

Chapter 6

Nuclear Weapons Arms Control

6.1. Brief Background

My interest in controlling nuclear weapons was originally prompted by the Cuban Missile Crisis of 1962. Gina, my teacher wife, was encouraged by her school principal to fill our bathtub with water. We did this in spite of the fact that Urbana and the University of Illinois were very unlikely targets. It seemed unreal. What would have happened if Khrushchev had not capitulated? Why was he constrained to keep the knowledge of the removal of US missiles from Turkey a secret, while his removal of missiles from Cuba was front-page news.

Two years later I obtained a fellowship to the Los Alamos National Laboratory, to do basic, unclassified physics studies on nuclear and condensed matter. During these two years, LANL gave new temporary employees secret briefings on nuclear weapons. The main lecturer was Samuel Glasstone, the well-known co-author of the text, *The Effects of Nuclear Weapons*. It didn't make sense to tell these secrets to those of us who intended to return to the University. Two big events took place during my time in New Mexico. On October 16, 1964, China exploded its 1st nuclear bomb. It took them only 3 years to move from fission weapons to the hydrogen fusion bombs. Suddenly, we had to confront the issue of proliferation beyond the U.S. and the Soviets. I wondered if anyone was in control of the situation. The 2nd event was the January 17, 1966 crash of a B-52 bomber near Palmares, Spain. Plutonium was spread across the tomato fields from two H-bombs. The other 2 H-bombs landed in the ocean. One was found quickly, but the second one was more difficult to find. Finally, a Spanish fishermen told a US official that he thought he saw where the bomb entered the ocean. He was correct but it was about to fall into a deep ocean canyon. Finally, the submersible Alvin collected it. Again it seemed like no one was in charge. But, I had a family to raise, classes to teach at Carnegie Mellon and Cal Poly, and physics research to do. After all, the US-Soviet Cold War was big and I was infinitesimal.

It was my pleasure, to make friends with Max Riedlspurger at Cal Poly. Max was a lively expert in Russian and Austrian history. He told me about his class on the history of Russia, so I audited him for the year. I didn't do homework or take exams, but I absorbed lots of Soviet history. During the initial Reagan years there was concern about an expanding arms race as both the U.S. and Soviets were deploying new nuclear systems. Was anyone in control? The major argument used against arms-control treaties was that verification wasn't good enough to prevent the Soviets from breaking out and attacking the U.S. In response to this, I spent a year at MIT with Kosta Tsipis, obtaining grant money to run a conference and produce a book, *Arms Control Verification* (Pergamon). The two introductory chapters were written by former intelligence leaders, Admiral Noel Gayler, former director of the National Security Agency, and William Colby, former Director of the Central Intelligence Agency. We obtained technical chapters from an excellent group of monitoring experts. My chapter, "A *breakout from arms control treaties: A sensitivity analysis*," showed that the US retaliatory, second-strike force retrained much of its

robustness after an attack. The book got good reviews, and the CIA library bought three copies. There had been good books on *political aspects* of verification but very little on technical aspects. The results of the book were summarized in the March 1985 issue of *Scientific American* and entitled “*Verification of Compliance to Arms-Control Agreements.*”

Home computers of the late 1970’s allowed us to quantify analysis of arms control issues. I marketed a disk with 15 programs and an 80-page manual for \$10, which was used in a debate on the *freeze movement* in Little Bridges Hall, Pomona College. By varying parameters for yield, reliability, hardness, number of warheads per target, and total number of warheads, one could determine the surviving forces. To add a flare, a joystick was used to add the bias-error from gravitational uncertainties. *Minuteman vulnerability* was a hot issue in the 1980s. This disk allowed you to determine US surviving forces when the Soviets attacked with a worst-case analysis. One of the panelists at the meeting was Sam Cohen, the inventor of the neutron bomb.

6.2. Back-Channel Soviet-American Study on SDI

On March 23, 1983, President Reagan gave his famous speech on the Strategic Defense Initiative. In this speech Reagan called for SDI “to make nuclear weapons impotent and obsolete.” I published a couple modest papers on the x-ray laser as pumped with a nuclear explosion and the necessary scientific requirements needed to place effective beam weapons in space. I was asked by the Federation of American scientists to join a joint American-Soviet study group on these issues. In 1987 I traveled to Washington to meet my Soviet counterparts. This was a big deal, as I had never met a live Russian communist. I easily spotted our counterparts on the sidewalk.

Our subgroup was tasked to examine the use of nuclear power in orbit to make electrical energy for the beam weapons. The SDI program had been heralded as a nonnuclear program, but this did not consider nuclear power for electricity. It was clear you would need nuclear power in orbit because of the large energy requirements for neutral particle beam weapons and rail guns. Our subgroup consisted of three American and three Soviet scientists. The Soviets were led by Roald Sagdeev, the Director of the Institute of Space Research of the USSR Academy of Sciences. In addition, Sagdeev was the Chairman of the Committee of Soviet Scientists for Peace and Against the Nuclear Threat. Sagdeev was accompanied by Oleg Prilutsky and Stanislav Radionov. The three Americans were Joel Primack, Physics Professor, UC Santa Cruz; Steve Aftergood, Director of the Committee to Bridge the Gap and myself. Our research resulted in a paper, “*Nuclear Power in Space*”, in the June 1991 *Scientific American*, and 5 papers in *Science and Global Security*. These papers showed it was easy to monitor a ban on nuclear power reactors in space, since reactors emit copious amounts of infrared radiation, which is readily detectable. Data was obtained at the NASA Ames Laboratory, Moffett Field, California by participating in an overnight flight at 45,000 feet in the Kuiper Airborne Observatory. If the ban on nuclear power in orbit had been accepted it would have constrained SDI and saved considerable funding.

Twenty-five years later, what do I think of this joint American-Soviet research on arms control? Were the Soviet scientists part of an effort to use naïve American scientists? I am totally convinced that these 3 scientists from the Soviet Union were honorable people with international survival as their first criteria. We had productive and honest debates as we worked on the science

and technology of nuclear power in Earth orbit. After the Cold War ended, Sagdeev became a professor of physics at the University of Maryland, marrying Susan Eisenhower, President of the Eisenhower Foundation and granddaughter of President Eisenhower.

While at the National Academy of Sciences, I had a chance to chat several times with Roald and Susan. I recalled quizzing Sagdeev on whether SDI had an impact on the way the Cold War ended. He pointed out that much was known through the back channel with our National Academy of Sciences panel, with physicists Richard Garwin and Wolfgang Panofsky. The basic science, as shown by the 1987 American Physical Society study, showed that SDI needed several orders of magnitude improvement in many areas before it might be of some interest to destroy incoming missiles. Sagdeev and Evgeny Velikhov, Vice President of the USSR Academy of Sciences and Director of the Kurchatov Institute and Member of Central Committee of the Supreme Soviet, had excellent access to President Mikhail Gorbachev. They knew that Gorbachev knew that SDI was an immature project and it didn't have to be feared. I agree with those that concluded that SDI did not shorten the Cold War, and if it did have an effect it was to extend the Cold War, rather than to speed its end. SDI slowed agreement on START and on nuclear testing at Reykjavik, this slowed the conclusion of the Cold War by months.

6.3. Arms Control in President Reagan's State Department

The Strategic Arms Reduction Treaty, START

From January to December of 1987, I was a visiting science fellow in the Office of Strategic Nuclear Policy in State's Bureau of Politico Military Affairs, working on START, the Intermediate Nuclear Forces Treaty (INF), the Anti-Ballistic Missile Treaty (ABMT) and the Threshold Test Ban Treaty (TTBT). Here are a few dates to put things in perspective:

December 8, 1983: Soviets suspend START negotiations because of US Intermediate Nuclear Force deployments.

October 14, 1985: Secretary of State George Schultz accepts the broad interpretation of the ABM Treaty as "fully justified" to allow SDI testing of other *physical principles* in space.

October 11–12, 1986: Reagan and Soviet leader Mikhail Gorbachev agree to cut strategic weapons by 50%. They almost agreed to ban all nuclear weapons, but the issue of SDI-ABM tests and limitations scotched the deal. When I arrived in January of 1987, the State Department was confused by this attempt to abolish all nuclear weapons. Twenty-five years later the spirit of Reykjavik has blossomed by senior diplomats Kissinger, Schultz, Perry and Nunn to abolish all nuclear weapons, but without a specific plan.

November 28, 1986: The 131st B-52 bomber with air-launched cruise missiles is deployed, ending SALT II. The U.S. is the 1st country to publicly renounce an arms-control agreement.

December 1986: Ten Peacekeeper missiles become operational in Minuteman III silos.

The Office of Strategic Nuclear Policy (SNP) was the State Department's lead location for negotiations on arms control treaties. The negotiations on START had been going on for half-dozen years, but the discussions at Reykjavik gave it political push. I was asked to co-chair, with the Defense Department, a subcommittee of the START working group. The subcommittee was

to examine the ratio of throw weight to launch weight for all missiles. Each of the super-powers has its own advantages in the missile race.

The U.S. had advantages in accuracy of aiming, reliability, and the invulnerable submarine fleet. The Soviets had an advantage in the size of their missiles. The SS-18 was incredibly large and could have carried more than 20 warheads, twice its listed 10 warheads. And Soviet warheads were slightly bigger, perhaps 500 kton compared to the US ILBMs of 350 kton and SLBMs at 450 kton. The disparity in physical size can be worrisome, but it has been overused by those who believe the Soviets could carry out a successful first strike on the United States. Senator Scoop Jackson, would hold a model of an SS-18 next to a model of a Minuteman to traumatize the audience. This was fraudulent, because accuracy is far more important than yield. If you reduce the accuracy from 200 meters to 100 meters you can reduce the yield of warheads by a factor of eight (8!) for the same lethality effect. The U.S. is stronger in this important respect since US accuracy is 100 m and Soviet accuracy is 200 to 250 m.

To worry about Minuteman vulnerability by itself is not being complete. The Soviets would have to be suicidal to attack a Minuteman base. If they could get 100% of the Minutemen, which they couldn't, they would still have to contend with 14 submarines with 24 missile tubes each carrying 8 warheads, for a total of 5000 warheads to respond. And the US has other warheads on bombers and other systems, which are better than the Soviets. The Soviet air defenses were shown to have holes on several occasions. The issue of throw-weight to launch-weight is a surrogate argument for cheating potential. A missile with a throw-to-launch ratio of 5% is good, if it's 3% it's not good. What really has to be done is a sensitivity analysis, which I did in the MIT verification book, to determine what survives of the total US nuclear force. My SNP/State boss co-chaired the interagency group and was interested in my spread-sheet analysis of Soviet Testing, but he was too timid to present them in the interagency forum. I was told to pass along to people in various agencies but they were not to be presented under the signature of the assistant secretary. These results were classified because the whole START process is classified, but they were of the type that I and others had already published. The only reason to classify them is so that the Soviets would not know what the U.S. was thinking, but there was nothing that would endanger national security by putting them in the newspaper. Or was it to diminish substantive discussion in the domestic press?

The ABM Treaty

The March 23, 1983 Reagan's speech called for the strategic Defense initiative to make nuclear weapons impotent and obsolete." The new defensive technologies for SDI would depend on directed energy weapons systems, such as neutral particle beams, chemical lasers, x-ray lasers, rail guns and so forth. In my view, Agreed Statement D of the ABM treaty bans testing these weapons in space. I recall calmly riding the elevator with Judge Abe Sofear, who wrote the legal finding that that gave Secretary Schultz the broad interpretation of the ABM treaty to allow SDI tests in space. It was my task to develop a monitoring scheme to put limits to the measured sizes with new verification technologies, an approach suggested by Ambassador Paul Nitze.

The American physical Society was asked in 1985 by the *Presidential Office of Science and Technology Policy* to investigate SDI technologies. The APS report was declassified in 1987.

The APS group was prepared to speak at the classified level to the Executive Branch, but they were not invited to do so. I got a call in State from the Executive Director of the APS, Bill Havens, asking me to set up a briefing for State and ACDA. I checked with my-ABM boss who concurred. I set up the room and invited in the State and ACDA (Arms Control and Disarmament Agency) scientists. Later my ABM-boss said he gotten a call from the White House, canceling the briefings. We chatted and agreed that State and ACDA should not be denied technical information. His only request was to move it to a room on the 1st floor since it was more isolated from State-ACDA, which I did. I then told the attendees and my contact at Office of Science and Technology Policy (OSTP) about the new room. My boss then got a second call from the White House, saying that if briefing leaked to the press we would be in big trouble. I later found out that the OSTP under William Grapham, who had funded the APS project, was behind the cancellation threats. At the APS-ABM meeting, I cautioned everyone that this should not be leaked to the press or I would be in serious trouble. It did not leak!

The APS report on SDI technologies was science and public policy at its best. The panel of 17 scientists was extremely qualified, with excellent professional reputations. The panel was made up equally by those who were actively involved in SDI research at DOE/DOD/private laboratories, and those from academia. This was an excellent combination because the practitioners had seen the data, written the papers and reports, and were prepared to determine new results, and the academic scientists were imminently well-qualified scientists. Let me quote some of the conclusions (*Reviews of Modern Physics*, July 1987):

Although substantial progress has been made in many technologies of Directed Energy Weapon Systems over the past two decades, the study group finds significant gaps in the scientific and engineering understanding of many issues associated with the development of these technologies. Successful resolution of these issues is critical for the extrapolation to performance levels that would be required in an effective ballistic missile defense system. At present, there is insufficient information to decide whether the required extrapolation can or cannot be achieved. Most critical elements required for a DEW system need improvements of several orders of magnitude. Because the elements are inter-related, the improvements must be achieved in a mutually consistent manner. We estimate that even in the best of circumstances, a decade or more of intensive research would be required to proved the technical knowledge needed for an informed decision about the potential effectiveness and survivability of directed energy weapon systems. In addition, the important issues of overall system integration and effectiveness depend critically upon information that, to our knowledge, does not yet exist.

This paragraph does not say that that SDI will fail. However, the more you dig into this paragraph and the report, you will see that it is unlikely that these technical barriers will be overcome because of questions of the amount of fuel on board, accuracy in timing, countermeasures by the Soviets, reliability over decades, and so forth. Recall that the SDI system could never be tested in its entirety, but only on a piece-meal basis, before it's called to defend the U.S. The APS report did not examine the more complex system questions, but mainly examined if there could be enough energy on target with the proper resolution to destroy the incoming missile within the time allotted and it distances of the thousands of miles. The APS report was not strongly worded, but stuck to numerical estimates and assumed best-case analysis in many places. Let's briefly quote some APS conclusions:

We estimate that chemical laser output powers at acceptable beam quality needs to be increased by at least one order of magnitude for HF/DF lasers for use as an effective kill weapon in the boost phase.

This might not sound insurmountable, but it really is when you consider volume and costs. And

it ignores other problems with chemical lasers in orbit such as its basing duty factor, burning a hole in the defense, under shooting the laser barrier and counter measures.

... excimer lasers... need improvements by at least four orders of magnitude.... Free electron lasers operating near 1 μm will require validation of several physical concepts... Neutral particle beam accelerators must be scaled up by two orders of magnitude in voltage and duty cycle.... Ground-based laser systems for BMD applications need geographical multiplicity to deal with adverse weather conditions... Ground-based laser systems require techniques for correcting atmospheric propagation aberrations. We estimate that these techniques must be extended by at least two orders of magnitude in resolution than presently demonstrated. Phase correction techniques must be demonstrated at high powers... Nonlinear scattering processes in the atmosphere impose a lower limit on the altitude at which targets can be attacked with a laser beam from space... Detection and acquisition of ICBM launchers will pose stringent requirements for high detection probability and low false alarm rates.... For boost phase, infrared tracking of missile plumes will have to be supplemented by other means to support sub-microradian aiming requirements of DEWS.... For post-boost and mid-course, precision tracking will require active sensor systems... For midcourse, when the RVs are interspersed with penetration aids, interactive discrimination may be required... Housekeeping power requirements for operational maintenance of many space platforms for strategic defense applications necessitate nuclear reactor driven power plants on each of these platforms... During engagements, prime power requirements for electrically driven space-based DEW present significant technical obstacles.... Survivability is an essential requirement of any BMD system employing space-based assets; such survivability is highly questionable at present.... Survivability of ground-based facilities also raises serious issues... Directed energy weapons with capabilities below those needed for many ballistic missile defense applications can threaten space-based assets of a defensive system... X-ray lasers driven by nuclear explosions would constitute a special threat to space-based sensors, electronics and optics... Nuclear-explosion-pumped x-ray lasers require validation of many of the physical concepts before their application in strategic defense can be evaluated... Since a long time will be required to develop and deploy an effective ballistic missiles defense, it follows that a considerable time will be available for responses by the offense. Any defense will have to be designed to handle a variety of responses since a specific threat cannot be predicted accurately in advance of deployment.

The initial tests by Livermore of Excalibur, the x-ray laser weapon, showed slight multiplication, and that was controversial. Where would these x-ray lasers be based? The proposal was to place them on submarines based near the Arctic coast of the Soviet Union. Excalibur was to be boosted into space quickly to make x-rays to destroy the Soviet missiles while they were still rising. The Soviets would have plenty of time to respond with a better attack plan. The easiest thing for them to do would be to base their ICBMs further south towards Kazakhstan. Since the earth is round, this means that the Soviet ICBMs would have more time to release warheads. They also could build fast burn missiles, rising in 1 minute, compared to 5 minutes for the SS-18. Or use countermeasures.

In 1987, DOD shifted the main focus of SDI from directed energy weapons to hit-to-kill, kinetic-kill vehicle (KKV) weapons. Objects in low Earth orbit have kinetic energy density about the same as that of high explosives. The moving mass in orbit can destroy missiles and RV's. This shift took place in 1987, but I don't know if this shift was from the APS report or from Executive-Branch ruminations. I did pick up gossip on this issue. My officemate at State/SNP was from the CIA, it was his job to be the note-taker when Assistant Secretary of Defense Richard Perle came to tell Secretary Schultz about the transition from DEWS beam weapons to KKV's. At that time the lead KKV technology was *Smart Pebbles*, which would remain in orbit for ten years, waiting for the call to attack. My office mate said the conversation between Perle and Schultz implied that neither of them seemed to believe in the Smart Pebbles technology. I came to the conclusion that the whole SDI task was political, not can we stop a first strike, but can we terrify the Soviets with our prowess. I conclude that Sagdeev and Velickov are serious

people and they told Gorbachev the truth.

6.4. CFE: End of the Conventional-Armed Cold War in Europe

I was new to the Senate Foreign Relations Committee (SFRC), when suddenly Chairman Pell asked me to be his only staffer for ratification of the Conventional Armed Forces in Europe (CFE) Treaty. This gave me access to a variety of places in short order. I specialized on monitoring, verification and military implications, issues that use numbers. Working with Biden's Jamie Rubin, we organized five hearings, only with the Executive Branch. We obtained significant non-government input by recruiting written testimony on NATO-Warsaw Pact issues. The testimony from Jonathan Dean, former State diplomat, was particularly important. We obtained extensive and specific answers for the record, forcing the Executive Branch to be more complete, providing 83 pages of Q/A in small font. CFE concluded the Cold War, once conventional arms were controlled, reductions of nuclear weapons under START would follow.

One of the perks of CFE ratification was a helicopter ride from Fort McNair over Washington and Baltimore to Aberdeen Proving Ground. There I obtained a show-and-tell driver's license for the M1 Abrams tank, the M2 Bradley Fighting Vehicle, humvees, trucks and jeeps. It was great fun taking a 65-ton tank with a 1500 horsepower turbine into a turn at 40 miles/hour and up an inclined plane. CFE was such an obvious triumph for NATO and even Senator Helms was supportive. The photo shows me commanding an M1 tank with Senator-Helms key staffer, David Sullivan, as the driver. These were fast moving events but it was clear to me that CFE ratification was not only necessary and very positive, but the precursor to the ratification of START and the end of the Cold War.

I will quote liberally from the SFRC report on CFE. The treaty was signed on November 19, 1990 by 16 NATO states and 7 Warsaw Pact states. The reduction in conventional arms eliminated a fundamental cause of tension in Europe, present since the end of World War II. The huge numerical advantage of Soviet conventional forces threatened the security and prosperity of the West and was integral to Soviet domination of Eastern Europe. Of course, it would have been suicidal (and stupid) for the Soviets to attack NATO, but the threat was always there. This false-numerical superiority also fueled the nuclear arms race. In every strategic doctrine adopted by NATO and the West—from massive retaliation to flexible response—nuclear weapons were intended to compensate for the Soviet edge and conventional arms. Indeed the tens of thousands of nuclear weapons we deployed to support these strategies all had a principal purpose to deter the Soviet Union from threatening Western Europe.

The key effect of the treaty was to force the Soviet Union to withdraw its forces from Eastern Europe, reduce the major armament holdings in its European-based forces by more than half, destroy a large quantity of these weapons, place 20% of the remaining weapons in storage, and distribute the rest geographically in order to comply with all the ceilings and sub-ceilings. The CFE treaty provisions did not require NATO members to reduce armament holdings in a substantial way. The treaty set ceilings for each group of states within the area from the Atlantic to the Urals (ATTU), neither group may field more Treaty Limited Equipment (TLE) than 20,000 tanks, 30,000 armored combat vehicles (ACV), 20,000 artillery pieces, 6,800 combat aircraft and 2,000 attack helicopters. This gives a total of 78,800 TLE for NATO and 78,800 for

the former Warsaw Pact. No single country may exceed the following levels from the “sufficiency rule:” 13,300 tanks, 13,700 artillery, 20,000 ACV's, 5,150 aircraft and 1,500 helicopters. Senator Pell placed the final TLE numbers into the *Congressional Record* on the day of ratification.

The Soviets unilaterally reduced their TLE in the ATTU from 152,000 to 73,000 between 1988 and 1990, for an early reduction of 50%. It is true that the Soviets didn't throw away older equipment for bureaucratic reasons but these reductions are very significant. Once these old tanks were moved beyond the Urals, it was generally believed they would quickly rust into obsolescence, which was readily monitored by satellites and Open Skies Treaty aircraft.

The total Soviet TLE moved from the ATTU, destroyed or converted was 103,000, plus 21,000 from the 6 non-Soviet Warsaw Pact states, for a total of 124,000 TLE moved, destroyed, or converted. The total amount of Soviet TLE to be destroyed or converted was 57,700, plus 21,000 TLE destroyed by non-Soviet Warsaw Pact nations, giving 79,000 TLE destroyed or converted. This number includes 10,700 East German TLE now owned by the Federal Republic of Germany. At the beginning of CFE negotiations, the Warsaw Pact had an advantage of a factor of 2.7/1 in TLE over NATO. The CFE treaty reduced this to a 1/1 ratio. The demise of the Warsaw Pact made a ratio of Soviet/NATO to 0.67/1. The exit of Ukraine, Belarus and Kazakhstan gives a ratio of Russia/NATO of 0.5/1. Thus, the ratio changed from an advantage of 2.7 to a disadvantage of 0.5, a reduction in ratios by a factor of 5. This major change happened in an open and peaceful manner, a highpoint for mankind.

CFE Chief Negotiator Jim Woolsey worked on the following issues: (1) Individual TLE would not be tagged with bar-code or other labels, but rather displayed in groupings of TLE, accessible to group counting from satellites or helicopters. This approach could detect a violation a thousand TLE, which was much less than the NATO final advantage of 25,000 TLE. (2) The Soviet SS-23 missile had a range of 500 km, which barely qualified it for INF regime, which had a lower range of 500 km. The discovery of 72 SS-23's in East Germany, Bulgaria and Czechoslovakia were violations of INF. My speculation is that this politically confusing time caused this accidental violation, which was more political than significant. It is hard to debate that the Soviet's could expect to get away with this. I view it as a stupid bureaucratic Soviet error with little to gain by cheating. This issue wasn't solved until START was ratified. The Soviet Krasnoyarsk phased-array radar was a violation, but I also view it as a stupid bureaucratic Soviet error. Gorbachev admitted this, as he asked to turn the radar site into a furniture factory. The US held firm and he dismantled it. The Resolution of Ratification contained the phrase “The Senate declares that it will take into account, as part of its consideration of the START, [these two violations]”. (3) The Soviets removed 80,000 TLE to the East of the Urals. This massive force was a concern to the U.S., even though it was older equipment, which was soon to decline. A resolution of ratification condition required the President to inform the Senate if this force became militarily significant.

The Cold War Ends

It would have been suicidal for the Warsaw Pact to invade Western Europe through the Fulda Gap to Frankfurt, which was a powerful symbol of the Cold War. Such a hypothetical tank

invasion would have been met with US tactical nuclear weapons, that was the goal of the neutron bomb. Supplying Soviet tanks far from their bases would have been difficult, it probably wasn't ever going to happen. But it seems that in military international affairs that perceptions often drive reality. Once the disparity in conventional forces disappeared (which was exaggerated because of poorer quality Soviet equipment), progress could be made on reducing strategic nuclear weapons that threatened Moscow and Washington. All was going well until the Belarusian parliament closed, without indications that it would return. The CFE Treaty could not *enter into force* until all the parties had ratified CFE. The long-time lead U.S. lawyer on these matters, Thomas Graham of ACDA, conceived a solution to this problem. I quote from Graham's book, *Disarmament Sketches: Three Decades of Arms Control and International Law* (University of Washington Press, 2002, pg. 208-9):

Why not amend the text of the provisional application protocol simply to provide that on a specific date in July the entire Treaty would actually be brought into force for the period of baseline inspections (4 months) on a provisional basis and as a minor administrative change?" After many phone calls the following was decided: "It was decided that Jim Timbie and I would meet with Senators Lugar and Pell (who was in Rhode Island but would be represented at the meeting by his aide David Hafemeister). I discussed the concept with ACDA Director Ron Lehman on Monday and he approved it. That afternoon Timbie and I went off to meet with Lugar and Hafemeister.... It was agreed that there would be an exchange of letters to this effect between Director Lehman on the one hand and Senators Pell and Lugar on the other. Ron would write asking for permission, setting forth the circumstances that necessitated this action and Pell and Lugar would reply giving their assent along with the aforementioned caveat that this was an extraordinary step required by events. This was accomplished the next day and our delegation at the Joint Compliance Group was instructed immediately to propose this and lobby for support. Not surprisingly there was resistance in Vienna because, to put it mildly, this was an unusual move. Nevertheless, Helsinki now was just a few days away and delegations increasingly came to support this procedure. Not without some anguish, however. The Italian ambassador told the US representative that his government's international lawyers in Rome 'had to swallow beach balls over this.' ... The CFE treaty was formally announced to have entered into force on July 16. Baseline inspections began one week later, Armenia ratified later in the summer, and Belarus ratified on November 9, one week before the expiration of the four-month period. As I said, Czechoslovakia did split in two in January but now the Treaty was fully in force and the Czech Republic and Slovakia became successor states, bringing the number of CFE parties to thirty, which remains the number today.

6.5. Nunn-Lugar Cooperative Threat Reduction

It was clear that the demise of the Soviet Union could lead to chaos since the Soviet plutonium and high-enriched uranium was vulnerable. As the KGB collapsed these sensitive materials became loosely guarded, some have said that potatoes were guarded more carefully than Soviet plutonium. In addition, the Soviets had not done proper materials accounting on its 130 tonnes of plutonium and 1200 tonnes of high-enriched uranium (HEU). And indeed, our government was asleep at the switch on this issue. It is easy to see why this happened as nonscientists are in control of science issues, and they often feel uncomfortable with technical matters. The Soviet's lead nuclear administrator, Victor Mikhailov, came to Washington after the ratification of CFE. When he met with Undersecretary of State Reggie Bartholomew, they did not make progress with the U.S. Executive Branch on the Russian dilemma of poorly-protected special nuclear material. There are reasons for this situation. There is not a science cone in the State Department, as promotions come through the Bureau of Politico-Military Affairs, country desks, and economics.

Frank von Hippel, Princeton professor and Chair of the Federation of Atomic Scientists, and Tom Cochran, Head of the Nuclear Policy Project at the Natural Resources Defense Council, arranged for Mikhailov to meet with Congressional staffers and various NGOs at Thanksgiving time. Mikhailov was clear that he was uncertain on where to store his nuclear materials, and this would take considerable funding. And it was clear he was going to have to shut down his nuclear industry of 1 million workers. Presumably Mikhailov met with Senators Nunn and Lugar, giving impetus to their legislation, which passed on November 27, 1991. Five days later on December 1, Ukraine voted to become independent of the USSR, followed by 13 other Soviet Republics and Russia. The Nunn-Lugar legislation authorized \$500 million to assist the Soviets to dismantle nuclear weapon and missiles, to enhance physical security to protect these systems and improve accountancy of these items, establish negotiations to buy Soviet reactor fuel obtained from Soviet HEU, and retrain and encourage Soviet scientists to enter the private sector and not participate in a brain drain. This was a tall order.

Tom Neff wrote an op-ed piece for the *New York Times* that suggested that the U.S. send food to the former Soviet states in trade for surplus unguarded plutonium and HEU. This op-ed piece stimulated much talk on this issue. Senators Alan Cranston of California and SFRC-Chair Pell submitted a bill to try and address this issue, entitled the *Nuclear Warhead Security and Plowshares Act of 1991*. It was clear that HEU was far more dangerous than plutonium because it is much easier to make weapons from uranium than from plutonium, which must be imploded in a fat-man design. And uranium is much less radioactive than plutonium, therefore easier to work with and harder to detect. And HEU can be converted into 4%-enriched reactor fuel that has economic value. On the other hand, plutonium has a negative economic value as a result of its radioactivity and it is less useful as reactor fuel. For HEU reductions, this was done by mixing HEU with natural uranium with an in-between stage. This would be paid for with American agricultural commodities. Our bill nudged negotiations forward as the U.S. and Russia were not yet in discussion on this. Since plutonium is not economically viable, we hoped legislation would stimulate thoughts on what to do with it. Because of plutonium's radioactivity, the discussion can quickly become political. Nunn-Lugar was managed on the Senate floor for SFRC by Senator Joe Biden. He was concerned that the Cranston-Pell bill would complicate the passage of the Nunn-Lugar legislation, which was reasonable. Biden recommended that the SFRC Committee take up the legislation, and Cranston-Pell agreed.

Within a year, the Executive Branch began negotiations on denaturing HEU to reactor fuel, which was led by ACDA-Director General Bill Burns, with whom I worked closely on the National Academy study on *Beyond START*. The U.S. and Russia formally agreed on February 18, 1993 to the sale of 500 tonnes of HEU turned into reactor fuel. This sale has covered 50% of US fuel needs over the past two decades, for 50 of its 100 nuclear-power plants. The issue of plutonium-for-food swaps was not addressed, as it was agreed to convert plutonium to mixed-oxide reactor fuel, but this continues to flounder.

6.6. The Soviet Union's Final Days

After Ukraine voted to become independent of the Soviet Union, the remaining 13 Soviet republics and Russia left the Soviet Union in December 1991. Arrangements were made for the new Russian Federation, which was to take power on January 1, 1992. To assist in this transition,

Frank Von Hippel and Tom Cochran arranged a unique international workshop on *Verified Storage and Destruction of Nuclear Warheads*, held in Moscow and Kiev on December 16 – 20, 1991. I stayed on until December 23 in preparation for the upcoming SFRC hearings on START ratification. This was a very unusual trip, indeed. The American delegation was a mixture of nongovernmental organization (NGO) scientists and Executive Branch scientists, along with former lab directors, the CIA, the Senate, and the press. Since these were tense times with a lack of communication between the two sides, the Executive Branch condoned the trip, which was accepted by Presidential National Security Advisor, Brent Schoolcraft. The following individuals participated: former director of Los Alamos National Laboratory Harold Agnew, former director of the Los Alamos Theoretical Division Carson Mark, the former vice-president of Sandia National Laboratory Jack Howard, three nuclear weapons designers and a CIA scientist. The NGO scientists were Frank von Hippel, Tom Cochran, Tom Neff, Chris Paine, Steve Fetter and Alex DeVolpi (DOE Argonne) and myself from the Senate. This unique delegation was completed with three reporters: William Broad of the *New York Times*, Jeffrey Smith of the *Washington Post* and Jonathan Schell of *Newsday* and author of *Fate of the Earth*.

My Lufthansa flight was canceled in Frankfurt. I managed to get an Aeroflot flight, but because of the delay, I missed my contacts at Moscow's Sheremetyevo Airport. This was particularly unfortunate because the last days of the Soviet Union was a time of major chaos at Sheremetyevo Airport. I did not speak Russian and no one seemed to speak English. I noted a fellow following me around the airport but I couldn't shake him. After about a half an hour of wandering, I showed him the address of where I was supposed to go. He indicated that he understood where it was and would take me in his car. I certainly was asking to be robbed, but I was somewhat desperate. Frank von Hippel suggested that I should take a small jar of peanut butter because it is easy to become lost in Russia. We drove along the Russian freeway until we got near Moscow, but then the driver headed into the dark woods. My forehead dampened with perspiration, as I feared that I might be abandoned in the winter woods without my wallet, far away from the US delegation. Ultimately we came to a hotel that was used by Soviet leaders. I was very cheered to see our delegation. I later found out that our hotel and meals were paid for by CHETEK, the quasi-private space program funded by the *Ministry of Atomic Power and Industry* (MAPI).

The Soviet Union (soon Russian Federation) was represented by 31 delegates, including the following: Victor Mikhailov, Deputy Minister, MAPI; Victor Karpov, Deputy Foreign Minister; General Vitali Yakovlev; General-Lieutenant Sergei Zelentsov; General Gelili Batenin, senior arms-control adviser to RF President Boris Yeltsin; Major General Alexi Leonov, CHETEK, first Soviet to walk in space; Victor Ivanoff, lead negotiator on nuclear testing and Deputy Director MAPI, Nuclear Weapons Development and Testing; Academician Yuri Trutnev, Deputy Scientific Director, Arzamas-16; Vadim Simonenko, Director, Theoretical Department, Chelyabinsk-70; Victor Slipchenko, Ministry of Foreign Affairs; Anatoli Diakov, Director, Center for Arms Control, Moscow Institute of Physics and Technology (a Russian academic, who did serious arms control). The Ukrainian delegation had 15 members, led by General-Major Vadim Grechaninov.

CHETEK Offer to Destroy Chemical Weapons and Radioactivity

MAPI and its commercial firm CHETEK made a proposal to end two of Earth's problems in one

stroke by incinerating large stocks of chemical weapons with surplus Soviet peaceful nuclear explosions (PNE). I quote from the trip report:

“At the arrival dinner, Trutnev presented a variation of the CHETEK-PNE waste disposal concept, purposing that one such explosion could also be used to destroy 5,000 plutonium pits from dismantled nuclear warheads. In response to a question regarding the disposition of the commercially valuable high-enriched uranium components from these destroyed warheads, one of the Russian scientists present stated that would be a ‘simple matter’ to ‘unscrew’ the uranium-laden secondary stage of the weapon from the plutonium-bearing primary stage. Air Force Major General Alexei Leonov served as toastmaster for the occasion. Leonov, twice named a hero of Socialist Labor, gained fame in the USSR as the first cosmonaut to walk in space and as Soviet commander of the joint Apollo-Soyuz Mission in the mid-1970’s. The exact nature of Leonov’s affiliation with CHETEK was also unclear, but it seems probable that Mikhailov, Trutnev, Tchernyshev and Leonov may be shareholders and/or directors of the company. An October 1991 report in the industry journal *Nucleonics Week* quotes CHETEK Vice-President Valery Siderov as saying that ‘about ten experienced scientists’ from Arzamus-16 are now CHETEK shareholders.”

Many were hesitant about this offer because it would make peaceful nuclear testing viable and that radiation would leak. On the other hand, 25 years have past with slow chemical weapon destruction and we are still faced with over 100 tonnes of surplus plutonium with an uncertain future. Russia appreciates plutonium more than the U.S., it is unlikely that Russia would put 100 tonnes of plutonium into explosive cavities. More government-to-government discussions on plutonium disposition might have accelerated the slow progress on the plutonium disposition. On the other hand, meetings with Deputy Foreign Minister Victor Karpov and with Alexander Penyaguin, Chair of the Supreme Soviet Subcommittee on Nuclear Security showed the Russian distrust of CHETEK. The CHETEK press release of December 11, 1991 stated the following:

Scientists of this institute are conducting scientific research on nuclear explosion technology, the goal of using this technology for the destruction of chemical weapons, as well as highly toxic and radioactive waste.... A general agreement was finalized between the Ministry of Atomic Power and Industry and the international joint stock company CHETEK in May 1991... This project and its financial-commercial, component part is an example of the high moral standards in approach by a commercial organization and cooperation with a government organization which, during a time of difficult economic situation of the country in regard to attracting funding from outside the budget (including from abroad), is solving a most important ecological and disarmament problem for mankind.... Signed by V. Mikhailov and V.B. Dmitriev, CHETEK

Where to store the excess Soviet plutonium and HEU?

The meeting with Victor Mikhailov at the Ministry of Atomic Power and Industry revealed Soviet thinking on Nunn-Lugar funding:

The nuclear weapons of the FSU will be dismantled in the plants of Mr. Gorobrets... near Chelyabinsk or Tomsk. At one point, Mikhailov mentioned Sverdlovsk as a site, but he quickly corrected himself. He asked the delegation not to publicly discuss the potential sites for the new plutonium storage facility, because MAPI's plans had not yet been discussed with local officials in the affected region.

A year later the citizens from Tomsk strongly opposed building the plutonium storage facility near their city, closing-down our meeting for an hour. It was refreshing to see the public speak up in this formally closed society. Quoting from the December 1992 trip report:

Mikhailov said that the entire \$400 million should be spent on a single new MAPI facility, rather than spread around among several different projects... which would diffuse the impact of the funds. In this way the United

States could assure itself that the money would not be spent on 'dual-purpose' equipment that might later be used to produce weapons as well as disassemble them.... The large uncertainty in the estimate 'from 10,000 to 20,000 warheads to be destroyed' stems from the vague language used by Gorbachev when he announced the reciprocal Soviet reduction initiative. In a side conversation, Mikhailov said that the weapons storage depots in Russia were filled to capacity and that trains carrying weapons to the depots had been stopped en route.

Plutonium

The 1991 trip report discusses some of the interactions between MAPI and US scientists on plutonium issues:

Jack Howard, a former vice-president of the Sandia National Laboratory gave two short presentations, one on permissive action links and another on methods of securing nuclear weapons in transport and storage against unauthorized access. Howard suggested going beyond reversible steps for disabling weapons by introducing a sticky material into the interior of the hollow plutonium core of the primary (trigger) stage through the channel reserved for tritium gas injected into the core prior to detonation. He later joined former Los Alamos Director Harold Agnew in private discussions with the Soviet MoD and MAPI officials, in which they suggested using a borated epoxy that would harden inside the sphere, eliminating the risks of a nuclear yield in the event of an accidental detonation of the high explosive surrounding the core, and enabling the plutonium cores to be stored closer together.

In 1991 Mikhailov commented as follows: "We have spent too much to just throw this plutonium away.... We need plutonium for small reactors in the North, for district heating." We returned to the plutonium issue in December 1992, but now the delegation consisted only of NGOs and myself, as the new Russian Federation preferred to deal with formal government-to government procedures. We discussed with the Russians plutonium storage, plutonium production and reprocessing, MOX fuel in light water reactors and breeder reactors. MAPI scientists did not waiver in their support for a plutonium economy. You might think as Russia went from state-controlled markets to free markets that this would have changed, but they had invested their lives in plutonium. Additional commentary from the 1992 trip is as follows:

A year ago a trip with 6 scientists and 6 DOE employees was ahead of the Executive Branch since Nunn-Lugar policies and funding were not yet in place. One year later, as one would expect, the Executive Branch has been negotiating on many of the dismantlement issues, but there are still great uncertainties, especially on the issue of the final disposition of plutonium. Russian Minatom officials stated that they plan to continue to reprocess and burn their plutonium in the new generation of breeders, an unlikely scenario. At this point, the oversight by the Congress has been limited to a one-hour hearing in SFRC on July 27, which took place before the decisions on LEU/HEU purchases and plutonium storage.

Monitoring Warhead Destruction

Discussions on monitoring warhead destruction, and extending arms control to count warheads took place at MAPI, the Soviet Foreign Ministry, the Russian Duma in their White House, the Ukrainian Rada Parliament and the Ukrainian Foreign Ministry. This was a divisive issue in the U.S. delegation because some were interested in prompt Russian ratification of CFE and START and the NGO's had their eye on a future world without nuclear weapons. I was aware of the difficulty of this goal because of the strong legal demand to protect warhead secrets and the fact that new warhead monitoring technologies needed to be developed. I had observed that Frank Hippel was severely buffeted by Senator Malcolm Wallop before the Senate Armed Services Committee on the detection and identification of warheads in the field. Acting with the near term

in mind, I passed SFRC hearings and the SFRC CFE report to the Russian and Ukrainian Supreme Soviet staff members, to use for their ratification of CFE and START, a first for new Russia. The warhead monitoring issue will return below as we discuss START ratification and the National Academy study on *Beyond START*. The 1991 trip report states the following on warhead dismantlement:

In what amounted to a preemptive strike against the principal objective of the sponsors of the US delegation—verification of the elimination of nuclear warheads removed from Ukraine—General Zelentsov lead off the workshop with the presentation of the Ministry of Defense position in opposition to any verification measures that had not been formally agreed-upon ‘by the two Presidents. Since Gorbachev and Bush had not raised the need for additional control measures when they undertook their mutual declarations, Zelentsov maintained that there was no political basis for the Ministry of Defense to pursue such measures. ‘No inspection of nuclear weapons by strangers are allowed. Only trained Army–staff are allowed to get near the weapons. We cannot expand access to nuclear weapons’ because strict procedures had been designed to exclude access by ‘journalists, terrorists and other outsiders.’ If tags were to be applied to U.S. as well as Soviet weapons, then this should be done by the Ministry of Defense personnel or a special inspectorate created for this purpose, Zelentsov noted. But he indicated that tags are unnecessary for tracking warheads through the dismantlement process because all Soviet warheads and their principal complements....are stamped with serial numbers, and the Soviet Army has quality-control inspectors who follow warheads from production to dismantlement.

In rebuttal, members of the US delegation (Cochran and DeVolpi) explained that (1) the purpose of *sealing* was not to prevent access to the warhead but to *reveal* unauthorized access; (2) fiber-optic seals could be applied *after* the weapons had been disabled and made safe prior to shipment to storage facilities in Russia, and (3) that the Soviet and Ukrainian military personal accustomed to handling nuclear weapons could themselves apply the tags and sealed with a minimum of direct involvement by the inspecting party. Cochran demonstrated 10 types of tagging and sealing technologies for warheads and warhead containers.

Monitoring warhead destruction became a flash point in Kiev when the Deputy Chair of the Ukrainian Parliament, Volodymyr Gryniiov, made an offhand remark that perhaps the Soviet weapons in Ukraine might be dismantled in a third country, other than Ukraine or Russia. This drew a strong response from General Zelentsov of the MOD and Victor Ivanov of MAPI. General Zelentsov not only vigorously quashed this notion, arguing that the appropriate personnel and facilities for this task were in Russia, but he used the opening provided to renew his argument that only qualified MOD personnel could be allowed near the weapons, and that international inspectors would compromise their safe removal from the Ukraine. The latter comments sparked a strong response from Cochran, who warned Gryniiov, ‘don’t be fooled by the General’s argument’ concerning the alleged dangers of verifying warhead elimination. Cochran repeated his suggestion that it would be a short and relatively simple task to tag and seal weapons before they left Ukraine. This comment angered Ivanov, who later accused Cochran of attempting to drive a wedge between Ukraine and the FSU ministries.

At the final banquet Ivanoff drew me into a corner, he was concerned by the interchange with Cochran on monitoring warheads. This looked serious as Ivanoff was a high MAPI official, as the Deputy Director for Nuclear Weapons Development and Testing, well known to US nuclear negotiators. Ivanov incorrectly thought my label of *Senate Foreign Relations Committee* exuded Senate power. SFRC Chairman Claiborne Pell was also tall and thin. Ivanov far preferred dealing with the US Executive Branch (and even the Congress) as compared to NGO’s. I didn’t want to get maneuvered into things, so I convinced a Livermore weapons designer, Gerald Kiernan, to join Ivanov, a translator, and myself in these discussions. I calmed Ivanov by saying that the U.S. would examine the science of warhead monitoring and hopefully the new Russian government would join in. This later happened under President Bill Clinton, but it took five years to obtain DOE agreement on how to retain warhead secrets. Warhead monitoring re-enters below in START ratification and the National Academy study on warhead monitoring.

Five months later, Bill Ashworth and I had a memorable lunch with Nikolay Vorontsov, who was famous for standing on the tank with Boris Yeltsin at the Russian White House as they defied the Soviet military at the time of the military coup and Gorbachev's capture. Quoting from Murray Feshbach's *Ecocide in the Soviet Union* (Basic Books, 1992, pg. 251):

At noon on the first day of the putsch, Boris Yeltsin, the most popular politician in the Soviet Union, clambered to the top of an Army tank in front of the white skyscraper that housed the Russian Republic Parliament. Yeltsin used that unlikely podium—a symbol of what proved to be a decisive split with the Soviet military—to rally the crowd in front of him, the city around him and the world beyond to defy what he had sneeringly termed the 'junta' in the Kremlin. Vorontsov was the next to speak from the tank's deck to denounce the takeover attempt as 'illegal.' Having declared his defiance in public, he repeated it in private at an evening meeting of the Soviet cabinet. Even behind closed doors he was the only minister to voice uncompromising opposition to the men he later called 'incorrigible conservatives.' Two of his Kremlin colleagues—a deputy prime minister and the cultural affairs chief—declined to endorse the coup and its aims, but only Vorontsov truly resisted the conspiracy while the outcome was still in doubt.

A Bribe to Escape Moscow

The US delegation departed after the meetings in Moscow and Kiev, but I stayed for further discussions at the Soviet Ministry of Defense and at the Soviet On-Site Inspection Agency (OSIA). I needed specific information for the upcoming SFRC hearings on START and on the breakup of the Soviet Union. I was accompanied by the US Military Attaché to the Soviet Union. From my trip report:

The US military chief of the US OSIA in Moscow arranged for a briefing at the headquarters of the Soviet OSIA, which is located in Soviet Ministry of Defense. The communication facilities were examined. One thousand messages annually pass through the Nuclear Risk Reduction Center, which is co-located with the Soviet OSI. The Soviet leader, General Vladimir Medvedev pointed out that the Soviet bases in Eastern Europe had been closed and these facilities should be removed from the inspection list at the Standing Consultative Commission meeting. Gen. Medvedev stated that 'we have had just a few problems that would raise discussions, to the surprise of some people.'

General Medvedev was a gracious host, giving me a piece of the last SS-20, which were destroyed pursuant to the INF treaty. Further details on INF implementation were given to us, which were transmitted to Washington by the attaché. I followed this with a cable from the US embassy, describing details of our US-Soviet meetings, described above.

This extra work forced me to stay two days beyond my visa dates. I naively hoped that the Soviet airport authorities would honor my government passport and ignore this detail. Moscow's Sheremetyevo Airport was mobbed as Russians and foreigners were fleeing Moscow to avoid the chaos. The panic level was compounded by a lack of jet fuel as the Soviet system started to collapse. As I waited in line, a petite Russian woman came and beat on me with her fist as she thought (incorrectly) that I had a better place in line. Her husband apologized to me as his wife had panicked about obtaining a flight to Soviet Georgia for their family of four.

Finally the Air France line began to move. As I reached the head of the line, I noticed three ominous-looking Soviet soldiers, packing AK-47's. I held my breath and handed them my passport with its outdated visa. My heart sank as they quickly spotted the discrepancy. They pointed towards Moscow and said that I must get a new visa. But how could that really happen

as the Soviet Union was crashing, while the new Russian government barely existed? It could take months. Where was I to stay? There were the forthcoming hearings on START, and my family in DC was awaiting my Christmas arrival. At last I thought of something I had never done before (or since). Why not try good old-fashioned bribery? I stuck three ten-dollar bills into my passport and said something in English, which I knew they could not understand. At this time a \$10 bill was worth about \$1000 as the ruble crashed. The senior officer and the two young recruits huddled in the corner. I broke into a sweat. Will they send me to jail? Will they send me back to an uncertain Moscow? Happily, they motioned to me to enter the plane. Here we were, former enemies but yet four humans reaching out to survive. After all, these were decent soldiers put into an impossible situation. Their lives were going to get much worse before they got better. I view the \$30 visa expense as a necessary evil for me and as a bonus for the three soldiers and their families. I hoped things worked well for them as I returned to the comforts of the U.S.

A decade later in 2001, I returned to Moscow to present a paper representing a National Academy of Sciences study on *Beyond START*, primarily on the issue of monitoring warhead dismantlement under a new treaty. I knew some of the Soviet scientists and government officials would know English but most would not. These presentations can be deadly dull if you use a translator who speaks with no eye contact, losing the audience. A friend mine at the National Academy translated my view graphs into Russian. At the Russian Academy I ran into Stanislas Rodionov from the previous FAS-Soviet back channel. I asked Stanislaus if he would read these sentences in Russian, which he did. I was later told that this was the most interesting event of the two-day conference on monitoring warhead dismantlement.

6.7. Ratification of START

My previous involvement with START was primarily academic, writing papers, the MIT verification book and as State co-chair with the Pentagon on the launch weight to throw weight committee. Starting in January 1992, my full-time job was the ratification of START. It was not as if the issue was in doubt, as the anti-START senators only got six votes. But it was an issue of substance and future directions. Would the anti-START forces be able to attach an unsavory amendment, or would hearings on a particular issue become overly clouded. It was nice to have the Senate-majority Democrats join with President George H.W. Bush, as we agreed on most START issues. *Minuteman vulnerability* was always much more complicated but yet more simple than described in the press. The U.S. had many other nuclear systems that. Even if the Soviets had been able to attack and destroy 900 of 1000 Minuteman missiles, there was still an over abundance to respond. My various calculations used the parameters of hardness, yield, reliability, range, accuracy, number of warheads on a target, and total number of warheads of all type. This can be complex for hearings, but it does allow one to ask questions based on these concepts to prove a point.

SFRC had 20 hearings on START between January 1992 and ratification in September 1992, out of a total of 45 SFRC on arms control with fifty physicists as witnesses. We will discuss the highlights of the 900-page START hearings.

START History with Scientist Hans Bethe and Negotiator, Paul Nitze

Chairman Pell wanted Bill Ashworth and myself to get into the important details. This begins with history, who better than a pair of 85-year-olds, Hans Bethe, on the history of nuclear weapons science, and Paul Nitze, on the history of nuclear weapon policy. Each of them had detractors, as Edward Teller argued with Hans Bethe, and arms-controllers argued with Paul Nitze. SFRC enjoyed the hearing as it placed START into a broader perspective. Let's start with Bethe: I phoned Bethe at his house in Ithaca, New York and they responded he was at UC San Diego. I phoned San Diego and they said he was at Stanford, who said he was at Livermore, who said he was at the University of Washington, where we finally chatted. Eighty-five-year-old Bethe got around nicely. At the hearings, Bethe said the following:

The Cold War is ended.... On the basis of the situation, President Bush, in September, took a most important unilateral step: he ordered withdrawal of all tactical nuclear weapons from Europe, with the prospect that many of them would be destroyed. He also ordered elimination of tactical nuclear missiles from naval ships, including sea-launched cruise missiles, which were a great obstacle to any arms control agreement. He stopped the alert of nuclear-armed intercontinental bombers and ordered several further measures contributing to relaxation. Gorbachev responded promptly and positively in the same spirit. These unilateral measures with responses are much to be welcomed and are much quicker than negotiations of a treaty. Some people believe that in this way, START has become irrelevant. In my opinion, START is as important as ever. It will provide a firm basis for the future.

At this point, Nitze was evolving from the author of stern memos and leader of the Committee on the Present Danger, to the *walk-in-the-woods INF negotiator* in Geneva, and soon to become a nuclear-abolitionist. I thought that some of his older arguments on such things as *Minuteman vulnerability* were not scientifically accurate, but he was kindly to me and I liked him. At the hearings, Nitze said the following:

As nuclear weapons systems become increasingly survivable on each side, the prospects for counter nuclear targeting, or counterforce nuclear targeting, will continue to diminish. I would continue to target nuclear installations that could be attacked efficiently, such as bomber bases and SSBN ports. But I would not reserve the large numbers of warheads necessary to target mobile ICBMs, nor what I plan to target ICBM silos. The latter should be mostly empty by the time the United States retaliated, as I would expect fixed ICBMs to be the weapons of choice in a first strike, while the reserve force will rely mostly on mobile ICBMs and SLBM's.... I would also retain the option to target leadership, but with much more flexibility than we have had in the past in order to adjust to the broader range of possible conflict scenarios.... With all this in mind, I believe we can safely reduce our inventory of deliverable strategic warheads to no more than 3,000 to 5,000 in the near-term, provided that the states of the former Soviet Union agree to reduce at least that far.... In the long run, further cuts in the U.S. strategic inventory should be possible as conventional weapons gain additional effectiveness or if other nuclear powers shift from their current reluctance to participate in arms reductions.... Taken as a whole, U.S. strategic forces are sufficiently survivable to give us a strong deterrent.

Why did the U.S. fail to predict the end of the Cold War?

This question was interjected into the Bethe-Nitze hearing by Senator Daniel Patrick Moynihan:

In 1979, *Newsweek* had a forum on...what will happen in the 1980's. I wrote a short piece which said that in the 1980's it should be obvious that the Soviet Union will break up along ethnic, national lines; and then you will have a problem of who gets control of the warheads if they begin to divide among ethnic, national lines. I wrote this and rewrote it, and argued it in the intelligence community. It comes out of an analysis of Marxist propositions about class solidarity. If you look at the history of the century and the behavior of the Marxists, they always stressed nationalism themes; even that nationalism would eventually lead to proletarian internationalism.

But it never did. Nobody could hear you in Washington, but you could make the case that the Soviet Union was about to break up. And one did. And now it has.

Nitze responded: "My view is that the situation is highly uncertain and all you can deal with today is probabilities, various probabilities. I've been asked that question recently: what probability would you put upon this and that and the other thing happening. I would put a probability of 1 in 10 on their being able to solve economic problems within the next 5 years.... I would put the probability as 1 in 2 that they will have a takeover with the military important in the takeover within the next 2 years.

Q and A on Minuteman Vulnerability, etc.

One thousand questions were asked of witnesses and others. The responses fill 150 pages in very small type. It was our mission to learn all aspects of START and its implementation. This is what Senators Lugar and Pell had to say:

Senator Lugar: I just say once again, for the record, that the Administration has now written answers to more than 1,100 questions that have been offered by Senators. That is a substantial amount of interest. The body has been characterized as apathetic. I just want to set the record straight—1100 inquiries, all answered in writing. Let me say simply there were 30 hearings held by 3 committees, and I say that there has been substantial understanding of the elements of this Treaty for years—not simply in the very intense period of the hearings and the questioning.

Senator Pell: If the Senator will yield for a moment, I would like to demonstrate the number of pages, over 1,000. They weigh several pounds, and one can see the amount of wordage in these responses by the Administration to the Committee's questions.

Some of these issues involved classified information, but if you wrote the question in general terms you could sufficiently learn the essence. For example, what is the effectiveness of a possible Soviet breakout from START by attacking Minutemen? The SFRC START report contains the following commentary:

The Committee asked the Administration to quantify the marginal utility of additional hard-target killing warheads on silos for 2 cases: (1) Without the destruction of one warhead by another warhead, or without fratricide, and (2) with fratricide that was only effective for warheads beyond the first two warheads on a target. Under the worst case assumption that the Russian weapons are very reliable and very accurate, it was assumed that they could destroy 81% of the targets in a one-on-one attack (90% reliability and 90% single shot kill probability), the Administration was asked to determine the marginal destruction rates of the last Soviet warhead for various attacks on U.S. silos. The Administration response is given below in tabular form" for one to four warheads on targets of Minuteman II with one RV, Minuteman III with 3 RVs and Peacekeeper with 10 RV's. The Committee "defined an effective attack as one in which the last warhead used on a silo destroyed one or more warheads on average." The Administration responded: "There is no *effective attack* against Minuteman II (or any single warhead system). A one-warhead attack on a Minuteman III [with 3 RVs] and a one- or two-warhead attack against a Peacekeeper silo would be effective attacks.

This response shows that attacks of more than 2 warheads, even on the target-rich Peacekeeper, disarms the attacker since such attacks use more warheads than they destroy. Attacks with more than two warheads had been of concern since it is possible, but not likely, that the SS-18 could contain as many as 20 warheads. But the U.S. Trident missiles could, in principle, contain 14 warheads, 6 more than the declared value of 8. These over-loaded missiles would be detected by

the RV on-site inspections, which counted the RV's on each missile. Quoting from the SFRC START Report:

Because the marginal return from the use of a 3rd (or fourth) warhead is very small, with or without fratricide, the ratio of hard target (counterforce) warheads to hard targets greater than two is not militarily significant. Since counterforce weapons can only be effectively applied to silos at the rate of two per silo, and because counterforce weapons cannot successfully attack submarines at sea and bombers aloft and away from airfields, the effective use of counterforce weapons is definitely limited for those above twice the number of silos and launch control centers.

Verification Standard for START

The standard for *effective verification* of arms control treaties was established by Ambassador Paul Nitze when testifying on the INF Treaty in 1988: "What do we mean by effective verification? We mean that we want to be sure that, if the other side moves beyond the limits of the treaty in any militarily significant way, we would be able to detect such a violation in time to respond effectively and thereby deny the other side the benefit of the violation." The START report language gave the results of an exchange model that started with 10,000 US warheads but was reduced by a Soviet first-strike-attack to 3,600 survivable warheads. This was a worst-case analysis, one that I didn't believe. It's interesting to point out that Senator Jesse Helms' staff organized the ratification of START II, using the same approach, but they probably believed in worst-case analysis. Even with worst-case analysis, the U.S. had 3,600 warheads remaining, when ten warheads aimed at the 10 largest Soviet cities would in effect destroy the Soviet Union.

Presidential Report on the Treaty Compliance for All Arms Control Treaties

The resolution of ratification required the president to determine whether arms control had more costs from noncompliance versus benefits from reducing Soviet nuclear arms. Condition number 7 required the following:

(A) a listing and discussion of actions which are violations or probable violations of the obligations of the SALT I, SALT II, ABM, INF and START Treaties and the ultimate resolution of these issues;

(B) a listing and discussion of the actions which are in compliance with the SALT I, SALT II, ABM, INF and START Treaties; and

(C) a comparison of the military significance of those actions listed in subparagraphs (A) and (B).

Ultimately the bureaucracy produced the report, which I analyzed in *Presidential Report to the Congress: Net Benefit Analysis of US/Soviet Arms Control (Science and Global Security 2005)*. This effort was necessary to understand Soviet violations, to prove that arms control (B) was far more important than Soviet violations that lacked military significance (A).

The Biden Condition, Nuclear Stockpile Weapons Arrangement

The NGO's established the movement to create warhead monitoring at the end of the Cold War between the US and USSR, discussed above in Sec. 6.6. The lead Soviet General Zelentsov wanted no part of this, nor did U.S. Secretary of Defense Richard Cheney, who stated the following: "We wanted to make certain that what we were agreeing to were agreements that

could be verified. And getting into the area, verifying the destruction of warheads is a much more complicated subject.” Declaration Three, adopted by SFRC, instructed the President to move ahead with warhead destruction, but it did not require verification by the two countries. The Resolution of Ratification was *marked up* in the small SFRC hearing room in the Capital Building, which held 30 visitors. Things were going well as the Executive Branch and a few reporters were on one side of the table and the senators and staff were on the other side. SFRC was about to adjourn when Senator Joe Biden made a motion to add an Eighth Condition:

.... the president shall seek an appropriate arrangement, including the use of reciprocal inspections, data exchanges, and other cooperative measures, to monitor (A) the number of nuclear stockpile weapons on the territory of the parties to this Treaty; and (B) the location and inventory of facilities on the territory of the parties to this Treaty capable of producing or processing significant quantities of fissile materials.

I knew the Biden amendment would create a problem because the next treaty, START II, did not have these monitoring provisions. But I also knew the amendment was vaguely worded since it wasn't clear to which treaty it was to be applied. Upon hearing the amendment, the Executive Branch's Tom Graham and Jim Timbie became ashen-faced. Ultimately, Senator Sam Nunn became involved, forcing Biden to agree that his amendment would not complicate the de-MIRVing of missiles in START II, but that it would apply to the future START III. Monitoring warheads gained stature when it was agreed *to be considered* in START III by Presidents Yeltsin and Clinton on March 21, 1997 in Helsinki. A joint Soviet-American work program was established by the weapons laboratories of the two nations during 1997 to 2001. New approaches were tried for monitoring warheads, using techniques called attributes and templates. This approach was dropped when President George W. Bush became president. Ultimately, I became involved with warhead monitoring, as the Study Director of the National Academy of Sciences study, *Monitoring Nuclear Weapons and Nuclear-Explosive Materials* (2005).

Team B and the Strength of the Triad

At the end of the Ford administration, the NGO group, *Committee on the Present Danger*, obtained access to CIA data on Soviet forces to write a *Team B* report on Soviet military prowess. At the end of the Cold War, it seemed useful to examine what *Team B* said and how their results compared with what the General Accountability Office (GAO) determined about the relative strengths of the Soviet and American triads. Senator Glenn agreed to chair the hearing in the Government Affairs Committee with Deputy DoD Secretary Bill Perry. The un-classified GAO volume was backed with 8 classified volumes. The hearings became tense when the Air Force was caught in a bold lie to Congress about the magnitude of B-1 radar cross-section. Glenn was particularly incensed because he had been a B-1 supporter. The hearing showed that the submarine-based weapons were as accurate, lethal and timely as those from ICBM's. The hearings further showed that on a survivability basis, the SLBM's were the best buy. The 1992 GAO report concluded the following:

The Soviet threat to the US triad was overstated, that the performance of existing US systems was understated, and that the performance of new US systems was overstated..... In the case of the land leg...the claimed *window of vulnerability* caused by improved Soviet missile capability against [US] silo-based ICBMs was overstated on three counts. First, it did not recognize existence of sea and air leg deterrents, that is the likelihood that the Soviets would hesitate to launch an all-out attack on the ICBM silos, given their inability to target submerged US submarines or on-alert bombers and their thousands of warheads that could be expected to retaliate. Second, the

logic behind the claim assumed the highest estimates for Soviet missile performance dimensions as accuracy, yield and reliability, while at the same time discounting very substantive substantial uncertainties about performance that could not have been resolved short of nuclear conflict. Third, it ignored the ability of US early warning systems to detect a Soviet ICBM attack, and thereby allow a reasonably rapid response. [*Science and Global Security*, 1997]

Four Days of Killer Amendments

Senators Claiborne Pell and Dick Lugar and their three staff sat in the *Well of the Senate* for four days, from September 28 to October 1, 1992, fighting killer amendments. The purpose of Senators Wallop, Smith, Symms and Helms was to pass at least one amendment that would change the bargain with the Soviets, in effect blocking the treaty from ever entering into force. These four senators did not have the votes to block START, as it would ultimately pass 93 to 6. But they could cause mischief along the way. These four senators were too busy to write the 61 amendments, which were written by my counterpart David Sullivan, Senator Jesse Helms' key staffer on arms control treaties. As an example, we will list Amendment Number 3260:

The START Treaty, including the May 23, 1992 Protocol, the two Annexes, six Protocols, Memorandum of Understanding and Corrigenda, shall not enter into force until the President certifies that all MIRVed ICBM's, and all launchers for MIRVed ICBM's, shall be eliminated in accordance with the agreement in the Joint Understanding on deep cuts on June 17, 1992 signed by the President of the United States of America and the President of the Russian Federation.

This amendment may sound like apple pie, but it is mixing 2 different treaties to make it a killer amendment. President George H.W. Bush signed an agreement with President Yeltsin to move towards ratification at a later date with START II, which would ban land-based MIRV missiles. START I did not ban MIRV, that was going to happen in START II. This amendment was unacceptable to both treaty parties since it changes the basic bargains of START I. David Sullivan was too cute by one-half, but the amendment was handily defeated. There were 60 other amendments like this, but we won't discuss them.

The Evolution of MIRV

Multiple-Independently-Targetable-ReEntry Vehicles (MIRV) were invented to save money. If the nation wants to attack with 1000 warheads, it is cheaper to place them on 100 missiles with ten warheads on each missile, as compared to 1,000 missiles with one warhead per missile. But, the approach with 10 RV's per missile is unstable. The nation with 1000 warheads on 100 missiles could be attacked with 100-200 hard-target warheads, instead of 1,000-2,000 warheads if based without MIRV. One might look at the cost-exchange-ratio of ten-to-one or five-to-one and launch an early or pre-emptive attack to save the home weapons. But this ignores the fact that other warhead systems would level the attacker.

My first visit to the Senate was in June of 1969. The Senate chamber was essentially empty except for one lonely senator eloquently presenting his case on Senate Resolution 211 for a ban of the development of MIRV systems. The senator was from Massachusetts by the name of Edward Brooke, a rare individual in that he was a black Republican, the 1st black senator since the Reconstruction Era. This is what SR 211 said in part:

Whereas development of multiple independently targetable reentry vehicles by both the United States and the Soviet Union represents a fundamental and radical challenge to such stability;

Whereas the possibility of agreed controls over strategic forces appears likely to diminish greatly if testing and deployment of multiple independently targetable reentry vehicles proceed;

Resolved further, that the president should propose to the government of the Union of Soviet Socialist Republic an immediate suspension...of the further development of all offensive and defensive nuclear strategic weapon systems subject to national verification or such measures of observation and inspection as may be appropriate.

Now that was significant, in spite of the fact that the Senate was almost empty and it seemed unlikely to ever happen. But ultimately SFRC reported favorably on SR 211 on March 24, 1970, and it passed the Senate on April 9, 1970 on a vote of 72 to 6. I didn't forget that moment, and I felt fortunate to be able to recall that moment some 23 years later, as we worked on the SFRC report on START-1. At that point the proposed START-II treaty was to ban land-based MIRV missiles. For the United States, this meant the removal of the Peacekeeper with 10 warheads each on 50 missiles, the Minuteman 3 with 3 warheads each on 450 missiles. For the Soviets this meant the removal of the SS 18 with 10 warheads on 310 missiles (cut in half by START-1), the SS 19 with six warheads, and other systems. Thus, de-MIRVing would reduce thousands of warheads. A month after the ratification of START-1, I decided to write a note of thanks to Sen. Edward Brooke:

In order to place Declaration Number 1 for START-I in context we chose to point to Senate Resolution 211 which you introduced in 1968, because, after all, that was the point in time when the Senate correctly understood the danger of MIRV. Two decades have passed and at least a 3rd decade will be needed to fulfill SR 211, billions of dollars were wasted, and great dangers were taken with the instabilities of MIRV. If the US government had listened to you we would have been much better off...I felt fortunate to be able to recall SR 211 as we worked on the SFRC report on START-1.

Sen. Brooke responded as follows: You may consider yourself fortunate to have been present in the Senate at the introduction of SR 211, but I feel even more fortunate in that you remembered.

START I to START III in ACDA

The 1997 calendar year was spent as a Foster Fellow in the U.S. Arms Control and Disarmament Agency on START I-II-III. Presidents Clinton and Yeltsin agreed in Helsinki on March 21, 1997 to proceed to a START III Treaty to reduce to 2000–2500 deployed, strategic warheads. Recall the Biden Amendment on warhead monitoring a few pages back. The two presidents agreed to “measures relating to the transparency” for inventories and destruction of strategic warheads. I joined this issue because of recruiting by Michael Nacht, Assistant ACDA Director. I had never placed monitoring warheads first on my list, but it now looked more likely, but still difficult. It turned out to be a very long year, my slowest in Washington. Republicans didn't want Clinton moving in this direction and they forbid ACDA from working in this area. They required the *entry into force* of START II to negotiate on START III, but START II was held up with a disagreement with Russia on the ABM treaty. I spent most of the year working on START-I compliance issues, a back-burner event. Both the Americans and the Russians exaggerated various compliance questions. There were legal points, but none rose to the level of militarily significant. It was and is true that individuals can use such issues to derail arms control. I spent a

fair amount of my time on the Bilateral Implementation Commission (BIC), on encrypted telemetry, and on future force structures. This was my slowest year in Washington.

6.8. Nuclear Test Ban Treaties

Threshold Test Ban Treaty

My first involvement with nuclear testing was in the 1987 State Department, where I was lead State technical analyst on Soviet compliance to the Threshold Test Ban Treaty (TTBT). The issue is complex because Western US geography is younger, absorbing seismic signals more, while the Soviet's Asian plate is older, absorbing seismic signals less. The Reagan and Bush-I administrations concluded that Russia was in "likely violation" to the TTBT. The day I arrived at the TTBT interagency meeting, the newspaper stated that the East-West bias-number of 0.2 magnitude units had been leaked to the press. This was a tense time on these issues: In 1985 Gorbachev stopped Soviet testing, calling the United States to join him. The US House of Representatives had blocked US nuclear testing. In February 1987, the Soviets ended their unilateral nuclear testing moratorium after 18 months. Negotiations were not going well in Geneva. My main effort was to examine many spreadsheets of data by varying the parameters, including the bias factor. I wrote a lengthy memo, which showed that by using the 0.2 bias factor, the data would not give the result of a likely violation. We have to remember that monitoring amplitudes of explosions is a statistical event. By assuming reasonable distributions of explosions, I could see that the few explosions at higher yield could be explained as a violation. I suggested to my boss that we submitted it to the interagency process. He did not want to ask the assistant secretary for a signature. But he did tell me that I could spread my results to other interagency members, which I did. My work moved the State vote from *likely noncompliance* to *compliance with the possibility of a few tests with small excessive yield*. The final interagency result was a vote of 3 to 3, in favor of noncompliance were DOD, JCS and ACDA and in favor of compliance were State, DOE and CIA. President Reagan broke the tie, making the Soviets in "likely noncompliance." I believe this was bad science and done to avoid dealing with Gorbachev's offer of a Comprehensive Test Ban Treaty. There was nothing I could do, but I made sure my calculations and spreadsheets were deposited in a State Department vault.

Six months later I was at Stanford's Center for International Security and Cooperation with Fred Lamb, a physicist from the University of Illinois, who told me that the House of Representatives was about to have a hearing on *TTBT compliance*. I sent a one-page commentary to the House Committee on Foreign Affairs hearing of June 28, 1988. I learned about the event because Gary Carl, a friend of mine from San Luis Obispo, was in attendance. The three government witnesses were General Burns, ACDA Director; Bob Barker, Secretary of Defense Richard Cheney's lead nuclear assistant; and Paul Robinson, the TTBT Chief Negotiator, all of whom I know. At the end of the hearing, the Committee Chair, Dante Fascell of Florida said the following to which the government witnesses showed great concerns:

Without objection, I would like to insert in the record a letter from Professor David Hafemeister. He writes in his individual capacity about the question of Soviet compliance with the Threshold Test Ban Treaty. The whole letter will be put in the record for examination, but basically he says: 'Taking into account the uncertainties, I conclude that one cannot state that the Soviets have or have not been violating TTBT. Or to put it another way, the data is not inconsistent with Soviet compliance with the TTBT.' And then he goes on to support the OTA

report on seismic verification of nuclear testing on this issue, and he refers to pages 17 and 19. I thought the Administration witnesses might want to take a look at the letter. We will give you a copy of the letter, of course.

The House TTBT hearing had a bigger impact on my life than getting the TTBT truth out. The following September I got a phone call from Bill Ashworth, the lead Senate Foreign Relations Committee staff member on arms control matters, with whom I had worked on the Glenn-Symington sanctions, discussed in Chapter 5. Ashworth told me that he had been at the House hearings and would like for me to tell my story to the Senate Foreign Relations Committee. On October 6, 1988, the Administration witness was TTBT Chief Negotiator, Paul Robinson, followed by three technical witnesses who disagreed with the Executive Branch compliance decision. The other two witnesses were Mylo Nordyke of *Lawrence Livermore National Laboratory* and Greg Vander Vink of the *Office of Technology Assessment*. These results appeared in the *New York Times*. From my testimony:

In particular, I carried out a thorough statistical analysis of the seismic data taking into account the random and systematic errors and using the accepted U.S. government value for the bias factor.... If one applies the same standard of evidence to the testing programs in both the US and USSR, one can state that both sides are complying to the TTBT within the accuracy of the measurements.... Therefore I agree with the OTA report on this issue which states that: 'All of the estimates of Soviet and U.S. tests are within the 90% confidence level that one would expect if the yields were 150 kton or less.

A Job at SFRC

After testifying, I chatted with Bill Ashworth, Chairman Pell's lead person on arms control treaties. I knew the next few years were going to be a busy time for SFRC as we were moving towards an accommodation with the Soviet Union. I suggested to Bill that I joined him at SFRC to help with the treaties, and to my surprise he was interested. The following February I interviewed with Chairman Pell in Washington. Soon I had an offer that became a two-year job from 1990 to 1992, working on ratification of TTBT, START I, and CFE; and maintenance on the ABM Treaty, Open Skies Treaty, Chemical Weapons Convention, ACDA authorizations, the Iraqi Desert Storm War, the test ban from Mitchell-Hatfield-Exxon, a plutonium control bill with Cranston, and further nuclear sanctions with Senators Pell, Glenn and Helms.

A Nuclear Testing Ban Passes

The U.S. had been a holdout on the Comprehensive Nuclear Test Ban Treaty. There were questions of monitoring, reliability of older weapons, and safety from unsafe weapons. But there were questions about no plans to stop nuclear tests by increasing numbers of other nations. We held only one hearing on nuclear testing, in conjunction with START, with witnesses Frank von Hippel and Ray Kidder and the Executive Branch. Bill and I worked with the Armed Services Committee, drafting an amendment for Senators Mitchell, Hatfield and Exxon.

Practically all the released radioactivity came from crashed aircraft. A key paper was written by Steve Fetter and Frank von Hippel, showing that these nuclear weapon accidents didn't cause as many deaths as they appeared to have done. One can estimate the probability of such accidents from historical record. The thought occurred to me to require the Executive Branch to carry out a cost/benefit calculation on the cost to make safer weapons, and from that determine to cost to save a life. This amendment did not state a numerical standard for weapons change to be

accepted. We let the Executive Branch decide *how much is safe*, but the Executive Branch should at least do the calculation. To my surprise this law stopped all US nuclear tests. The last US nuclear test took place on September 23, 1992. The final result on cost-benefit standards appears in the 1992 law:

Subsection F: A plan for installing one or more modern safety features in each warhead identified in the assessment referred to in subparagraph (C), as determined after an analysis of the costs and benefits of installing such feature or features in the warhead, should have one or more of such features.

National Academy CTBT Studies 1 and 2

When I was approached in 2000 for to the job of National Academy of Sciences study director on *Beyond START*, I surprisingly said “no thank you” because we had been traveling too much. As I rode my bike to campus that day, I passed the newsstand, which said that CTBT ratification was defeated by the Senate. As I rode to class, I felt my compass changing from *no to yes*. I called NAS back, the job was still open, which keep me busy from 2000–02. The first study, *Technical Issues Related to the Comprehensive Nuclear Test Ban Treaty* (2002) was chaired by John Holden with 10 committee members. The committee's charge was to review the state of knowledge about three main technical concerns that were raised during the Senate debate of October 1999 at the failed ratification of CTBT: (1) the capacity of the US to maintain confidence in the safety and reliability of its nuclear stockpile; (2) the capabilities of the international nuclear-test monitoring system (with and without the national technical means); (3) the additions to their nuclear-weapon capabilities that other countries could achieve through nuclear testing at yield levels that might escape detection. Jo Husbands was the study director and I was the technical staff. From 2000 to 2002 the NAS Panel of 10 experts met in Washington and at Lawrence-Livermore national Laboratory, concluding the following:

(1) We judge the United States has the technical capabilities to maintain confidence in the safety and reliability of its existing nuclear weapons stockpile under the CTBT, provided that adequate resources are made available to the Department of Energy's nuclear-weapon complex and are properly focused on this task.

The NAS Panel examined each of the potential problems with each warhead design. The question was always asked, “Would nuclear testing help solve this problem?” The answer always came back, “No, we can do it without nuclear tests.”

(2) Underground explosions can be reliably detected and can be identified as explosions, using IMS data, down to a yield of 0.1 kton in hard rock if conducted anywhere in Europe, Asia, North Africa, and North America. In some locations of interest, such as Novaya Zemlya, this capability extends down to 0.01 kton or less. [If the explosion took place in a large underground cavity at great depths, the limit of cheating is about 1–2 kton for sophisticated nations.]

(3) China and Russia might use the option of testing to make certain refinements in their nuclear arsenals. In the case of Russia, it is difficult to envision how such refinements could significantly increased the threats to the US security interests that Russia can pose with the previously tested nuclear-weapon types it already possesses. In the case of China, further nuclear testing might enable reductions in the size and weight of its nuclear warheads as well as improve yield-to-weight ratios. Such improvements would make it easier for China to expand and add multiple-independently targetable re-entry vehicles to its strategic arsenal if it wanted to do so.

The Academy was asked in 2009 to update the 2002 report. I testified my results in September 2009 from my studies at Stanford in 2005–06 (SAGS 2007) and CTBTO presentations in Vienna [2007, Article XII Meeting; 2009 Keynote Speech at the Science Study Program]. The panels of experts were made up of national lab directors, chairmen of the joint chiefs, and weapon experts. The second NAS panel gave these conclusions in 2012:

[The stockpile stewardship program] has been more successful than was anticipated in 1999 [when the Senate last considered the CTBT]. The status of US national monitoring and the International Monitoring System has improved to levels better than predicted in 1999.... Constraints placed on nuclear-explosion testing by the monitoring capabilities of the IMS and... US NTM will reduce the likelihood of successful clandestine nuclear-explosion testing, and inhibit the development of new types of strategic weapons.... Other states intent on acquiring and deploying modern, 2-stage thermonuclear weapons would not be able to have confidence in their performance without multi-kiloton testing. Such tests would likely be detectable [even with evasion measures].

6.9. The CTBT-NPT Connection

The Nuclear Non-Proliferation Treaty regime has many weaknesses, as we look at India, Iran, Iraq, Israel, Libya, North Korea, Pakistan, South Africa, Syria, and more. Can the world forever be divided into two camps; one side with nuclear weapons and one side without? The present division is split into those that are the Nuclear-Weapon States, the Big Five from World War II and Non-Nuclear Weapon States, those that are not the Big Five. The list of nuclear weapon states will grow unless we are diligent. If the US flaunts NPT norms with that acts that are legal but defy the spirit of the law, not the actual law, then this can come home to roost. The NPT was extended by consensus in 1995 only because the five nuclear weapon states promised they would deliver a CTBT. Since the NPT was decided to last in perpetuity, forever, then the CTBT ought to last the same time, in perpetuity, forever. Of course many nations will not go to the bomb just because they know they don't want to live in a nuclear neighbourhood, such as Norway and Sweden. But this argument doesn't carry everywhere. With this in mind, I contacted Tom Graham, the long-time, top legal mind on arms control treaties and the author of *Disarmament Sketches*. The outcome was an article that appeared in the summer 2009 issue of *Disarmament Diplomacy* called “*Nuclear testing and proliferation– an inextricable connection*,” from which I quote:

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.*’

As in 1968, the non-nuclear weapon states 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.*’

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.