


Citizen Scientist: Frank von Hippel's Adventures in Nuclear Arms Control PART 4. Soviet Nuclear Transparency, the Collapse and After

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ABSTRACT

von Hippel describes a transparency tour during the summer of 1989 to the Soviet Union's first plutonium-production complex in the Urals and to the Soviet test site for anti-satellite lasers in Kazakhstan. In December 1991, immediately after Ukraine declared independence, he participated in a mission to persuade it to return its nuclear weapons to Russia. He describes the thus far unsuccessful effort to dispose of the weapons plutonium that the US and Soviet Union declared excess at the end of the Cold War. The discussion then turns to the US-Russian lab-to-lab program in which the US nuclear-weapon laboratories helped Russia upgrade the security of its plutonium and highly-enriched uranium for the new and more open environment and to the failed US Government attempts to help Russia downsize its huge nuclear weapons complex. Also, in 1991, a summer school was hosted at the Moscow Physics and Technology Institute (MPTI) for young scientists interested in nuclear arms control that has been an annual event ever since and also led to the creation of an arms control center at MPTI. In 1988, von Hippel was involved in a first seminar on nuclear arms control with China's nuclear-weapons establishment. Finally, he describes a 1993 meeting with President Clinton's new Secretary of Energy, Hazel O'Leary, that laid the basis for the president's decision that the US could sustain its nuclear weapons without testing.

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Ozersk, the Soviet Union's First Plutonium-Production City

Tomoko Kurakawa (TK): I am very interested in the Russian “nuclear cities” that you visited.

Frank von Hippel (FvH): I first visited one of the nuclear cities in 1989, before the Soviet collapse, as part of a “glasnost” (transparency) tour that Velikhov organized that ended up with the Black Sea Experiment (see Part 3).

After 1987, Tom Cochran and the Natural Resources Defense Council (NRDC) for which he worked had taken the lead in developing the relationship with Velikhov. The NRDC had much more expertise and interest in the public-relations than I, and Cochran

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had developed a strong relationship with Velikhov as a result of the NRDC seismic monitoring project around the Semipalitinok test site in Kazakhstan (see Part 3).

I was not involved in the NRDC's second transparency initiative with Velikhov. It had to do with a Soviet violation of the Antiballistic Missile (ABM) Treaty limiting Soviet and US ballistic missile defenses. The Soviet Union was constructing a huge early-warning radar near Krasnoyarsk in Siberia, which was not at a treaty-allowed location. The ABM Treaty said early-warning radars were supposed to be on the boundary of a country, pointing outward. The Krasnoyarsk radar was not and was therefore suspected of being for guiding interceptor missiles to incoming warheads. It had become a major treaty compliance issue for the United States.

Cochran proposed to Velikhov that the NRDC would recruit a group of US Congressmen and journalists to visit the radar in the hope that such openness on the part of the Soviet Union would be a step toward resolving the issue. Velikhov got approval and the visit took place in September 1987. It included three members of the House of Representatives accompanied by their staffers and a journalist from the *New York Times*. After the visit, one of the staffers was quoted by the reporter to the effect that the construction work on the radar was "shoddy" and Velikhov later complained to Cochran, "It's as if I invited you into my house, and then you go out and tell the newspapers my bathroom is dirty!" The trip did deflate US concerns about the radar, however, and, two years later, the Soviet government admitted that it was a treaty violation and tore it down.

In those days, both sides had some respect for objective facts.

The third glasnost tour, in the summer of 1989, started at the Soviet Union's first plutonium-production site outside the town of Ozersk, previously known only by its postbox number in the nearest large city, Chelyabinsk 40. The city did not appear on public maps of the Soviet Union.

The NRDC again brought three members of the House of Representatives plus senior reporters from the *New York Times* and *Washington Post*. We flew to Chelyabinsk on the Minister of Defense's airplane. When I asked how the minister had been persuaded to provide it, Velikhov told me that the minister was up for confirmation before a committee of the Supreme Soviet of which Velikhov was a member.

We were the first foreigners who had ever visited the city (Figure 1).

The town of Ozersk is not especially beautiful but the countryside around it is: forests and lakes as well as farms. It is located on the eastern side of the Ural Mountains, which divide European Russia from Siberia. The mountains are old and relatively low (up to about 1,000 meters high) –like the Appalachian mountains inland from the east coast of the United States. Russia's second nuclear-weapon lab, VNIITF, is 35 kilometers to the north of Ozersk, in the town of Snezhinsk.

Velikhov arranged this stop in our tour because he knew I was promoting a Fissile Material Cutoff Treaty that would end the production of plutonium and highly-enriched uranium for weapons. He wanted us to see that the Soviet Union had begun shutting down its plutonium-production reactors.

We were shown and stood on top of the Soviet Union's oldest plutonium-production reactor, the "A" reactor, which had been permanently shut down (Figure 2). The reactors are basically huge blocks of graphite with channels bored through them vertically to hold the uranium fuel and through which cooling water flows to carry



Figure 1. Curious Ozersk citizens gawking at Velikhov and Representative Jim Olin of Virginia (NRDC).



Figure 2. The managers of the “A” reactor stand on its top where cylindrical slugs of aluminum-clad natural uranium metal were loaded into vertical channels. After irradiation, the fuel was dropped out of the bottom of the tubes into a cooling pool before being reprocessed to recover the plutonium (NRDC).

off the fission heat from the fuel. The design was based on the US plutonium-production reactors that were built on the Columbia River in Washington State during World War II. The main design difference was that the fuel channels in the US reactors were horizontal. The Soviet design was later adapted to generate power in Chernobyl-type reactors by pressurizing the water in the tubes so that it could be heated up to a higher temperature without boiling. The heat was then transferred to less pressurized water to generate steam.

The population of Ozersk was almost 100,000. During Soviet times, its residents lived a privileged existence. That has resumed to a considerable degree under Putin. It is a company town. The children of the nuclear cities tend to come back and take jobs in them.

TK: And the reactors are not underground?

FvH: Not in Ozersk, but they are underground in the Soviet Union's third plutonium city, Zheleznogorsk, way to the east in Siberia near Krasnoyarsk. I will discuss my visit there later in this part.

Modern light-water power reactors are inside thick reinforced concrete "containment" structures in case there is a core melt-down accident. The building over the "A" reactor which we visited was not a containment building. In fact, it had windows.

US plutonium-production reactors did not have containment buildings either. After the 1986 Chernobyl accident, this became a concern and they were shut down.

We learned to our astonishment that the Ozersk plutonium-separation plants had been dumping the fission product, cesium-137, recovered from reprocessing irradiated uranium, into a small lake, Lake Karachay. Cesium-137 is the 30-year-half-life gamma-ray-emitting fission product that caused the massive long-term population relocations downwind from the Chernobyl and Fukushima accidents. We were asked whether we would like to go see the lake. I asked, "What is the dose rate on the lake shore?" It was very high – at one location, if one stayed for an hour, the dose would be lethal. So I said, "No, but thank you!"

In 1968, they had a dry summer. Lake Karachay dried up and a lot of contaminated dust was blown off the lake bed into the surrounding area. In 1989, when we visited, the lake was being filled in and covered over.

A much more serious accident had occurred in 1957. It was the world's worst peacetime nuclear disaster prior to Chernobyl. A large tank filled with liquid concentrated reprocessing waste dried out and then exploded, blowing a huge amount of 30-year half-life strontium-90 into the air. Fortunately, the wind did not blow the plume toward the nearby cities. Still, about 10,000 people were evacuated from the "Urals trace" (Figure 3). Strontium-90, unlike cesium-137, does not emit penetrating gamma rays when it decays. But it does emit beta-rays (high-energy electrons) and is an internal hazard if ingested in milk or other food because of its biochemical similarity to calcium as a "bone seaker." It has a long biological half-life in the body and delivers a correspondingly magnified radiation dose to the bone marrow. A very large area of contaminated land had to be taken out of production.

TK: Wow! Was it kept secret?

FvH: The Soviets kept it secret for two decades and US and British intelligence kept it secret as well – possibly because they didn't want to alarm people living near their own plutonium cities. It only became public in 1978 and 1979, when Zhores Medvedev, a dissident Soviet biologist-historian who had moved to London, published an article and then a book (Medvedev 1979). Our visit was ten years later. We knew about the accident and they did not try to hide it. In fact, they showed us a map of the contamination area.

We stayed at a small hotel with ten to fifteen rooms for visiting Soviet officials and experts. In front of the hotel was an electronic signboard that showed in succession the time, temperature, and radiation level. Probably, it was a legacy of the 1957 accident.

TK: It said zero radiation level?

FvH: A low level, approximately that of natural background.

SCHEMATIC MAP OF DENSITY CONTAMINATION BY STRONTIUM-90 (ON 1997) OF THE TERRITORIES OF THE SOUTHERN URALS REGION

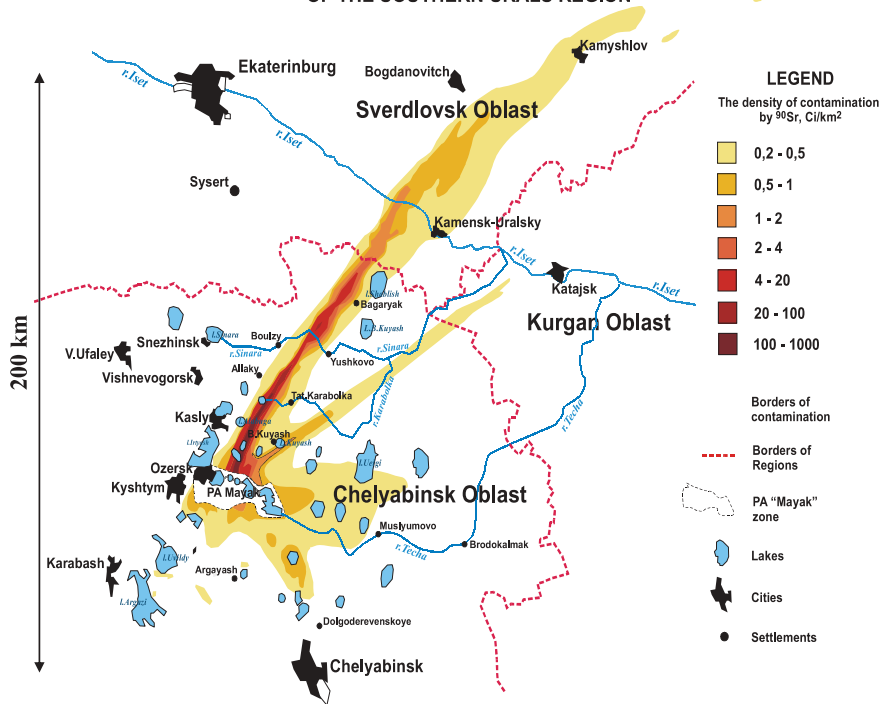


Figure 3. Strontium-90 contamination map from the 1957 waste tank explosion at the Soviet Union’s first plutonium-production complex. The population was relocated from areas contaminated above 2 Curies per square kilometer (corresponding to 0.8 Ci/km² in this map of the contamination as of 1997) (Peremyslova et al., 2004).

TK: So, did you see the facility that exploded?

FvH: We were not shown the reprocessing-plant area.

There was such great urgency to get the plutonium for bombs to balance the nuclear threat from the US that the Soviets took extraordinary risks for both the workers and some of the nearby population. Through 1951, the radioactive waste from the reprocessing plant was dumped directly into the Techa River, the water supply for about 28,000 people who eventually suffered from a statistically significant increase in leukemia rates. When the river flooded, it contaminated the floodplain. Eventually, 7500 people were evacuated from the upper reaches of the river and 80 square kilometers of floodplain were fenced off.

The workers at the Mayak facility also received high doses and are the best population in which to study the consequences of plutonium inhalation.

TK: Before you were taken there, did you know of the existence of the Soviet nuclear cities?

FvH: After US intelligence started flying reconnaissance satellites in the 1960s, they quickly identified the nuclear cities. Tom Cochran had started a Nuclear Weapons Databook

project at the NRDC for which he and his colleagues collected and then published all the information that they could find on the US and the Soviet nuclear-weapons programs (Cochran, Arkin, and Hoenig 1984; Cochran et al. 1987a, 1987b, 1989a).

When we visited, Tom had with him the proofs of the *Nuclear Databook* volume on the Soviet Union. It had a lot of information on the Mayak complex, including commercial satellite images.

They didn't have complete information and they were confused on some things but it was a good start. Later, in 1995, when much more information was available, Cochran, Robert Norris and one of our Princeton group's Russian post-docs, Oleg Bukharin, published a much more complete description and history (Cochran, Norris, and Bukharin 1995).

During the evening of our visit, the director of the enterprise took us on a motor boat out to an island in Lake Irtyash, upstream from the plutonium complex. We had a magical dinner in a grove of birch trees at a table covered with white tablecloths (Figure 4).

After dinner, the director took off his clothes and jumped in the lake. I did as well – after he did. It was mid-July, so good swimming weather.

TK: And what was the status of the reactors?

FvH: There were four high-power plutonium-production reactors at that site. The one we visited, the “A” reactor, was the oldest and had been shut down two years before. The AV-1 reactor was shut down the month after our visit and the AV-2 and AV-3 reactors the following year (1990).



Figure 4. Table set for dinner on an island in Lake Irtyash (NRDC).

There were eight other high-power plutonium production reactors at two other sites in Siberia: Tomsk-7 (now Seversk) and Krasnoyarsk-26 (now Zheleznogorsk). I visited Zheleznogorsk in 1996. There, the reactors were in deep tunnels behind a high cliff along the Yenisei River so that they could survive nuclear attack and continue to produce plutonium – I assume for World War IV (Figure 5).

Three of the eight production reactors at the two Siberian sites shut down in 1990 and another two in 1992. Two of the remaining three operated until 2008 and one until 2010 because they provided heat and electricity to their nuclear cities. They only shut down after the US funded the construction of coal plants to replace them. I was involved in that saga (von Hippel and Bunn 2000).

TK: What about the reprocessing facility?

FvH: Military reprocessing at Ozersk had ended in 1987. The spent fuel from the still-operating production reactors was then shipped to be reprocessed in Seversk, the nearer of the two Siberian plutonium cities. An older reprocessing plant in Ozersk had been converted in 1970 to reprocess naval, research, and civilian power reactor fuel to recover non-weapon-grade plutonium to start up future breeder reactors. I visited that plant five years later when I was in the Clinton Administration.

The nuclear complex is actually outside Ozersk and is called the Mayak Production Association. Mayak is the name of a little village about 60 kilometers to the east.

TK: And what about access to Ozersk?

FvH: Ozersk and the other Soviet/Russian nuclear cities are “closed.” They are inside double fences and you need government permission to enter them. Richland, next to Hanford, Washington State, the first US plutonium production site, was similarly closed until 1957.

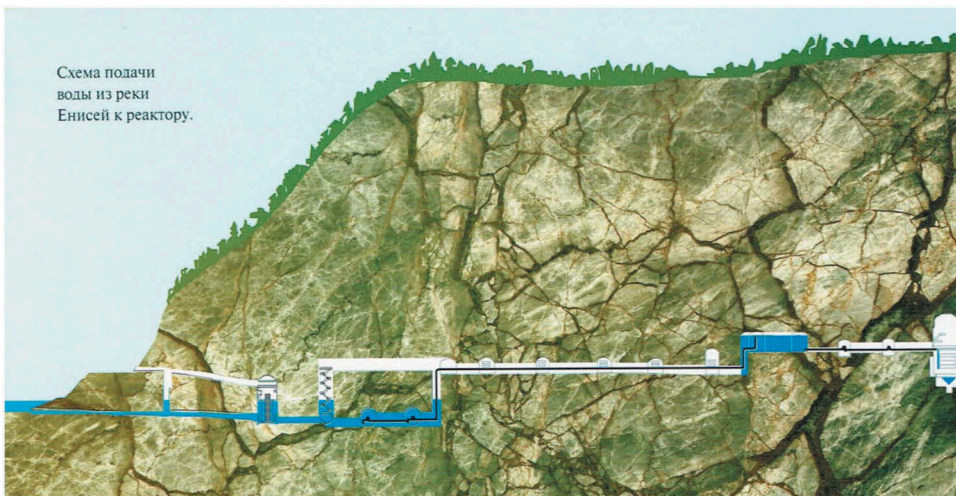


Figure 5. The cooling system for an underground plutonium production reactor in Zheleznogorsk, located on the bank of the Yenisei river. The reactor cavity (at the far right) is under about 100 meters of rock (from a brochure put out by the city’s mining and chemical combine).

TK: You said that Velikhov wanted to show you that the Soviet Union was trying to stop the production of plutonium.

FvH: It was the beginning of their shutdown. Later, in 1994, when I was in the Clinton Administration, Russia and the US signed an agreement “Concerning the Shutdown of Plutonium Production Reactors and the Cessation of Use of Newly Produced Plutonium for Nuclear Weapons.” Each could verify that the other’s reactors were shut down and, in the case of the remaining three Siberian reactors that were operating to produce heat and electricity for their nuclear cities, the US would be able to verify that the plutonium that was being separated from their fuel would not be used in weapons.

One last thing before we leave the subject of Ozersk. I remember talking to the chief engineer of the reprocessing plant, and asking him, “What is your annual budget?” It was the equivalent of a few million dollars a year. I thought, “Wow! Maybe we could get the MacArthur Foundation to pay to shut it down.”

The Soviet Union’s Anti-satellite Laser at Shary Shagan

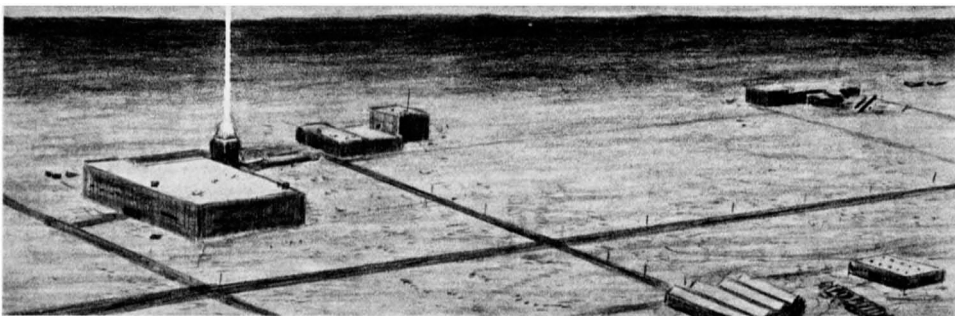
TK: On Velikhov’s glasnost tour, you visited a “killer laser” as well.

FvH: Yes, after stopping at the plutonium city in the Urals, the next stop was Sary Shagan in Kazakhstan, the Soviet Union’s ballistic missile defense (BMD) test site.

The 1985 edition of the Reagan Administration Pentagon’s glossy publication, *Soviet Military Power*, featured an artist’s rendition of a beam director shooting a laser beam vertically into space ([Figure 6](#)) with the caption,

The directed-energy R&D site at the Sary Shagan proving ground includes ground-based lasers that could be used in an antisatellite role today and possibly a BMD role in the future.

This was offered as evidence that the Soviet Union had its own Star Wars program.



The directed-energy R&D site at the Sary Shagan proving ground includes ground-based lasers that could be used in an antisatellite role today and possibly a BMD role in the future.

Figure 6. The US Defense Department’s ominous rendition of the Soviet anti-satellite laser facility at Sary Shagan.

Velikhov took us to the facility. It was in the middle of a desert area near the shore of Lake Balkhash in eastern Kazakhstan, a few hundred kilometers from the border with China.

We went inside the building and followed the beam lines from the beam director to see what kind of lasers the facility was equipped with. One beam line had nineteen ruby lasers with about 100 watts combined power (Figure 7). The other had a 20-kilowatt CO₂ laser similar to those used around the world for cutting and welding. We took lots of pictures.

After we returned home, the NRDC organized a briefing for people from the US military laboratories at Argonne National Laboratory. One of the US laser experts, when he saw the pictures of the lasers, burst out with the exclamation, “Toys!” The US Army had been testing a one-million-watt deuterium-fluoride Mid-Infrared Advanced Chemical Laser (MIRACL) for potential anti-satellite and anti-ballistic missile applications.

We also looked into the electronics of the beam director, and they were pre-chip transistors. The staff told us that the facility had been able to track an aircraft but had not been able to detect a reflection from a Cosmos satellite equipped with a retro-reflector.

Before the 1972 US-Soviet treaty limiting anti-ballistic missile (ABM) systems, however, the Soviet Union had had a more ambitious program. We were shown an underground bunker where the plan had been to install an explosion-powered gas-dynamic laser. But that program had been abandoned. Perhaps US intelligence thought it might still be ongoing.

TK: What is an explosion-driven laser?

FvH: In this case, the explosive combustion of a chemical to produce a large volume of hot CO₂ with some of the electrons in excited states whose energy can be converted into a pulse of laser energy.

Velikhov was familiar with the pre-1972 Soviet ballistic-missile defense (BMD) program because, around 1980, he had been involved in a high-level review of

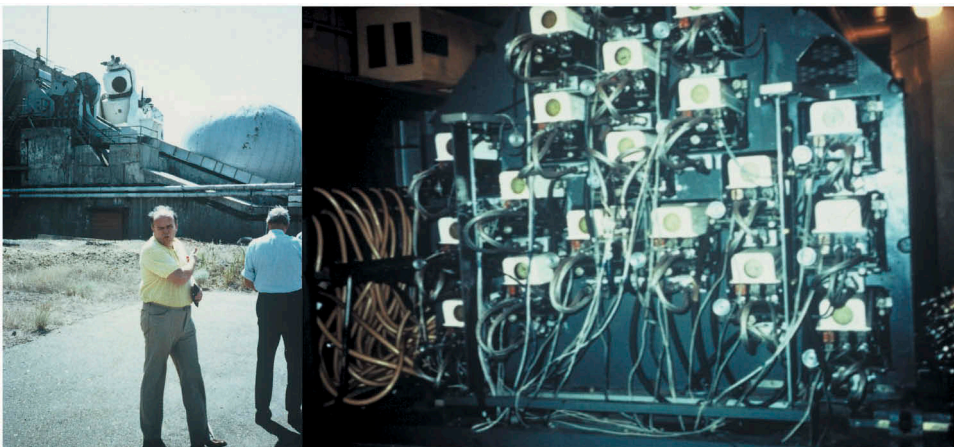


Figure 7. Left: Velikhov and Representative Jim Olin in front of the laser beam director at Sary Shagan. The dome to the right of the beam director covers it when it is not in use. Right: an array of ruby lasers at the end of one of the beam lines. (NRDC).

a proposal for a hugely costly Soviet BMD system based on space-based interceptors. The conclusion of the review was negative (Velikhov 1989) and the program did not proceed.

TK: Did you write something about your visit?

FvH: Cochran and I wrote an op-ed in the *New York Times*, “The Myth of the Soviet ‘Killer’ Laser” (von Hippel and Cochran 1989); I wrote an article in *Physics Today* about our visit to the laser facility in Sary Shagan (von Hippel 1989); and Cochran, Christopher Paine and I wrote a report in *Science & Global Security* about our visits to both Ozersk and Sary Shagan (Cochran, Paine, and von Hippel 1989b).

The Reagan Administration was pushing an open-ended BMD program. One of their arguments was that the Soviets were already doing it and, if the US did not, the Soviets would get ahead – classic arms race rhetoric. In 1990, the budget for the US BMD program peaked. But Republican support in Congress for more traditional but easy-to-countermeasure missile interceptors and lack of opposition from Congressional Democrats kept the US BMD program alive during the Clinton Administration until George W. Bush came into office. After the 2001 terrorist attacks, President Bush took the US out of the ABM Treaty and doubled the budget for ballistic missile defense. During the Obama Administration, Republican support in Congress kept the program alive at twice the funding level that had prevailed during the Clinton Administration and then, under President Trump, it began to rise again (Figure 8).

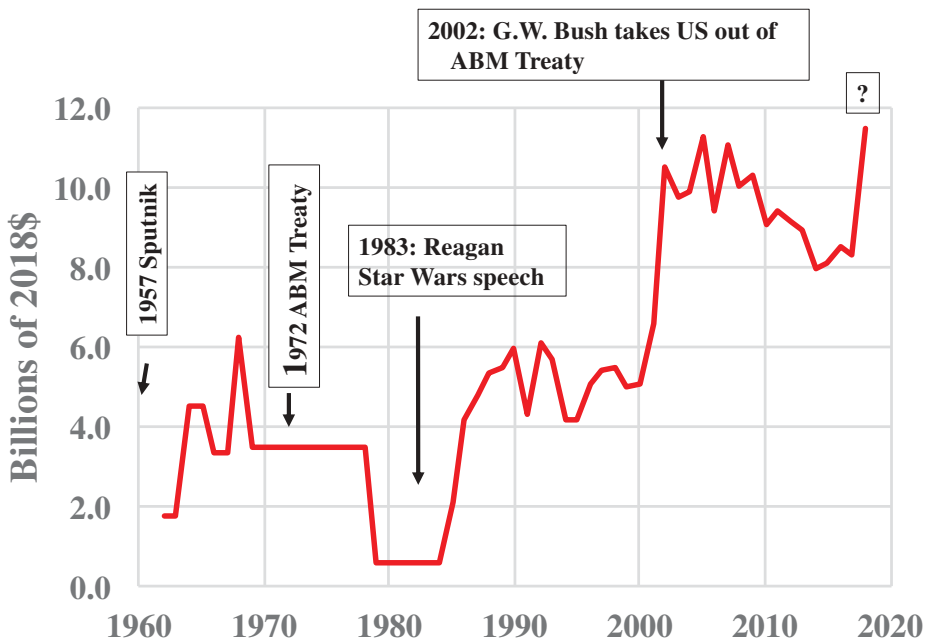


Figure 8. History of the US BMD budget (author).

The Soviet Collapse

TK: Where were you at the time of the Soviet collapse?

FvH: The collapse took a year. I was in Moscow in January 1991 when the uprising in Lithuania was put down. Then there was the August coup attempt by the hardliners against Gorbachev that Boris Yeltsin put down. Overall, however, the collapse unfolded with amazingly little violence. The culmination was in December 1991 when I visited Moscow again: Ukraine declared independence by referendum on December 1, Kazakhstan on December 16, and Russia on December 26. The other twelve republics had already declared independence. At the end of the year, Yeltsin took over in Moscow as President of Russia.

Velikhov tracked down Yeltsin and persuaded him to sign a declaration making the Kurchatov Institute independent. Perhaps Velikhov was already worried about privatization.

TK: He was worried about what?

FvH: Under Yeltsin, state property was privatized and a relatively small number of people took over the major industries, becoming hugely wealthy and influential. They are known as “the oligarchs.” Velikhov’s nightmare scenario might have had the Kurchatov Institute, which is located on prime real estate in Moscow, bulldozed for high-rise buildings.

Velikhov was very bold. He didn’t know Yeltsin but he went looking for him and found him at an airport. He explained what he wanted and said, “Please sign here.” So Yeltsin, as the new President of Russia, signed the document declaring the Kurchatov Institute independent. So far, it remains so.

Velikhov has an interesting role under Putin. Velikhov has always been interested in grassroots democracy while Putin seeks centralized control. That makes them an unlikely pair. But, in 2004, Putin created the Civic Chamber of the Russian Federation and appointed Velikhov chairman. According to Wikipedia, the Chamber is supposed to

Help citizens interact with government officials and local authorities in order to take into account the needs and interests of citizens, to protect their rights and freedoms in the process of shaping and implementing state policies, and to exercise public control over the activities of executive authorities.

I doubt the Civic Chamber has real power, but I imagine that Velikhov used his remarkable powers of persuasion to do what he can.

TK: Was the collapse of the Soviet Union shocking to you?

FvH: I was as surprised as anyone. No one had thought seriously about the implications of a country with 40,000 nuclear warheads collapsing.

Nuclear-weapon materials are long-lived. Plutonium-239 has a 24,000-year half-life and uranium-235 a 700-million-year half-life. But the institutions that control nuclear weapons are relatively short-lived and don’t plan for their own demise. All that destructive power is in the hands of transient institutions.

A Visit to Ukraine Right after the Collapse

TK: Why were you in Moscow at the time of the disintegration of the Soviet Union?

FvH: It happened that, during December 1991, a group of us, organized by the NRDC, went to Moscow for a workshop on nuclear-warhead arms control. The Russian Foreign Ministry then asked us to go to Kiev to talk to the Ukrainian leadership about allowing the return of the Soviet warheads in Ukraine to Russia.

We had some senior Soviet weapon scientists along. I recall talking on the train with the Deputy Director of VNIITF, the second Soviet nuclear-weapons design laboratory. I asked him what his team would do now that the Cold War and the development of new nuclear weapons were over. His eyes glistened and he said, “You can do such wonderful physics research with nuclear explosions!”

TK: For what?

FvH: Sakharov had written an article about how one could produce magnetic fields way beyond anything that could be achieved in any other way by imploding a magnetic field with a nuclear explosion.

TK: How did you respond to him?

FvH: I dropped the subject.

We also had along a general who headed the Soviet Ministry of Defense’s 12th Main Directorate, the one responsible for stored nuclear weapons. He told us that he had every single Soviet nuclear warhead listed in a ledger and that we should not worry about any of them getting lost.

Tom Neff was along and planted the idea with the Ukrainians that they could trade their warheads to Russia in exchange for low-enriched power-reactor fuel containing an amount of U-235 equal to the amount in 50 tons of weapon-grade uranium. I understand that this was ultimately agreed.

Sergei Kortunov, my friend in the Foreign Ministry embarrassed me by sending the message to our hosts in Ukraine that I was a Nobel Peace Prize winner. I had to explain that I was not.

Plutonium Disposal

TK: Did the collapse of the Soviet Union inspire you to make new initiatives in nuclear arms control?

FvH: I began to focus more on getting rid of nuclear weapons materials. Neff had found a solution for the highly-enriched uranium (HEU), but how about plutonium? For plutonium there is no dilutant like the natural or slightly enriched uranium that can be used to isotopically dilute weapon-grade uranium to low-enriched uranium fuel, which cannot be used to make a fission explosive. And it costs an order of magnitude more to make plutonium into power-reactor fuel than the alternative of making low-enriched uranium fuel. So, unlike HEU, there is no profit motive to drive plutonium disposal.

In 1993, before I joined the Clinton Administration, seven of us, including a Russian colleague, Anatoli Diakov from the Moscow Institute for Physics and Technology, published an article in *Science & Global Security* on the options for plutonium disposal (Berkhout et al. 1993). We winnowed the options down to two:

- (1) Subsidize the manufacture of plutonium into mixed-oxide (MOX) plutonium-uranium fuel for light-water power reactors, or
- (2) Mix the plutonium into the liquid reprocessing waste from which it had originally been separated and then mix the resulting mixture into molten glass. The resulting “vitrified” waste would be buried in deep underground repositories.

We preferred the second option because it would treat plutonium as waste. We were still fighting the dangerous idea that it made economic sense to separate the plutonium in spent reactor fuel for “recycle.”

Our article provided the starting point for a major National Academy of Sciences (NAS) study that John Holdren¹ chaired and for which Matthew Bunn² was the study director.

The NAS study arrived at the same conclusions we had. It also noted that either of those two options would make the plutonium roughly as inaccessible as the much larger quantities of plutonium in spent power reactor fuel. They turned that into a criterion for disposal, “the spent fuel standard” (National Academy of Sciences 1994).

Later, when I went into the Clinton Administration, the National Security Council staff asked me to take responsibility for White House oversight over the Department of Energy’s studies of plutonium disposal options.

TK: How about the Russian side?

FvH: On the Russian side, the nuclear establishment reacted with horror at the idea of treating plutonium as a waste. They said, “People died to produce this material! You can’t just throw it away! You have to use its energy content!”

This debate took place in the context of prolonged negotiations over what became the US-Russia Plutonium Management and Disposition Agreement. The PMDA was not concluded until 2000, long after I left White House. Under that agreement, each side agreed to dispose of 34 tons of weapon-grade plutonium, approximately the amount in 10,000 warheads. The Russians decided that they would fabricate their plutonium into fuel. They also insisted that the US use most of its plutonium (25 of the 34 tons) in MOX fuel but agreed that the remaining nine tons of US weapon-grade plutonium, which did not come from excess Cold War weapon pits, could be mixed with reprocessing waste.

¹John Holdren was one of the Stanford physics graduate students I taught who decided to pursue careers in public policy. He co-founded and led the Energy Resources group at the University of California, Berkeley in 1973 and moved to Harvard’s Kennedy School of Government in 1996. He was chair of the Pugwash Conference on Science and World Affairs (1987–97). He served as chairman of the National Academy of Sciences’ Committee on International Security and Arms Control (1994–2005) and was President Obama’s science advisor (2009–17).

²Matthew Bunn is a professor at Harvard University’s Kennedy School of Government. His research focuses on the prevention of nuclear-materials theft and terrorism, nuclear nonproliferation, and the nuclear fuel cycle. We worked together in President Clinton’s Office of Science and Technology Policy.

At the beginning of the G.W. Bush Administration, however, it was decided that it should be less costly to dispose all 34 tons of US excess weapon-grade plutonium in MOX fuel. The Bush Administration estimated that it would cost about 2 billion USD to build a MOX-fuel fabrication plant and process the 34 tons of plutonium into MOX fuel.

That cost estimate proved to be wildly optimistic. The contract to build the MOX-fuel plant was given to a consortium led by AREVA, which had built France's MOX fuel fabrication plant. After that, the estimated cost of the MOX program grew and grew. Part of the growth was due to the Department of Energy's practice of "cost plus" contracts and incompetent oversight, and part of it was due to the need to add a whole section to the French design of the plant to extract the gallium that is used to alloy plutonium in weapons. Finally, in 2013, after the cost estimate reached 18 billion USD, the Obama Administration proposed to scrap the MOX plan and simply dilute the plutonium and bury it in the Department of Energy's deep repository for plutonium-contaminated waste, the Waste Isolation Pilot Plant (WIPP), in New Mexico. Tom Clements, who runs Savannah River Site Watch, a one-man NGO in South Carolina; Ed Lyman of the Union of Concerned Scientists; and I brainstormed with Congressional staff and with the appointee who was leading the plutonium-disposal review in Secretary of Energy Ernest Moniz's³ office (Clements, Lyman, and von Hippel 2013). The Trump Administration has continued down the track chosen by the Obama Administration.

Some of us have also encouraged the UK to go down a direct-disposal track with its own huge stock of more than 100 tons of separated civilian plutonium (von Hippel et al. 2012).

TK: And on the Russian side?

FvH: Russia initially agreed to dispose of its plutonium in MOX fuel on the condition that the US and its allies would pay for the construction of a MOX-fuel-fabrication facility in Russia. The estimated cost of the Russian MOX plant grew in parallel with that of the US MOX plant, however, and Congress refused to increase the US funding commitment for the Russian MOX plant. So Russia decided to use its excess weapons plutonium as fuel in its breeder reactor program. In 2010, the Plutonium Management and Disposition Agreement (PMDA) was amended accordingly.

In 2015, Russia finally completed its BN-800 prototype breeder reactor and started using plutonium fuel in it. The plutonium used was not Russia's excess weapons-grade plutonium, however, but rather separated civilian plutonium from Ozersk. The US similarly has not used plutonium covered by the PMDA in its initial implementation of its blend-down decision. Nor has either country completed negotiations with the IAEA for international verification of the disposal of its excess weapons plutonium, to which both agreed in the PMDA.

³Moniz was a professor of physics at MIT who had co-chaired a number of MIT energy-policy studies. After I left the Clinton Administration, he was Associate Director for Science in the White House Office of Science and Technology. He is now co-chair with former Senator Nunn and philanthropist Ted Turner of the Nuclear Threat Initiative, a Washington, DC-based NGO. Moniz was another of the Stanford physics graduate students who took one of my classes while we had our consciousnesses raised during the Vietnam turmoil.

In 2016, President Putin took Russia out of the PMDA. He cited both the US decision not to use MOX, and the sanctions that the US and Europe imposed on Russia after its 2014 seizure of Crimea and invasion of eastern Ukraine. Some of my Russian colleagues believe that Russia may eventually come back into the PMDA.

Despite the breakdown of nuclear arms control, it seems to me highly unlikely that either Russia or the US will use in weapons again the plutonium that they have declared excess. They both have huge reserves of weapon-grade plutonium that they have not declared excess.

In any case, Russia's decision to use the plutonium for breeder reactor fuel is not really disposal. Breeders are designed to produce more plutonium than they consume and the plan is to separate the plutonium out of the irradiated fuel and new weapon-grade plutonium out of the uranium "blankets" around the breeder reactor core and recycle the plutonium indefinitely. The Russians argue that the isotopic mix of the plutonium from the core will no longer be weapons-grade. It still will be weapon-usable, however, and a terrorism threat if stolen.

In some ways, I prefer that Russia use its civilian rather than its weapons plutonium in its breeder-reactor program. During the Clinton Administration, the US built Russia a highly secure storage facility for the weapons plutonium that Russia had declared excess that cost about a half a billion dollars⁴. I have visited Russia's stored civilian separated plutonium and it is much less secure.

TK: Where is it?

FvH: Both storage facilities are outside Ozersk. I visited Ozersk again in 1994 when I was in the Clinton Administration. I was accompanying a group from the Department of Energy that was looking into how to upgrade the security of the civilian plutonium storage facility. That facility is in the middle of a closed nuclear city that is guarded by Interior Ministry troops. But the facility itself was a small ordinary warehouse with a single young nervous guard with a rifle standing in front of it. At the time of my visit, it contained more than 20 tons of plutonium in oxide form stored in about 10,000 cans, the size of coffee pots, lined up on the floor.

TK: Wow!

FvH: If someone had bribed or threatened the guard and took away a few cans, they would have had enough for a bomb.

Cooperative Nuclear Threat Reduction

TK: Please tell me your connection with "The Nunn-Lugar Act".

FvH: In 1991, Senators Sam Nunn and Richard Lugar managed to get legislation passed that authorized the limited use of Department of Defense funds for destroying excess Soviet strategic missiles, bombers, ballistic-missile submarines, chemical weapons, etc.

⁴With Google Earth, it may be found at latitude 55.713 N and longitude 60.648 E.

I became concerned, however, that Russia was being treated as a defeated nation, and that the US was demanding, as a condition of providing assistance, access to sensitive Russian nuclear-weapons facilities – access that the US was not willing to provide Russia at US nuclear-weapons sites and facilities.

My concerns coincidentally got support from the Senate Foreign Relations Committee where Senator Biden added a condition to the Foreign Relations Committee approval of the START Treaty requiring *bilateral* transparency.

[I]n connection with any further agreement reducing strategic offensive arms, the President shall seek an arrangement, including the use of reciprocal inspections, data exchanges and other cooperative measures to monitor: (A) the numbers of nuclear stockpile weapons on the territory of the parties of 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.

The Pentagon apparently did not like this condition. So, in August 1992, the Senate Armed Services Committee had a hearing on the matter in which I was invited to testify.

In my opening statement, I said,

The Nunn-Lugar Act requires Russia to forgo reuse in nuclear weapons of fissile material recovered from . . . tactical nuclear weapons. But the Bush Administration apparently is not ready to make the reciprocal commitment. If the U.S. keeps open the option of recycling fissile materials from warheads that we have committed ourselves to destroy while the Nunn-Lugar Act insists that Russia cannot do the same, the Yeltsin Administration is likely to get into trouble with Russian conservatives (von Hippel 1992).

I proposed that the US instead accept Russia's offer of reciprocal verified declarations with regard to weapons and material stocks; verified elimination of warheads committed to be destroyed and disposal of the fissile material recovered from them, and a verified bilateral ban on the production of plutonium and HEU for weapons.

The rebuttal witness was Robert Barker, a former weapons designer from the Lawrence Livermore National Laboratory who had just stepped down after serving in the Reagan and Bush Administrations as Assistant Secretary of Defense for Atomic Energy.

Barker argued,

A concern about Russian nuclear weapons security should not result in a mandate for Russian inspection of U.S. facilities. An automatic requirement for reciprocity is, frankly, old-think.

Senator Nunn, the chairman of the committee, agreed with Barker as did the ranking Republican member and two other Republican Senators who were present. Toward the end of the session, Senator Carl Levin, who was to succeed Senator Nunn as the Democrat chair of the Senate Armed Services Committee, rushed in to support my position. After the hearing, he told me that the Democrats on the committee had not been informed about the hearing. My guess is that this was the doing of Senator Nunn's staffer, Bob Bell, who later tried to exclude me from arms control discussions when we were both in the Clinton Administration White House.

The basic attitude in the Defense Department was that the situation was not symmetrical. The United States was providing money to Russia and, as a condition of receiving the money, Russia had to provide access so that the US could confirm that the funding

was being used as agreed. Since the Russians weren't providing money to the US, why should the US provide reciprocal access? In the Pentagon's view, it was that simple.

I think the Department of Defense also saw the US as the world's remaining nuclear superpower. Why should we tie our future needs for nuclear weapons to what a collapsing Russia could afford?

My view was different. I thought we were extraordinarily lucky to have ended the Cold War without a nuclear catastrophe and that we should give priority to reducing the residual nuclear danger, including from our own nuclear weapons.

I believe the US government's attitude under the Clinton and G.W. Bush Administrations was that Russia was a defeated enemy whose desires the US could safely ignore. That attitude helped turn Russia from its path of cooperation under Yeltsin to the vengeful destructiveness that we have under Putin.

Strengthening Nuclear-material Security in Russia

TK: How were you were involved in the lab-to-lab collaboration?

FvH: The leaderships of the US and Russian nuclear-weapons laboratories reached out to each other before I went into the Clinton Administration. Siegfried Hecker, at that time director of Los Alamos National Laboratory, has edited a two-volume collection telling the story (Hecker 2016). The relationship started with reciprocal visits between the laboratory directors of Los Alamos and Livermore National Laboratories on the US side and their counterparts from the Russian Institutes of Experimental and Theoretical Physics (VNIIEF and VNIITF).

They were therefore already talking to each other when I arrived in the White House, and there were people in the US labs who wanted to work with their Russian counterparts on improving the security of nuclear materials in Russia.

After I joined the Clinton White House in September 1993, I very quickly became involved in providing White House support for this effort. Ken Luongo was the key official supporting the effort in the Department of Energy. As a result of my work with the FAS and NRDC in Russia, I knew some of the key people in Russia. In fact, I was at the first meeting between Secretary of Energy Hazel O'Leary and Russia's Minister of Atomic Energy, Viktor Mikhailov. When he saw me, Mikhailov greeted me warmly and said, "If von Hippel is in the White House, then I have much greater confidence that we can work together!"

I had first met Mikhailov when he had anonymously sat in on Velikhov's May 1986 meeting at the Soviet Academy of Sciences on Velikhov's proposal to invite a foreign group to set up seismic stations within Kazakhstan to monitor the Soviet testing moratorium. At that time, Mikhailov was the head of the Soviet Institute for Impulse Technologies, which was responsible for instrumenting Soviet nuclear tests. My guess is that he was at Velikhov's meeting to watch out for the security interests of the test site. In the end, the NRDC seismic monitoring sites were located at a safe distance of about 200 kilometers from the test site.

TK: Wasn't there an interception of stolen Russian plutonium during this period?

FvH: In August 1994, while I was working in the White House, there was an interception at the Munich airport of about 0.3 kilograms of weapon-grade plutonium – too little to make a bomb but possibly a sample from a larger cache of stolen plutonium. In July and December 1994, there were two more interceptions in Saint Petersburg and in the Czech Republic. Each was of 3 kilograms of weapon-grade uranium – again about one tenth the amount required to make a bomb. These interceptions lent additional urgency to our concerns about the adequacy of nuclear-material security in Russia.

In the Soviet Union, the security system had been focused on monitoring and controlling the movements of people. Now, in the more open environment of post-Cold War Russia, it would have to focus, as in the West, on monitoring the nuclear materials themselves.

Attempts to Convert Russia's Nuclear Cities

TK: After the collapse of the Soviet Union, you held a workshop that invited scientists from closed nuclear cities in Russia to discuss job creation in their cities.

FvH: Yes, we had two such workshops. The first, in February 1992 in Washington, DC, was organized by the NRDC and co-sponsored by the Federation of American Scientists (FAS) where I was still chairman. It concerned both what to do with excess Soviet warheads and materials and also how to downsize Russia's two nuclear-weapon laboratories. The Russian participants included the directors and the senior weapon designers of those labs plus senior generals responsible for Russia's nuclear weapons.

With regard to conversion of the weapon labs, the effort was disappointing. The Russian weaponeers were promoting peaceful applications for nuclear explosions. They proposed, for example, to destroy the large stocks of chemical weapons that Russia and the US had accumulated during the Cold War by putting them into deep boreholes, adding a nuclear explosive, backfilling the boreholes and detonating the explosive. They had even established a company, Chetek, that would offer waste-disposal services in this manner.

TK: The heat of a nuclear explosion would decompose toxic chemicals and they would be trapped inside the glass produced from molten rock, right?

FvH: Yes, if everything worked the way it was supposed to.

Later on, the Russian and US weapon labs would have joint conferences on using nuclear weapons to deflect or destroy asteroids heading toward the earth, in order to prevent an event like the asteroid strike that caused the dinosaur extinction 66 million years ago.

Another problem with converting the nuclear cities was that the security people were unwilling to remove the fences around the cities and shrink the security areas to just those where nuclear-weapon-related activities were taking place. One of the proposed projects of the Department of Energy's Nuclear Cities Initiative in Sarov, Russia's equivalent to Los Alamos, was the production of filters for dialysis machines. A Swiss

company was interested, but the Russian security people were not willing to guarantee the company free access to its factory in Sarov, so the project was eventually abandoned.

On both sides, the weapons labs were able to survive the end of the Cold War without being significantly downsized or converted. Early in the Clinton Administration there was a proposal to shut down the Livermore National Laboratory in California. The idea was that, in an era of no testing and no new nuclear-weapon development, two nuclear-weapon laboratories: Los Alamos for the “physics packages” and Sandia for the electronics, should suffice. But the Clinton Administration was worried about the impact of closing Livermore on the 1996 election in California and, in the end, Livermore became the home of the National Ignition Facility (NIF) with 192 huge lasers focused on tiny 1-millimeter-diameter pellets of frozen deuterium and tritium as a way to maintain US expertise in thermonuclear explosions. Today Livermore, Los Alamos and Sandia each have annual budgets of about 2 billion USD for weapons work. In constant dollars, their funding level is higher than at the peak of the Cold War.

During the Clinton Administration, we launched small assistance programs for Russia’s nuclear cities. These programs may have been successful in preventing the migration of a larger number of nuclear-weapon experts to Iran and North Korea but, when the price of oil rose again after 2000 and Putin took over, business went back to usual in Russia’s nuclear weapons labs and the US was told its assistance was no longer needed.

The four Russian nuclear cities that had produced the highly-enriched uranium for the Soviet weapons were saved initially by Tom Neff’s idea to have them blend down excess Russian weapon-grade uranium to fuel US nuclear power plants. That arrangement came to be known as the Megatons to Megawatts Initiative. Later, these cities shifted to the production and export of low-enriched uranium for the world’s power reactors. Today, Russia has almost half of the world’s uranium enrichment capacity.

Two of the plutonium cities shifted to the storage and reprocessing of power-reactor fuel. At one point, there was hope that Russia would take in foreign spent nuclear fuel, which would solve a political problem in countries that were not able to site deep geological repositories for their spent fuel. Tom Cochran became involved in promoting that idea. But, after the ascent of Putin in 2000, Russia’s relations with Europe and the US went downhill and those efforts died.

I was involved in a number of efforts related to the nuclear cities. One effort I helped launch while in the White House was DOE’s Nuclear Cities Initiative. In 1996, the head of that program invited me to join him for a visit to Zheleznogorsk, the eastern-most of Russia’s plutonium cities, down the Yenesei River from Krasnoyarsk ([Figure 9](#)). The focus was on an effort to convert some of the infrastructure that had been built for a never-completed civilian reprocessing plant into a refinery for purifying silicon for solar cells. In the end, however, the Russian government decided to build a new reprocessing pilot plant there for civilian power-reactor fuel.

After my time in the White House, my most consequential efforts to maintain US relationships with Russia’s nuclear cities were as a member of the board of Ken Luongo’s Russian-American Nuclear Security Advisory Council (RANSAC). With funding from the Department of Energy and a few US foundations, we set up “analytical centers for nonproliferation” at four Russian nuclear labs: the two weapon labs, the Kurchatov Institute in Moscow and the Institute of Physics and Power Engineering in Obninsk,



Figure 9. Left: Zheleznogorsk city center with the obligatory statue of Lenin; Right: Visit with the mayor in 1996. At left, Anatoli Diakov of the Moscow Physics and Technology Institute; third from left, the chief engineer of the mining and chemical combine; to his right, the mayor, to his right John Hnatio, then director of the Department of Energy's Nuclear Cities Program; at far right, FvH. Behind the group is the city's coat of arms: a Siberian bear inside an atom, splitting its nucleus.

which was focused on the design of plutonium breeder reactors. The longest-lasting and most serious of these efforts were in Obninsk and Sarov.

My wife Pat and I visited the Sarov center in 2000. After that, the paranoid group around Putin made such visits impossible. In 2007, the young, entrepreneurial executive director of the Sarov center, left to work first for the UN Institute for Disarmament Research in Geneva and then for the IAEA in Vienna.

Recruiting New Generations of Concerned Scientists

Much earlier, in 1991, we had a summer workshop at the Moscow Physics and Technology Institute (MPTI) to try to interest their physics graduate students in nuclear arms control. MPTI was the Soviet Union's elite training institute for physicists going into nuclear-weapons design. I had suggested the workshop to Velikhov and he tasked Elena Loshchenkova, the Executive Director of the Committee of Soviet Scientists and herself an MPTI graduate, to find a faculty member who might be interested. Loshchenkova found Anatoli Diakov, who in turn found a number of graduate students who were interested in arms control.

That was the first of an unbroken succession of annual International Summer Symposia on Science and World Affairs. The second was at Princeton, organized by our post-doc Valerie Thomas⁵. Thereafter, Lisbeth Gronlund and David Wright, two physicists who co-direct the Union of Concerned Scientists' (UCS) Global Security Program were the principal organizers and the summer symposium has been held in many locations. In 2019, it was in Beirut⁶. With Gronlund and Wright retiring from the UCS, the plan is to host the 2020 summer symposium in Princeton.

Two of Diakov's students ultimately came to Princeton as postdocs. Oleg Bukharin came in 1993 and became our expert on Russia's nuclear complex. In 2004, he joined the

⁵Now a Professor of Natural Systems at Georgia Tech, jointly appointed in the School of Industrial and Systems Engineering and the School of Public Policy. Thomas married Oleg Bukharin, our first Russian postdoc.

⁶<https://www.ucsusa.org/nuclear-weapons/international-summer-symposium-science-and-world-affairs>.

US Nuclear Regulatory Commission to work on nuclear-material security. Currently, he is with the IAEA. Pavel Podvig was the second of our post-docs from MPTI. With Bukharin and others, he had decided to emulate the NRDC Nuclear Databook project and they wrote, *Russian Strategic Nuclear Forces*, a comprehensive history and description of Russia's nuclear forces based on Russian sources. The book was published first in Russian and then in translation by MIT Press (Podvig 2001)⁷.

Putin had taken power by then, however, and the security services had become suspicious of Podvig's project. In 1999, they arrested one of his coauthors, Igor Sutyagin, as a spy. For many years, our Princeton program paid for Sutyagin's lawyers in Moscow but he was not released until 2010 as part of a US-Russia spy swap. Podvig left Russia for the US in 2000 and is currently based in Geneva at the UN's Institute for Disarmament Research, working halftime on projects there and halftime for our Princeton program.

At the time of Sutyagin's arrest, Joshua Handler, one of my PhD students and a former campaigner for Greenpeace, was doing research in Moscow and sharing an office with Sutyagin. After Sutyagin's arrest, Handler was advised by the US embassy to leave Russia (Sullivan 2001). Today, he works for the State Department in Washington, DC.

Other students stayed with Diakov to run a Center for Arms Control, Energy and Environmental Studies at MPTI, which was funded by the MacArthur Foundation. In 2016, however, the Putin Administration began to require groups with foreign funding to declare themselves to be foreign agents. Rather than do that, Diakov and his group shut down their center. It is a real loss. The center's website, with its publications and courses through 2015, is still accessible on the internet⁸.

Helping to Launch Nuclear Arms Control in China

TK: In the meantime, you also developed a connection with China's nuclear-weapons establishment?

FvH: By way of background, the Chinese counterpart of Los Alamos National Laboratory is the Chinese Academy of Engineering Physics. Its headquarters are in Mianyang, near Chengdu in central China. But its theoretical division, the Institute of Applied Physics and Computational Mathematics (IAPCM), is in Beijing.

In the mid-1980s, with the Soviet Union and United States beginning to talk about significant cuts in their nuclear stockpiles, two of the deputy directors of IAPCM, Hu Side and Du Xiangwan, became interested in learning more about nuclear arms control. Hu Side and a couple of other colleagues decided to attend the 1986 International School on Disarmament and Research on Conflicts (ISODARCO) in Italy. The conference was held in an old monastery in San Miniato, a small town in Tuscany. By coincidence, I was one of the lecturers that year.

I do not recall talking to Hu Side at San Miniato. His English is limited, so he and his colleagues probably mostly just sat and listened. But they understood enough to decide that nuclear arms control is important.

⁷Podvig provides updated data on the blog, <http://russianforces.org/book/>.

⁸<https://www.armscontrol.ru>.

So, they invited ISODARCO to have its 1988 meeting in Beijing. The meeting was co-sponsored by the China Institute of Contemporary International Relations, a very large think tank associated with China's intelligence ministry. Eight foreigners were invited as lecturers. Garwin and I were the Americans. I believe the others were all Italians, led by Carlo Schaerf, an Italian nuclear physicist and the founding father of ISODARCO.

This was my first trip to China but I had already developed a relationship with Fudan University in Shanghai through its president Xi Xide, who Jerome Wiesner had recruited onto the Board of Velikhov's International Foundation (see Part 3). Xie Xide, small and energetic, was an MIT-educated physicist. She walked with a limp, the legacy of a beating she had received from radical students during Mao's (1966–76) Cultural Revolution.

At one of the meetings of the International Foundation's Board, Xie told me she had a student finishing his PhD who was interested in international relations. Subsequently, the student, Shen Dingli, won a fellowship and came to our group as a post doc before returning to China to lead Fudan's Center for American Studies. Shen is extremely hard working and has become an internationally-known expert on China's international security relations. In the fall of 2018, I took four Princeton graduate students to Beijing, and he flew up from Shanghai to give them a lecture on China's relationship with North Korea. The students were mesmerized.

I also got to know Yang Fujia, Xi Xide's successor as President of Fudan. Yang was a classmate of Hu Side and also headed the Shanghai Institute of Nuclear Research. In 1991, Shen and Yang invited me to give a series of lectures on nuclear arms control at Fudan and Yang gave me a tour of his institute. The lucidity with which he explained the research there was very impressive.

My wife Pat came along for our trip to the 1988 Beijing conference. We both enjoyed Beijing, which was still mostly "hutongs," narrow alleys lined with small one- and two-story homes where people cooked on the street over charcoal fires. The main streets were full of bicycles and people exercising. The terminal at Beijing airport could only accommodate about ten aircraft and there was little traffic on the road from the airport on which bicyclists and horse-drawn farm carts also traveled.

From that time till 2010, China's GDP grew at an average rate of 10% with another doubling since then, for, in total, an approximately 20-fold increase. Beijing has been transformed into a modern city. My wife found the city so fascinating in 1988 that she has been reluctant to visit modern Beijing.

At the end of the ISODARCO meeting in Beijing, Hu Side and Du Xiangwan came to me (Du speaks English quite well) and told me that they would like to have ISODARCO meetings in China every two years and invite many more foreigners. But their institute did not have funds for hosting international meetings.

I thought that opening up discussions of nuclear arms control with some of the leaders of China's nuclear-weapons community represented a great opportunity. I therefore drafted a proposal to the MacArthur Foundation, which did fund the biennial Beijing Seminars on International Security for about 20 years thereafter. The meetings grew to include perhaps 100 foreign and twice that many Chinese participants. Following the ISODARCO tradition, the hosts provide the conference venue and the food and lodgings while the participants are responsible for their own travel costs.

Until 1999, a number of scientists from the US nuclear-weapon labs attended. That virtually ended, however, after an ad hoc committee of the US House of Representatives

chaired by Republican Representative Christopher Cox alleged that the Chinese had penetrated the US nuclear weapons labs and stolen the design of the W88 nuclear warhead, which is deployed on the Trident II submarine-launched ballistic missile. Allegedly, the W88 is the most advanced US nuclear warhead in terms of yield per unit weight. Much of the evidence for the Cox Report's charge was subsequently discredited (Stober and Hoffman 2002) but the concern about Chinese penetration of the US nuclear weapons labs persists and the relationships between the US and Chinese nuclear-weapons laboratories have faded.

Hu Side and Du Xiangwan started an arms control research program at IAPCM. Before he moved on to work on energy policy, Du supervised the PhD theses of two excellent students, Li Bin and Zhang Hui. Both took post-docs with our group at Princeton. Li Bin returned to China to run the arms control group at IAPCM but Hu and Du had moved on. Li Bin quit and was supported as an independent arms control analyst by the U.S. Ploughshares Fund for two years⁹. He was then recruited by Tsinghua University (China's MIT) to start China's first arms control program. There, he has educated some excellent analysts – both Chinese and foreign.

After his post doc at Princeton, Zhang Hui joined the Managing the Atom Project at Harvard's Kennedy School. He is now the US expert on China's nuclear fuel cycle and the history of its nuclear-weapon program.

In the meantime, Hu Side rose within the Chinese Academy of Engineering Physics and, by 1993, when I joined the Clinton Administration, had become its head with Du Xiangwan as his deputy.

The End of US Nuclear Testing¹⁰

TK: Weren't you involved in arguments in the US related to China's nuclear tests?

FvH: Yes, in May 1993, before I joined the Clinton Administration, I was involved in discussions that led to the decision to end US nuclear testing. Later on, that decision nearly became unglued because the Chinese did not stop their testing until 1996.

By way of background, just before the 1992 election, the then Democrat-controlled Congress had included in an appropriations bill an amendment sponsored by Senators Hatfield, Exon and Mitchell requiring that, if other countries stopped testing by the end of fiscal year 1996 (30 September 1996), the U.S. also would stop testing. The amendment allowed testing before that deadline only to fix specific safety or reliability issues. Up to 15 safety and reliability tests could be carried out. Up to three of those tests could be done jointly with the UK, which, since 1962, had conducted its tests on the US test site in Nevada.

Since 1961, doubts about verifiability had been the strongest argument against a ban on underground testing. That year, a group, encouraged by Edward Teller, published an idea for how to muffle the seismic signals from underground tests. They argued that, if a nuclear test were carried out in the middle of a large enough underground cavern, “a

⁹At that time, the Ploughshares Fund was based in San Francisco and led by, its founder, Sally Lilienthal. After her death, it moved to its current location in Washington, DC.

¹⁰A more detailed version of this section can be found at (von Hippel 2019).

yield of more than 300 kilotons . . . could be made to look seismically like a yield of one kiloton” (Latter et al. 1961). Three hundred kilotons would be 20 times larger than the Hiroshima explosion.

Later, it turned out that you can’t build such a big cavity without it collapsing; and that the decoupling factor at low frequencies is by a factor of tens, not hundreds and declines at higher frequencies. But Teller’s claims for decoupling did succeed in derailing a Comprehensive Test Ban and the Kennedy Administration had to settle in 1963 for the Partial Test Ban Treaty which banned nuclear explosions everywhere except underground.

In the ensuing thirty years, however, seismology had advanced to the point where its practitioners believed that they could detect and distinguish even a decoupled one-kiloton explosion anywhere on earth and do much better in some areas – for example, the Russian test site on the Arctic island of Nuovo Zemlya, from which seismic signals propagate very well to seismic arrays in nearby Norway. There also was a more realistic assessment of the feasibility of building decoupling cavities with the most easily concealed method being solution mining of salt beds or salt domes, which only can be found in a relatively few areas (National Academy of Sciences 2002, chap. 2).

In 1987, Hal Feiveson, Christopher Paine and I wrote two articles in support of a ban on nuclear tests with yields above one kiloton. We chose that level because it could be verified (von Hippel, Feiveson, and Paine 1987; Feiveson, Paine, and von Hippel 1987).

When the Clinton Administration took office in January 1993, there was no agreement either nationally or internationally on a threshold. Proposed thresholds ranged from zero to 1 kiloton. At one point before I joined the Clinton Administration, I was arguing for a one-kilogram threshold, one million times lower than the one kiloton threshold we had argued for in 1987. A one-kilogram threshold would allow tests of the safety of nuclear weapons, which are supposed to be designed so that, if the chemical explosive around the plutonium “pit” is detonated unsymmetrically at a single point by, for example, a bullet, the nuclear yield would be less than the equivalent of about one kilogram of chemical explosive. During the Khrushchev-Eisenhower-Kennedy 1958–1961 nuclear testing moratorium, President Eisenhower had allowed such “hydronuclear” tests because of safety concerns about some of the designs then in the US stockpile.

At the beginning of the Clinton Administration, I was an outside policy activist writing memos on these issues. Daniel Ellsberg, who, at the time, was living in Washington and promoting the test ban, used his access to make sure that all the relevant officials in the incoming Clinton administration got my memos.

When Hazel O’Leary was appointed Secretary of Energy, one of the first policy decisions she faced was how many of the 15 tests allowed by the Hatfield-Exon-Mitchell amendment she should approve. The directors of the three US national labs (Livermore, Los Alamos and Sandia) were clear as to what they wanted: all 15.

O’Leary understood the importance of this decision and decided that she needed to know more before signing off on the tests. She therefore invited the directors of Livermore and Los Alamos to Washington to present their arguments for the 15 tests. And she decided to invite in some outside experts to offer their reactions to the arguments. On the anti-test-ban side, she invited former Secretary of Defense, Secretary of Energy, and Director of the CIA, James Schlesinger. On the pro-test-ban side, she invited Sidney Drell and me.

I told the DOE person who contacted me that I did not have a clearance to have access to classified information about nuclear-weapon design. That was no problem for O’Leary. She just gave me a clearance without the usual background check.

Because of my lack of classified knowledge, however, I suggested adding one more outsider, Ray Kidder, a retired Livermore weapons expert who was critical of Livermore’s arguments against a test ban (Kidder 1987, 1991a, 1991b). Three years earlier, in September 1990, at Velikhov’s invitation, Kidder and I had gone to Moscow and testified in support of a comprehensive nuclear test ban in front of a committee of the Supreme Soviet.

And so, in May 1993, we all spent two afternoons in Washington in a special room in the basement of the Department of Energy’s headquarters building on Independence Avenue. The room was a Sensitive Compartmented Information Facility (SCIF), which meant that access to it was controlled and that it had been screened for electronic listening devices.

The Livermore team actually brought in a full-scale model of a warhead sliced longitudinally through the middle so they could show Secretary O’Leary what the inside of a nuclear weapon looked like. I don’t recall that she paid much attention, but I certainly did.

George Miller¹¹, then an associate lab director for Livermore, with whom my colleagues and I had debated a threshold test ban in *Science* magazine (Feiveson, Paine, and von Hippel 1987) saw me gawking at the model and said, “Now, we’ve got you, Frank! You can’t talk to or write for the public about nuclear-weapon design anymore.”

After the Associate Directors from Los Alamos and Livermore had presented their arguments for each of the 15 tests, I was surprised to hear Schlesinger and Drell support the tests for political rather than technical reasons.

Schlesinger wanted the British to be able to test. Possibly it had to do with the fact that preparations had been made for a joint test that spring of the single UK warhead type. A borehole 8 feet (2.4 meters) in diameter had been drilled 500 meters deep, and a rack loaded with instruments was in place hanging in the tower above the hole, ready to be lowered as soon as the nuclear explosive was hung from the bottom of the rack (Figure 10). The tower, rack and hole are still there, now a tourist attraction.

Schlesinger argued that, if the UK were allowed to test, then the US might as well also, citing the old adage, “You might as well be hanged for a sheep as a lamb.”¹³

For his part, Drell thought it was critical that the directors of the weapon labs be supportive of Senate ratification of the Comprehensive Test Ban Treaty. If that required a final 15 tests, so be it.

I was not so political and I was not impressed by the technical arguments for the tests. There did not seem to be any good arguments for reliability tests beyond having one more for each warhead type, which would not be statistically significant. With regard to any safety issues, I suggested that any future concerns about one-point safety could be dealt with, as during the Eisenhower administration, with very low yield hydronuclear tests. (At that time, the Clinton Administration had not yet decided to embrace a zero-threshold test ban.) Kidder also was skeptical about the need for the proposed tests.

¹¹Miller subsequently became the Director of Livermore (2007–11).

¹²“Iccap” n.d. https://www.nnss.gov/docs/fact_sheets/DOENV_1212.pdf.

¹³That is, if you are able to get away with a small lamb (the UK test), why not a big sheep (all 15 tests)?



Figure 10. “Project Icecap,” a joint UK-US nuclear test that was supposed to be carried out in the spring of 1993 but was not because of Secretary O’Leary’s decision. I visited the site in the spring of 2019. The cables for the instruments that were to accompany the nuclear warhead down the 500-meter hole and the cranes were no longer there. But the building and the borehole were, as was the instrument rack hanging in the building over the hole.¹²

Two of the tests had a legitimate safety rationale, however, and the issue is still with us 26 years later. Los Alamos wanted to replace the chemical explosive in the two warhead types mounted on the Navy’s ballistic missiles, the W76 and W88.

During the Cold War, the Navy had asked for warheads as slim and light as possible so that eight could be loaded onto each of its Trident II missiles with the missile still able to achieve a 7500-kilometer range.

To achieve these objectives, Los Alamos had used “sensitive” rather than “insensitive” high explosive in the plutonium implosion systems. In either case, the warheads were designed to be “one-point safe”, i.e. not have a significant nuclear yield if the explosive was not detonated symmetrically. For sensitive high explosive, however, there is a higher probability of an accident dispersal of plutonium.

Given that the START Treaty was going to result in fewer warheads per missile, Los Alamos wanted to replace the sensitive explosive in the warheads with insensitive explosive. That would require at least one test for each of the redesigned warheads.

The problem was that the “customer,” the Navy, did not want to make the changes. Unlike the Air Force, which had experienced planes carrying warheads crash and/or burn, the Navy had experienced no plutonium dispersal accidents and flight tests of the new warheads would cost a considerable amount of money. Given the Navy’s position, testing a new design with insensitive high explosive was pointless.

Finally, the director of Sandia National Labs, after observing the underwhelming cases made by Livermore and Los Alamos, said to O’Leary in effect, “If you give us as much money for not testing as you have been giving us for testing, maybe we can make a deal.”

The deal turned out to be that the three labs would receive a combined budget of at least USD 3.6 billion a year for what came to be called the “Stockpile Stewardship Program.”

TK: In exchange for not opposing the Comprehensive Test Ban Treaty?

FvH: Right. Livermore was given funding to build the National Ignition Facility. Sandia got a “microtechnology” facility where they could make tiny mechanical switches and sensors. Los Alamos got a machine that could make X-ray movies of implosions from two different directions at the same time. And both Los Alamos and Livermore got very costly computers for modeling nuclear explosions in high resolution including 3-dimensional visualizations¹⁴.

When I went into the White House, I saw this deal enforced by Senator Nunn’s former staffer, Bob Bell who, on Senator Nunn’s recommendation, President Clinton had appointed to the National Security Council staff as Special Assistant to the President for National Security Affairs and as Senior Director for Defense Policy and Arms Control. Bell’s view was that we should not second-guess the weapons labs about what to do with the money.

The meeting with O’Leary was, of course, not the final decision in this case. Her recommendation had to be approved by President Clinton in consultation with the heads of the other agencies involved in nuclear-weapon issues.

I recently learned that, when the decision was debated at that level, both the Pentagon and the Secretary of State wanted to do the tests. The Pentagon, as represented by the Secretary of Defense and Chairman of the Joint Chiefs of Staff, and backed up by the House and Senate Armed Services Committees, is often described as the “800-pound gorilla” in meetings on national security.

That says a lot about the fortitude of Secretary of Energy O’Leary; John Holum, Director of the Arms Control and Disarmament Agency; and Jack Gibbons, President Clinton’s Science Advisor – and of President Clinton, who backed them.

TK: Why did the State Department want the tests?

FvH: I have been told because the UK felt that it needed to do the three more tests that they would have been allowed under the Hatfield-Exon-Mitchell amendment. The State Department often sees its role in such meetings as protecting the interests of US allies.

TK: Was there an argument in that meeting about yield limits in the Comprehensive Test Ban Treaty?

FvH: No, there continued to be a debate over the yield limit. Then, on 11 August 1995, after I left the Clinton Administration, France’s Prime Minister, Jacques Chirac, came out for a zero-yield treaty. The next day President Clinton announced that the US position would be the same and the issue was settled – except how to verify zero yield.

Later on, in 2002, the National Academy of Sciences did a study and concluded that clandestine low-yield tests would be of little benefit to the advanced nuclear-weapon

¹⁴For an unclassified example, see <https://www.lanl.gov/newsroom/picture-of-the-week/pic-week-44.php>.

states but might have some benefits for states such as North Korea, Pakistan and India (National Academy of Sciences 2002, chapter, 3).

In June 2019, the Trump Administration claimed that Russia “has conducted nuclear weapons tests that have created nuclear yield [which] naturally raise[s] questions about those activities in relation to the ‘zero yield’ nuclear weapons testing moratorium adhered to by the United States, the United Kingdom, and France” and suggested that China might be conducting non-zero-yield tests as well (US Defense Intelligence Agency 2019). This followed a letter to President Trump from four Republican Senators urging that he unsign the US from Comprehensive Test Ban Treaty that President Clinton had signed in 1996 but the Republicans in the Senate refused to ratify in 1999 (Sonne 2019). Unsigning would free the US to resume nuclear testing.

TK: You had not yet received an invitation to join the Clinton White House at the time of that meeting in May 1993?

FvH: That is correct. After I joined the Administration in September 1993, one of the first things I learned was that the Chinese were preparing a test.

TK: Were there news reports about possible Chinese tests?

FvH: I don’t believe so. The information came from US intelligence, probably from satellite observations.

On July 3rd, in his weekly radio address, President Clinton had announced that none of the 15 tests allowed by the Hatfield-Exon-Mitchell amendment would take place:

After a thorough review, my administration has determined that the nuclear weapons in the United States arsenal are safe and reliable . . . Additional nuclear tests could help us prepare for a test ban and provide for some additional improvements in safety and reliability. However, the price we would pay in conducting these tests now by undercutting our own nonproliferation goals and ensuring that other nations would resume testing outweighs these benefits.

He then added,

If, however, this moratorium is broken by another nation, I will direct the Department of Energy to prepare to conduct additional tests while seeking approval to do so from Congress. (Clinton 1993).

I sent a message to Hu Side through Yang Fujia, “Please don’t test. It’s going to cause problems!” But the Chinese tested anyway in October 1993 and then seven more times before signing the Comprehensive Test Ban Treaty in 1996.

I also wrote a passionate memo to Jack Gibbons, President Clinton’s science advisor, arguing that there was no need for the US to test and that, if we did, the Russians would restart and our hopes for a test ban would suffer a terrible setback (von Hippel 1993).

In the end, Clinton decided not to test.

TK: So what was the response from Gibbons to your memo?

FvH: I don’t recall a conversation but I know that his position was essentially the same as mine. I therefore saw my role in this case as providing him ammunition for his discussions with the President and ultimately for the cabinet-level debate.

TK: The result was? ...

FvH: President Clinton decided that it was unnecessary for the US to test in response to the Chinese tests (there were seven during 1993–96) or the French tests (there were six during 1995–96). Both China and France stopped before the Comprehensive Test Ban Treaty was opened for signatures on 24 September 1996.

There were no more Soviet/Russian nuclear tests after 1990 and no more US or UK tests after 1992. India and Pakistan both tested in 1998. Only North Korea has tested since 1998. So, the Comprehensive Test Ban Treaty has created a norm against testing, even though it has not come into legal force because of the lack of ratification by eight specific countries: the United States, China, Israel, India, Pakistan, North Korea, Iran and Egypt.

TK: What is Hu Side doing now?

FvH: After heading the Chinese Academy of Engineering Physics, he returned to the Institute of Applied Physics and Computational Mathematics in Beijing where he presides over a small arms-control group. In the fall of 2018, when I took four Princeton graduate students to Beijing for discussions of China’s policy toward North Korea’s nuclear program, Hu Side invited us to dinner with his group. Thanks to a young political scientist who acted as his translator, I had the best conversation with Hu Side I have ever had.

TK: In the 1988 ISODARCO meeting in Beijing, what was the main focus of the discussions?

FvH: After this length of time, I can only remember what I said. *[laughs]* I advised that China should not build two classes of nuclear weapons that the US and Russia had foolishly built:

- (1) So-called “tactical” nuclear weapons for battlefield use, and
- (2) Multiple Independently-targetable Reentry Vehicles (MIRVs) for intercontinental ballistic missiles.

They listened and afterwards a couple of them came up to me and asked, “Why?” I assume I answered that battlefield nuclear weapons make a transition from conventional to nuclear war more likely, and that MIRVs are destabilizing because they increase the incentive to strike first. In theory, one missile can use MIRVs to destroy several missiles on the other side.

In addition to the the arms control policy group in Beijing, Hu Side started up a technical arms control group at the main campus of the Chinese Academy of Engineering Physics (CAEP) in Mianyang. Most of the early technical work that they shared with us were replications of work we had published. They were very interested in the Black Sea experiment, for example. During 2014–15, we had a visitor from this group working with our Program on warhead verification. Since then, however, with the cooling of China-US relations, CAEP has been unable to sustain the collaboration.

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