credible.

Upon entering the end state from which nuclear weapons have been eliminated we would be in an entirely new situation of deterrence with no deployed or reserve nuclear weapons as first described by Jonathan Schell in his 1984 book "The Abolition." As he emphasized, this would not be a return to the pre-nuclear weapon world of 1944 since we would retain the knowledge of nuclear weapons – they wouldn't have to be reinvented.

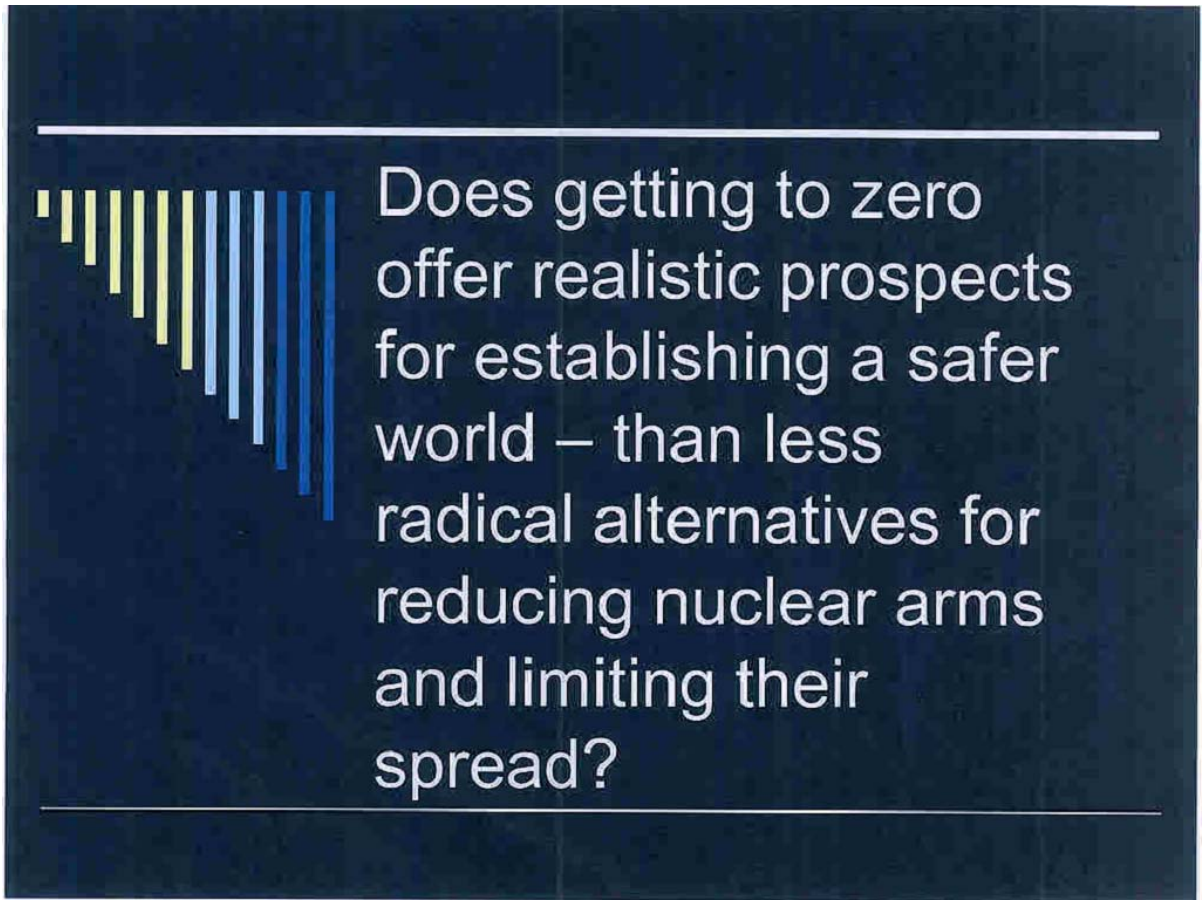

Figure 4

During final approach to zero, nuclear weapons nations will most likely maintain a basic nuclear infrastructure sufficient to ensure effectiveness of their shrinking stockpile. This will provide a capability for reconstitution that won't automatically disappear once all nuclear weapons have been eliminated. It also raises a daunting challenge to the whole idea of going to zero. If some nations retain such a hedge capability to reconstitute nuclear forces, would it be an invitation to a reconstitution race? Could conditions of stable strategic deterrence be developed under such conditions? Does in fact getting to zero offer realistic prospects for establishing a

safer world – if not a safe one, nevertheless safer than less radical alternatives for reducing nuclear arms and limiting their spread? (Figure 4)

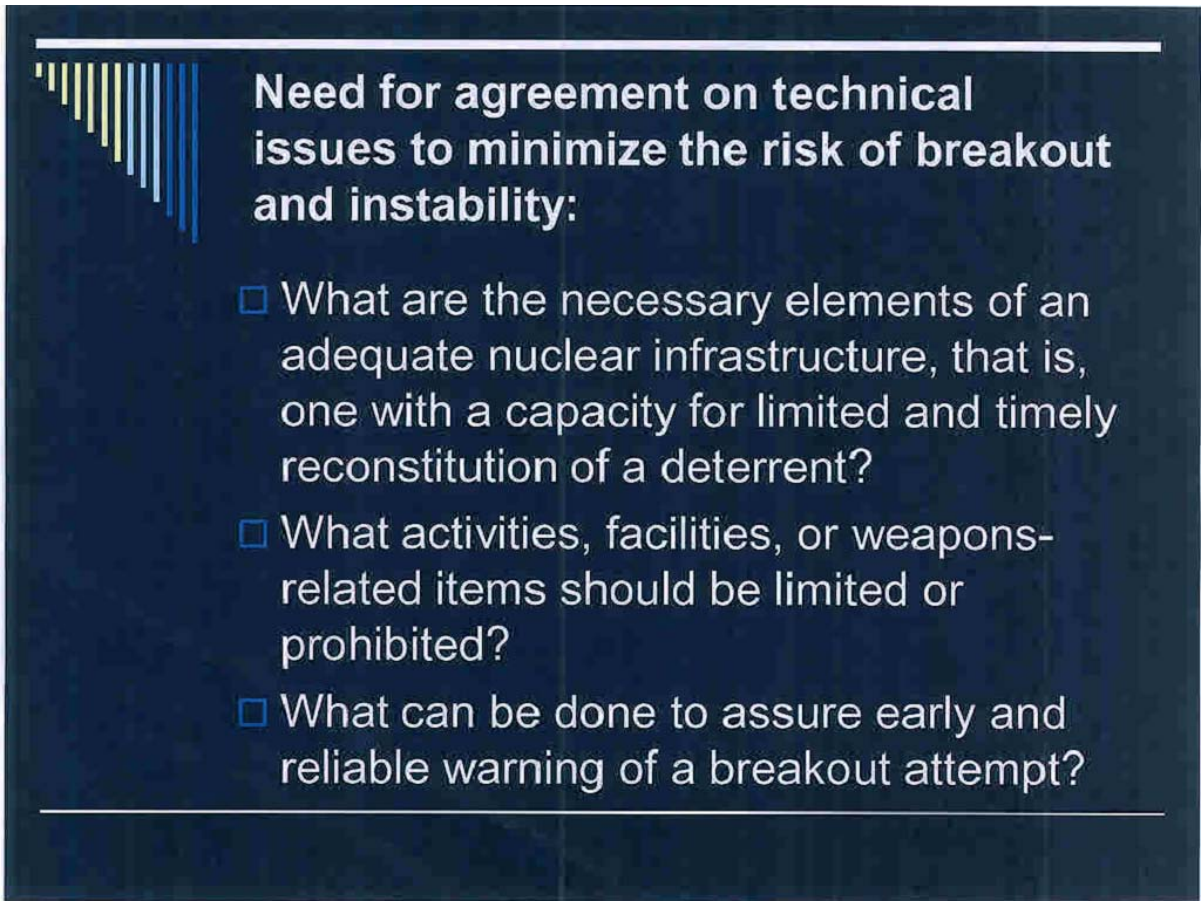

Figure 5

These are challenges we must begin to face up to. They will require new conceptual thinking. For example, (Figure 5) what are the necessary elements of an adequate nuclear infrastructure, that is, one with a capacity for limited and timely reconstitution of a deterrent? What activities, facilities, or weapons-related items should be limited or prohibited? What can be done to assure early and reliable warning of a breakout attempt? My colleague, Former Ambassador James Goodby, and I at Stanford's Hoover Institution are working on these questions, as are several others at other institutions, most notably George Perkovich and James Acton.[1] We have made a start[2] on a very difficult problem that I hope will draw serious attention particularly from the scientific community.

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[1] George Perkovich and James M. Acton, *Abolishing Nuclear Weapons*, Adelphi Paper No. 396, London: International Institute for Strategic Studies, 2008, 130 pp., ISBN: 9780415465830.

[2] *A World Without Nuclear Weapons: End-State Issues*, Sidney D. Drell and James E. Goodby, Foreword by George P. Shultz, http://www.hoover.org/publications/books/online/51319522.html

Getting to zero and monitoring the end state will require more comprehensive cooperation and improvements in all types of verification tools: national technical means, data exchanges, on-site inspections (both routine ones and those prompted by a challenge), perimeter and portal continuous monitoring, tags and seals, sensors and detection devices to monitor nuclear activity and the resulting effluents, remote viewing as conducted already by the International Atomic Energy Agency (IAEA).

It is evident that as we arrive at the End State, we will have banned the existence of a ready-to-use arsenal, but not eliminated the capability to re-build one. Inequalities will remain between former NWS and NNWS in building or reconstituting a nuclear capability. Inevitably, as confidence increases in managing stability in a world without nuclear weapons, such disparities will decrease over time. But until they wither away, we will face a major challenge to monitor and verify permissible activities that are part of a responsive nuclear infrastructure, even after reaching zero.

It is important to recognize that, in a world without nuclear weapons, we will not have done away with, or rejected, deterrence. A successful deterrent policy has the virtue of avoiding military conflict. To achieve this, and establish a stable world at peace, a nation must be prepared to meet its security requirements to respond effectively to hostile actions. But deterrence does not require nuclear weapons and, as we have argued, we will be better off in a world without them. The path to removing them starts by reducing the warhead numbers, and then by stretching out the time scale for their reconstitution. Today the delay between a decision and the actual ability to launch nuclear weapons can be as short as minutes. After we have removed all of them and are relying on a "virtual arsenal" that has to be reconstituted, that time would be measured in months or longer. As the numbers of nuclear weapons decrease toward zero, so will their damage potential, but until we reach the goal of a "virtual arsenal" we will still be vulnerable to the devastating effects – both physical and societal – of one or a few bombs delivered and detonated covertly by suicidal terrorists in urban areas.

There is a lot of hard work ahead on both technical and policy issues. Those who see hope for a world without nuclear weapons need to get to work on achieving it.