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Citizen Scientist: Frank Von Hippel's Adventures in Nuclear Arms Control Part 6. A Global Agenda and Beginning the Handoff to the Next Generation

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ABSTRACT

In this part, von Hippel discusses how his focus shifted in the first decade of the 21st century to a set of new concerns evoked by the terrorist attacks of 11 September 2001 and the G.W. Bush administration's retrograde policies with regard to nuclear arms control and nonproliferation. During this period, he co-founded the International Panel on Fissile Materials so that policy activists working in opposition to nuclear arms races and fissile material production in different countries could work together. He also focused on fostering another generation of activist scientists engaged with the nuclear arms control and nonproliferation agenda.

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***Tomoko Kurakawa* (*TK*)**: Let's move to the G.W. Bush years. What were you doing when the Al Qaeda attack on the US happened on 11 September 2001? What was your reaction?

***Frank von Hippel* (*FvH*)**: I was in Paris for a conference on the nuclear fuel cycle. That day, in the afternoon, I went to visit Thérèse Delpech at the French Atomic Energy Commission. I knew Thérèse because of our mutual interest in non-proliferation.

When I walked into her office, she had the television on, which was playing video clips over and over again of the passenger planes crashing into the twin towers of the World Trade Center and then the buildings' collapses about an hour later.

My wife Pat and our niece Vali were along and we continued with our planned trip to our next stop to visit my colleague and our friend, Klaus Janberg, who had retired with his wife to Provence.

Pat had a brother and a nephew working in the building trades in downtown Manhattan. Pat wanted to know that they were safe but it took days to get through to them because communications were down or overwhelmed.

Returning from Provence, we took the train through the tunnel under the English Channel to London. Our flight was on September 16th, the first day after the attack that planes were allowed to fly to New York. When we landed in Newark, we could see and smell the smoke still coming up from the ruins where the World Trade Center had stood.

TK: How many days after 9/11?

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FvH: Five. An hour after the first passenger plane crashed into the North Tower, the Federal Aviation Administration grounded all passenger jets traveling within or to the United States. This included thirty-eight planes that were in the air crossing the Atlantic with about 7,000 passengers. They were forced to land at Gander Airport, Newfoundland, Canada and stayed there for several days. There is a very sweet play, *Come from Away*, that describes how the population around the airport took in the passengers and the relationships they developed during those days.

TK: Was there any discussion at Princeton when you returned?

FvH: Initially, the issue was how would the US respond. The discussion was crazy. One physics professor wanted to "nuke" all of Afghanistan. I spoke at an anti-war rally at the university. Later on, I participated in a panel debate over what the US should do. I was opposed to the proposed invasion of Iraq. Another panelist, an assistant professor of Near Eastern studies, gave a cynical rationale for the invasion: The US was under pressure to remove its troops from Saudi Arabia, because they were infidels in the country with Islam's holiest sites. This panelist suggested that Iraq would be a good place to relocate. Shortly thereafter, he went to work in the Bush Administration.

Concerns about Terrorist Attacks on Spent Fuel Pools

FvH: The attack on the World Trade Center made people realize that, if a group like Al Qaeda was able to make a nuclear weapon, it would be willing to use it against a US city. That raised the public profile of the need to remove weapon-useable nuclear materials from as many locations as possible. It also added a new dimension to our concerns about the possibilities of major releases of radioactivity from nuclear power and reprocessing plants. Now we had to worry about the possibility of terrorists deliberately causing such events.

In 2003, a group of us wrote an article about the danger of a spent fuel fire if the water was lost in a power reactor's spent-fuel pool, and the possibility that a pool could be punctured by a terrorist group using a shaped charge.

The idea for the article came from Gordon Thompson. Gordon had been a post-doc with our Princeton group in 1979–80 and then had founded his own organization, the Institute for Resource and Security Studies, in Cambridge, Massachusetts.

I happened to encounter Gordon at a meeting in 2002 and asked what he had been doing during the two decades since he left Princeton. He said, "I've been fighting with the Nuclear Regulatory Commission about spent fuel pool safety." He was worried about an accident or terrorist attack that would result in a spent-fuel pool being drained.

If the fuel was left uncovered, it would heat up due to the radioactive heating of the spent fuel by the fission products it contained (Figure 1). Above about 1000°C, the zirconium cladding of the fuel would start to burn and, when it failed, huge amounts of volatile fission products – especially 30-year half-life cesium-137 – would be released into the air over the pool. If the building over the pool had been opened up during the course of the accident or terrorist event, a huge amount of radioactivity could be released to the atmosphere.

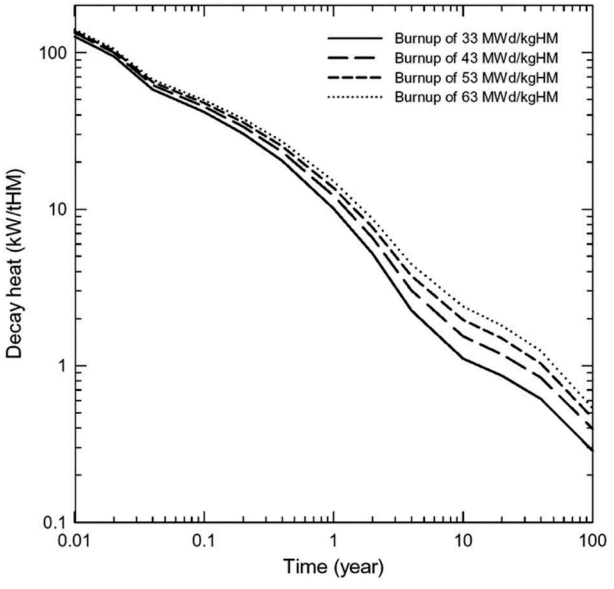

Figure 1. Decay heat per ton from spent fuel as a function of time after discharge from the reactor. At the time of the Fukushima accident, there was a full core of fuel in the spent fuel pool of unit #4 that had cooled for only four months (about 0.3 years) and therefore was generating about 20 kilowatts of decay heat per metric ton of uranium in the fuel. If the water had been lost, this fuel would have heated up within a few hours to the ignition temperature of its cladding (Alvarez et al. 2003).

After Gordon had explained the problem, I decided that he was onto something important and needed reinforcement. I suggested that we pull together a group to write a paper on the issue.

We assembled a terrific group. In addition to Gordon and me, it included:

- Robert Alvarez, who had worked for Secretary of Energy Hazel O'Leary. Bob became our public relations person;
- Jan Beyea, a physicist who had worked with me on reactor safety after the Three Mile Island accident;
- Jungmin Kang, a nuclear engineer who had been a post-doc with us in the late 1990s. In 2018, Kang would be appointed chairman of South Korea's Nuclear Safety and Security Commission;
- Klaus Janberg, who had headed the German company GNS when it first decided that spent-fuel transport casks could be used to store spent fuel after a few years of cooling in a spent-fuel pool;
- Edwin Lyman, who had started with us as a post-doc in the 1990s and had become one of the Union of Concerned Scientists' nuclear-reactor safety experts; and
- Allison MacFarlane, who was, in 2012, to be appointed by President Obama to chair the US Nuclear Regulatory Commission.

Our paper therefore had a long list of authors and, since we listed the authors alphabetically, it came known as "Alvarez *et al.*"

TK: Before writing that article, how many meetings did you have?

FvH: We had one meeting at MIT and then we worked by e-mail.

When our paper was about to appear in the journal, *Science & Global Security* (Alvarez et al. 2003), Alvarez contacted a reporter at the *New York Times* who wrote a story about it. The day the story came out, we gave a briefing in a meeting room in the US Capitol building, between the great chambers on either end where US Representatives and Senators meet. The room was packed with Congressional staffers.

Manufacturers of spent-fuel storage casks naturally liked our article because we said that any spent fuel that had cooled in a pool for more than five years should be transferred to dry cask storage. That would have meant sales of 2,000 to 3,000 casks much earlier than would otherwise have occurred.

The cask manufacturers' lobbyists therefore contacted the offices of key committees in Congress to draw their attention to our article. On the other side, however, the Nuclear Regulatory Commission immediately responded to our paper by insisting that the prevailing practice of dense-packing spent-fuel pools to five times their original design density was perfectly safe.

Dense-packing had been adopted after reprocessing had been abandoned in the US and opposition from Nevada had delayed the construction of the Yucca Mountain spent-fuel repository. With no offsite destination available for the spent fuel, the utilities had to accommodate more on the nuclear power plant sites. The least costly way to do so was to re-rack the pools to store the spent fuel as densely as possible. The resulting packing of the fuel was almost to the density of the fuel in a reactor core. Each fuel assembly was therefore put in a steel box either impregnated with or lined with plastic sheets containing neutron-absorbing boron to prevent a chain reaction from starting.

Given our credibility and the fact that the Nuclear Regulatory Commission had instantly rejected our proposal, Congress asked the National Academy of Sciences to study our proposal and make a recommendation.

TK: Which Congressional committee had an interest in this issue?

FvH: I believe the requirement came from the Energy and Water Subcommittee of the House Committee on Appropriations. That subcommittee has jurisdiction over the budget of the Nuclear Regulatory Commission. At the time, David Hobson, a thoughtful Republican from Ohio, chaired the subcommittee.

The Academy assembled a group that did a study and wrote a report, but the Nuclear Regulatory Commission (NRC) classified the report. Finally, after lengthy negotiations, a redacted version was published in 2006. It said that, although the details were necessarily classified, terrorists could cause a spent-fuel pool fire. It therefore recommended that the NRC do "plant-specifc vulnerability analyses" to determine whether or not to follow our recommendation for accelerated transfer of spent fuel to dry cask storage (National Research Council 2006, 8).

TK: You were a member of that committee?

FvH: No, I could not be because I was an author of the work that was being reviewed. But I provided an initial briefing for the committee, and I was asked by the Academy to

review the classified version of the report, which described some specific spent-fuel-pool vulnerabilities to terrorist attack. The NRC had to give me a clearance to review the report. They did not want to but the National Research Council's chief executive officer insisted. He had gotten to know our program at Princeton when he had a post-doctoral fellowship at the Institute for Advanced Study.

After the Fukushima accident in 2011, the NRC staff became more interested in spent fuel pool fires.

During the first two weeks after the accident began, the they were convinced that the spent fuel in the pool of unit 4 had been uncovered and was on fire. So was I.

The reason was that, four days after the earthquake, there was a hydrogen explosion in the building covering that spent-fuel pool. Since there was no fuel in the reactor, we all assumed that the hydrogen could only have been produced by steam reacting with the hot cladding of uncovered spent fuel.

We were wrong. Hydrogen from the meltdown of the reactor core in unit 3 had leaked into the building housing unit 4 through a shared exhaust system.

The NRC staff was frightened enough, however, that, after Fukushima, it decided to do a cost-benefit analysis of our proposal to remove the spent fuel from the pools after five years. It calle the proposal "expedited transfer." In parallel, Congress asked the National Academy to look at this question again – and for other lessons the US could learn from the Fukushima accident. This time, the request came from the Subcommittee on Energy and Water Development of the Senate Appropriations Committee then chaired by Democratic Senator Diane Feinstein from California.

Jan Beyea and I were invited to be members of this study. Because some of the issues related to the spent-fuel pools required access to classified material, that part of our work was done in a second phase of our four-year study.

In the meantime, the NRC did a cost-benefit analysis and found that, when it multiplied its estimate of the probability of a spent-fuel fire by its estimate of the consequences of a fire in a dense-packed pool, the probability-weighted cost of the accident to the public would be about 7 USD million per pool. On the other side of the balance, it estimated that expedited transfer would cost the utilities an extra 50 USD million to transfer the fuel to dry casks after five years. Therefore, it concluded, that expedited transfer failed the cost-benefit test (US Nuclear Regulatory Commission 2013, Enclosure 1, Table 10).

TK: Oh really?

FvH: I explain in Part 8 how some errors and omissions in their calculations helped them arrive at this conclusion.

TK: Let's first return to the Bush years. What else did you do?

Stopping the G.W. Bush Administration's Push to Reprocess in the United States

FvH: I spent a lot of time during the G.W. Bush Administration working on stopping their proposal to build a reprocessing plant in the United States. They argued – much like

Japan's government today – that this would solve the problem of the spent fuel accumulating on the reactor sites.

As I recounted in Part 2, more than two decades earlier, in 1982, the US nuclear utilities had decided not to reprocess and had persuaded Congress to pass the Nuclear Waste Policy Act ordering the Department of Energy (DOE) to construct an underground repository for their spent fuel. The utilities agreed to pay 0.001 USD per nuclear kilowatt hour into a fund to pay for the repository. The repository was to begin accepting spent fuel in 1998.

Congress chose a site inside Yucca Mountain, Nevada, and DOE started building the repository. But the State of Nevada filed suits challenging DOE's analysis of the risks from the repository and its completion was delayed – ultimately indefinitely.

Therefore, when their dense-racked spent-fuel pools filled up, the utilities had to buy casks to store their oldest spent fuel to make space in their pools for freshly-discharged spent fuel. They went to court and got judgments requiring the US government to pay for the casks because the government had not fulfilled its commitment in the Nuclear Waste Policy Act to begin to take away the older spent fuel to a repository starting in 1998.

TK: Those are dry casks?

FvH: Yes, and the cost for buying them has been about 400 USD million a year. Then AREVA, the French reprocessing company went to the Bush Administration and the key Congressional committees and persuaded them falsely that it would be cheaper to reprocess the spent fuel than to store it in dry casks.

In response, I literally gave about 100 briefings – mostly to Congessional staff but also to some Representatives – to explain the costs and proliferation issues of reprocessing.

TK: Which years?

FvH: Mostly during the second G.W. Bush Administration, 2005–8.

Finally, the Union of Concerned Scientists arranged a briefing for the Republican chairman and the senior ("ranking") Democratic member of the House Energy and Water Appropriations Subcommittee. That subcommittee is responsible for funding nuclear energy-related research and development in the Department of Energy.

We were able to convince them that they had been misled by AREVA and the Bush Administration: it would cost *much* more to reprocess than to pay for the dry casks.

They stopped supporting the Bush Administration's proposal and it died.

During this battle, I tried to find out who within the Bush Administration's Department of Energy was working with AREVA pushing reprocessing. I learned that there were two people. One was Clay Sells, who had worked on the staff of Senator Pete Domenici, the most powerful Republican Senator on nuclear-energy issues. Senator Domenici was an advocate of breeder reactors and reprocessing. When G.W. Bush won the 2000 election, Domenici proposed Sells to be Deputy Secretary of Energy.

The other person behind the reprocessing initiative was Vic Reis, who had been responsible during the Clinton Administration for establishing the DOE's Science-based Stockpile Stewardship Program as an alternative to nuclear testing. Somehow this success had convinced Reis and the people who hired him that he could solve

other intractable political problems. So Reis became a consultant to Sells on this reprocessing initiative.

Initially, they were talking about Argonne's proposal to pyroprocess spent fuel by dissolving it in molten salt and separating plutonium and uranium out by electroplating. But that would have involved endless research and development. In the end, they settled on a plan to buy a standard but very large reprocessing plant from France's nuclear-services company, AREVA.

I went to talk with both of them in Sells' office but they were not open to persuasion that they could be wrong.

TK: Reis was not a genius if he chose AREVA.

FvH: *[Laughs]* No, he wasn't – in this case, at least. AREVA designed Japan's reprocessing plant, whose price quadrupled and whose operation is 25 years delayed as of this point. AREVA also designed and supervised the construction of a mixed-oxide fuel fabrication plant in South Carolina to dispose of US excess plutonium. Its cost increased ten-fold before the project was finally cancelled in 2018.

But AREVA was lobbying very hard to build a reprocessing plant on the Department of Energy's Savannah River Site (SRS) in South Carolina, one of the two sites where the US produced and separated plutonium for its Cold War nuclear arsenal. Today SRS is mostly a clean-up site. AREVA convinced the local communities that their future was with civilian reprocessing. In fact, when the US abandoned reprocessing in 1982, construction of a large commercial reprocessing plant had almost been completed just outside the SRS fence. So the Bush Administration was promoting a second attempt to build a commercial reprocessing plant there.

TK: You said you presented a lot of briefings to congressional staff. Was it just you?

FvH: I worked with a couple of lobbyists in this effort. One was Leonor Tomero from the Council for a Livable World. Today Leonor is a senior Democratic staffer on the House Armed Services Committee. I have worked with her on a number of nonproliferation issues. Currently, members of her committee are interested in feasibility studies as to whether future US naval reactors can be designed to be fueled with low-enriched uranium.

The meeting the Union of Concerned Scientists (UCS) arranged with chairman David Hobson and ranking member Pete Visclovsky of the House Energy and Water Development Appropriations Subcommittee was critical, however. The UCS hired a former Republican representative from New York State to arrange the meeting. That's how it is done. If they are not ready to retire, a large fraction of representatives and senators, when they quit or are voted out, become lobbyists and use their old friendships to get access for whoever hires them. This is the only time I have gotten access in this way, however.

TK: Who was the president at that time at UCS?

FvH: Kevin Knobloch, who later went on to work as Chief of Staff for Secretary of Energy Moniz.

I've worked increasingly in recent years with Ed Lyman, the UCS' nonproliferation expert. Ed was a post-doc with our Princeton group in the mid-1990s. He did his physics

PhD thesis at Cornell on string theory but decided not to continue in that line because he was more interested in policy. So one of his advisors at Cornell suggested that he talk to me. He came to visit us in Princeton and said, "I'll work for free." *[Laughs]*

He worked with us for about two months, and then I decided we had to pay him.

TK: So how many years in total did he work in Princeton?

FvH: Three years and then he went to Washington.

TK: To UCS?

FvH: He worked first at a small NGO, the Nuclear Control Institute. Then, after NCI's president died, Ed became president for a few years. He joined UCS in 2003, which is where he was when we worked together to stop the Bush Administration's reprocessing proposal.

It was critical that the UCS arranged that meeting with these two key congresspeople. At that point, I was not politically sophisticated enough to develop that strategy by myself. And the lobbyists I worked with were early in their careers and unsophisticated as well.

David Hobson, the Republican chairman became my hero for another reason as well. He looked at all the strategic warheads that were coming off excess US Cold War missiles and bombers and asked why more were not being dismantled.

The initiatives in the fall of 1991 by G.H.W. President Bush to eliminate tactical nuclear weapons had reduced the US warhead stockpile from about 20,000 at the end of the Cold War to about 10,000. Then came the reduction of the 10,000 strategic nuclear warheads on each side by about half under the START Treaty and then to 2200 under G.W. President Bush's SORT Treaty. The Pentagon wanted to store all the excess strategic warheads but Hobson forced the Bush Administration to dismantle about 5,000.

TK: Because Congress passed legislation requiring that?

FvH: Yes, Congress said in effect, "You have way too many warheads in your strategic reserve. We want you to dismantle 5,000." And so that happened during the G.W. Bush Administration (Figure 2).

As I have recounted, they key Congressional committee also stopped supporting the Bush Administration's program to reprocess spent fuel in the US as a "solution" to Nevada's blockage of the Yucca Mountain spent fuel repository. Later, when the Obama Administration came in, it like previous Democratic administrations going back to the Carter Administration, was opposed to reprocessing.

TK: So when did the Obama Administration decide to stop it?

FvH: The Bush Administration's reprocessing initiative was dead already when the Obama Administration came in and the administration had no interest in restarting it.

TK: So the Bush Administration's reprocessing initiative was ended by this congressional initiative.

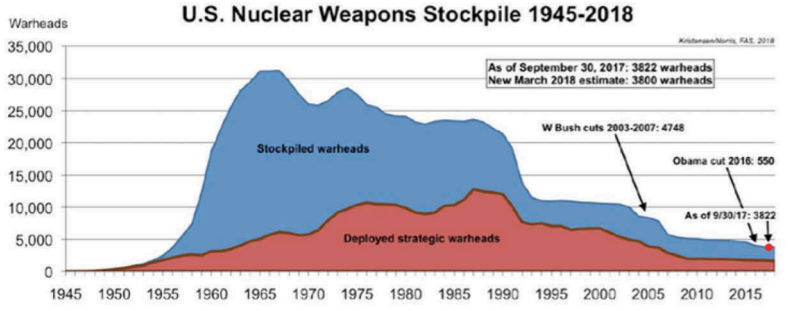

Figure 2. History of the US nuclear-warhead stockpile. The drop starting in 1991 was due to the mass retirement of short and intermediate range nuclear weapons. The drop starting in 2003 was as a result congressional pressure not to store more than one reserve warhead per deployed warhead. (Kristensen 2018).

End of the US-Russia Treaty Limiting Anti-Ballistic-Missile Defenses

TK: One more question about the Bush Administration. Right after the terrorist attacks of 11 September 2001, President Bush announced the US withdrawal from the US-Soviet /Russia treaty limiting antiballistic missile systems, the ABM Treaty. What was your reaction to that?

FvH: I was very upset but I didn't play a significant role in opposing it. The Republicans had taken over control in Congress in 1995 and had pushed relentlessly for ballistic missile defense. The Clinton Administration had resisted but had retreated step by step. Now, with President Bush in the White House, the Republicans had complete control.

The Clinton Administration had agreed to "theater" ballistic missile defense, that is, defenses in Europe against Iranian and Iraqi missiles and in South Korea, Japan and Taiwan against North Korean missiles. Then, in 1998, the Republican-controlled Congress created the Rumsfeld Commission to assess the potential future ballistic missile threat to the United States from those countries. The Rumsfeld Commission's unanimous conclusion was that, with outside help (from Russia, for example) North Korea and Iran could have ICBMs within five years and Iraq within ten.

Then came the terrorist attacks of 11 September 2001 (9/11) and the Bush Administration said, "See, we told you, it is a dangerous world!" and, although there was no logical connection between the Saudi terrorists and the possibility of launches of nuclear-armed intercontinental ballistic missiles from Iran, Iraq or North Korea, the Bush Administration was able to kill the ABM treaty without much resistance.

TK: Did you write something about that?

FvH: Not then. There were people who were more expert than I was, like Phillip Coyle, Richard Garwin, George Lewis and Ted Postol. The Union of Concerned Scientists also had David Wright and, more recently, Laura Grego.

The Bush Administration launched a program to produce and deploy missiles to intercept long-range missiles in space without any quality control, laying the basis for a costly disaster.

At this point, the US has 44 long-range ground-based interceptors weighing 22 tons each that, even with choreographed tests, work only half the time and would not be effective against even simple countermeasures. The amount of money that has been spent on the them is equal to the cost of the interceptors' weight in gold.

TK: So, fear of terrorist attacks by rogue nations armed with nuclear weapons became overwhelming with no effective opposition from the scientific community?

FvH: Yes, the Bush Administration's argument was that the the ABM treaty was a Cold War relic. We were not enemies with Russia anymore and Russia had collapsed economically so fears that a US ballistic missile defense (BMD) system could stimulate an arms race with Russia could be dismissed as "old-think."

Of course, the price of oil went up and Russia began to develop new weapons including boost-glide warheads, hypersonic cruise missiles, and intercontinental-range nuclear powered torpedoes to bypass US BMD systems, and China has been building up the number of its warheads on ballistic missiles with ranges that could reach the United States (Figure 3).

TK: Did you get some reaction from the Russian friends on the ABM issues at that time?

FvH: Well, since Putin took power in 2000, the policy-making process in Moscow has become quite closed and I go there only infrequently.

TK: How about Alexi Arbatov?

FvH: Abatov is an exception. He remains active trying to save nuclear arms control. Recently, I attended a talk he gave in Washington. As always, he was lucid and insightful. He mentioned that he had been in several meetings with Putin. He did not describe the nature of the meetings but said that, since Putin announced Russia's new BMD-

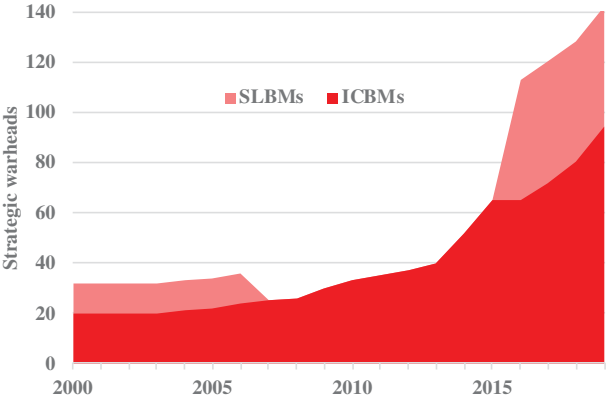

Figure 3. Although it still has only one tenth the number of the US deployed strategic warheads and not very capable ballistic missile submarines, China has been building up its strategic nuclear forces. One factor has been concern about the buildup of US ballistic missile defenses (Lewis and von Hippel 2018, updated).

bypassing nuclear-weapon delivery vehicles in March 2018, he appears much less concerned about US BMD.

TK: How about Velikhov?

FvH: Velikhov has moved on to other things.

In 2005, Putin created a third "Civic Chamber" of the Russian parliament and appointed notables to it with Velikhov as its first chairman. In principle, they can investigate anything and make recommendations to Putin and the other two chambers of the Duma. Unfortunately, it appears to be a top-down alternative to a true civic society, which Putin suppresses when it challenges his control. Velikhov is promoting bottom-up civic society to at least work on local issues.

The International Panel on Fissile Materials

TK: Why did you create the International Panel on Fissile Materials (IPFM)?

FvH: The idea for the IPFM came to me when I gave a talk about nuclear materials to a group of Caribbean and Central American ambassadors at the UN.

I said, half jokingly, that getting rid of nuclear weapons was easy in principle. All that was necessary was to get rid of about 2,000 tons of HEU and plutonium. I don't know what the ambassadors retained but I listened to myself and that sounded like a good focus! *[Laughs]*

Working with Velikhov during the Reagan Administration, I had also learned that I had much more impact in Moscow than I had in Washington during that period. The lesson I drew was that there could be a synergistic effect if you had an organization of like-minded policy activists in more than one country.

So I asked José Goldemberg if he would go with me to the MacArthur Foundation and ask for money to start up an International Panel on Fissile Materials. We would be the founding co-chairs. Goldemberg agreed and we went together to Chicago to make the pitch to the President of the MacArthur Foundation.

Let me tell you briefly about Goldemberg because he has had a remarkable career.

I have known Goldemberg since he was a visitor to our Princeton Program in 1978. He was president of the Brazilian Association for the Advancement of Science at the time and was a leading critic of Brazil's nuclear program.

What precipitated Goldemberg's first visit to Princeton was the seizure of his son, a student activist, by Brazil's military government. Goldemberg was desperately worried that his son would be "disappeared," as hundreds of political activists had been. So he prepared to visit Princeton and threatened that he would leave Brazil permanently if his son was not freed. His son was freed.

Goldemberg came for an extended visit anyway and became a member of a famous energy-policy "gang of four" with Thomas Johannson from Sweden, Amulya Reddy from India, and Bob Williams from Princeton. Together, they promoted a vision of an energy-efficient future for sustainable global development.

In the late 1980s, Brazil's military junta surrendered power and, in 1990, Goldemberg became Minister of Science and Technology in Brazil's first post-junta elected civilian

government. He advised President Collor de Mello in his successful effort to shut down Brazil's nuclear-weapons program in parallel with Argentina doing the same, and in setting up a Brazilian-Argentine Agency for Accounting and Control of Nuclear Materials to establish mutual transparency between the two nations' nuclear programs.

Goldemberg's support therefore gave instant credibility to my proposal for the IPFM.

The MacArthur Foundation agreed to support the IPFM and we recruited members from other countries – many of them had passed through our program as visitors and post-docs. In the spring of 2006, we had our first meeting in the Hague, the old capitol of the Netherlands and the headquarters of the Organization for the Prohibition of Chemical Weapons and the International Court of Justice.

Coincidentally, right after our meeting in the Hague, the Conference on Disarmament (CD) in Geneva was going to have a discussion of a Fissile Material Cutoff Treaty (FMCT). Our Dutch member, Arend Meerburg, a retired ambassador who had been a delegate to the negotiations on the Chemical Weapons Convention and the Comprehensive Test Ban Treaty, was invited to join the Dutch delegation to the CD as an expert. He talked with them and they invited me along as well (Figure 4).

TK: Oh really?

FvH: So I went to Geneva as a member of the Dutch delegation.

TK: Is that possible as an American?

FvH: They did it! I even offered to change my name from von to van to make it Dutch. *[Laughs]*

One of the issues discussed at the CD meeting was the definition of the fissile materials whose further production and the subsequent use of fissile material produced in the nuclear-armed states after the treaty came into force were to be placed under IAEA safeguards. The Russians wanted a very narrow definition. They said the ban on production for weapons should just cover weapon-grade uranium enriched to over 90 percent U-235 and plutonium with over 95 percent Pu-239.

I responded that the Hiroshima bomb was made with 80-percent enriched uranium. The Russian expert was absolutely furious with me. He turned beet red. *[Laughs]*

Figure 4. Left. Palace of Nations in Geneva, originally built between 1929 and 1938 for the League of Nations, now hosts UN meetings, including those of the Conference on Disarmament, held in the Council Chamber on the right. (Exterior, vassil; interior, Marc Ferre, UN).

The Russians still have that position. I don't know how firmly it is held, however, since there have been no negotiations.

Later on, Meerburg led an IPFM working group to draft a fissile material cutoff treaty (FMCT).

The reason we decided that we had to produce our own draft was that, at that same meeting at the Conference on Disarmament in 2006, the Bush Administration came in with a US draft of an FMCT that included no verification. The G.W. Bush Administration did not believe in verification, and had insisted that the 2002 Strategic Offensive Reductions Treaty (SORT) treaty with Russia, which reduced the two countries' deployed strategic warheads, also be unverified. This was in contrast with the START Treaty of 1994 and the New START Treaty of 2011, which both had detailed verification protocols, including on-site inspections.

I went with the Dutch delegation to a meeting of the NATO delegations during that CD session on the FMCT. There, the leader of the US delegation presented the US draft FMCT and then accused the NATO allies of suffering from the Stockholm Syndrome.

TK: What is that?

FvH: The Stockholm Syndrome is where, if you are a hostage, you start identifying with and accepting the beliefs of your captors. Apparently, it was first described in connection with a bank robbery in Stockholm.

I can't remember the details but I think that the US delegate made this accusation because the NATO delegations believed in verification and also were willing to negotiate on other subjects in addition to the FMCT. At the time, the Chinese and Russians were demanding parallel negotiations on prevention of an arms race in outer space, in part because the Bush Administration had withdrawn the US from the ABM Treaty.

It was really bizarre and I was outraged that my government was treating its allies in this fashion.

TK: I see. Which year was that?

FvH: 2006.

So we in IPFM decided to write an alternative draft FMCT because there needed to be an alternative to the US draft. In 2009, the Netherlands and Japan submitted our draft to the CD as an alternative to the Bush Administration draft[1].

TK: You drafted it?

FvH: Ambassador Meerburg was the lead drafter. Meerberg was a physicist by training and understood the technical issues as well as being familiar with the structures of multinational arms control treaties.

Meerburg was an adventurous man. Before he went into the Netherlands foreign service, he went on an Antarctic expedition and, before he retired from the foreign service, he served as the Netherlands's ambassador to Yemen. He and his wife started a school to educate girls there. His wife was also adventurous. She loved Yemen. She said,

[1]https://undocs.org/CD/1878.

"They kidnap you but they treat you very well!" That was before Yemen became a battleground.

Meerburg had been recommended to us by a senior diplomat in the Dutch foreign ministry. He was the best and most expert person they could think of. Most of our members are more enthusiastic about arms control than their governments. Ordinarily, therefore, we do not take government recommendations for members. But the Dutch foreign ministry liked our style.

The Next Generation of Activist Nuclear-policy Analysts

TK: You have had many promising young scientists at Princeton.

FvH: We have been lucky. Because our program is small, each post-doc, PhD and visitor becomes a member of our family. We collaborate with them while they are with us and often after they leave.

Zia Mian and M.V. Ramana came to us in 1997 and 1998 respectively as physicists interested in arms control. Zia initially spent a year at the Union of Concerned Scientists and then found his way to us. Ramana had a post-doc at MIT first.

We had a policy for our post-docs to move on after two years and most of them did but Ramana and Zia took root. Eventually Ramana took a professorship at the University of British Columia in Vancouver. Zia, along with Alexander Glaser, who originally came as a post-doc from Germany, now co-direct our Program.

David Albright was another early post-doc. We shared him with the Federation of American Scientists and then he went and created his own non-governmental organization (NGO), the Institute for Science and International Security. His work is good and his productivity is remarkable. Unfortunately, he became a relentless critic of the Iran nuclear deal, the 2015 Joint Comprehensive Plan of Action (JCPOA), for reasons that I have not been able to understand.

Dan Fenstermacher went to work in the State Department and became their lead person in the US program to convert foreign research reactors from highly enriched to low-enriched uranium fuel. He also led the US team to verify Russia's compliance with the US-Russian agreement to end plutonium production for weapon.

TK: How about the two Chinese?

FvH: We actually had three. Shen Dingli (1989–91), the first, was sent by the President Xie Xide of Fudan University in Shanghai, with whom I served on the Board of Velikhov's International Foundation. Shen returned to Fudan and became a Professor of International Studies there. He is as outspoken as an academic can be in China. He read my father's memoir and took to heart my father's mantra, "we shall not be intimidated!"

At one of the meetings of the board of the International Foundation, Xi Xide told me, "I have a PhD student who is interested in international relations." She told me that Shen, a physics student, had entered a Shanghai competition that tested knowledge of international affairs and had come out first among some incredibly large number of entrants. She said, "He should come to work as a post-doc with you." So he came.

During the fall of 2018, I took four Masters students to Beijing to research China's potential role in solving the North Korean nuclear problem. Shen flew to Beijing from Shanghai to talk to the students. He came in with no notes and just started talking. It was not clear until the end where he was going to end up, but the students were fascinated and learned a lot. *[Laughs]*

The other two, Li Bin (1995–6) and Zhang Hui (1997–99), were sent to us by Hu Side and Du Xiangwan from the Institute of Applied Physics and Computational Mathematics (IAPCM) in Beijing, the theory group of China's nuclear-weapons-design program. Zhang Hui is now a researcher in Harvard's Managing the Atom Program and has become *the* US expert on China's nuclear program.

Li Bin is now a professor at Tsinghua University (China's MIT) in Beijing. He was originally invited back to run the arms control program at IAPCM but, in the meantime, Hu and Du had gone to Minyan outside Chengdu to direct the weapons program. Their successors at IAPCM were not as interested in arms control. Li Bin resigned and was supported by the Plowshares Fund for a couple of years until Tsinghua recruited him.

Li Bin has created a new generation of arms control experts in China. They do original work and some are very impressive. We just recruited one of them, Tong Zhao, onto the IPFM.

I got Zhang into a little trouble in China. He and I wrote an article about how satellite imagery could be used to help verify a fissile material cutoff, and we included in the article a declassified US satellite image of a former Chinese military reprocessing facility and a commercial satellite image of a former military enrichment plant (Zhang and von Hippel 2000). Apparently, China's government was not amused. Zhang did not visit China for few years until the situation cooled down.

TK: So, in the late 1990 s and early 2000s, you felt the necessity to help create a younger generation of nuclear-policy activist-analysts?

FvH: They were mostly post-docs. But we also had a few PhD students and a few senior visitors.

My last PhD student, Scott Kemp, did as his thesis research a very important and deep study of the proliferation of gas centrifuges for uranium enrichment. He argued that centrifuges have brought the production of highly enriched uranium for weapons within reach of just about any country. Therefore, he argued, we must now depend more on the taboo on nuclear weapons than on technology denial to sustain the nonproliferation regime. Scott is now a professor of Nuclear Science and Engineering at MIT.

In addition to José Goldemberg, our senior visitors have included Anatoli Diakov, who created the Center for Arms Control, Energy and Environmental and Energy Studies at the Moscow Institute of Physics and Technology; Alan Krass, who used his visit to facilitate his transition from an academic to a State Department career; and three senior South Asian physicists who became important voices for restraint in their countries' debates over nuclear-weapons policy: R. (Doug) Rajaraman of the Jawaharlal Nehru University in New Delhi, and Pervez Hoodbhoy and Abdul Nayyar from the Quaid-i-Azam University in Islamabad.

We have not had many women postdocs or PhD students but that is finally changing, thanks to Alex Glaser. Right now, five of our six PhD students are women.

TK: What about the IPFM's activities?

FvH: From 2006 through 2010, we put out much of our work in annual reports. I am particularly proud of the 2010 report in which we reconstructed the histories of the military stocks of plutonium and HEU for all the nuclear-armed states (IPFM 2010). See Figure 5. We also wrote topical reports.

Tadahiro Katsuta and Tatsujiro Suzuki published a critique of Japan's reprocessing policy (Katsuta and Suzuki 2006); Michael Schneider and Yves Marignac critiqued France's continuation of plutonium separation after its breeder program collapsed (Schneider and Marignac 2008); and Martin Forwood critiqued the UK's continuation of reprocessing when it had no prospective use whatever for the separated plutonium (Forwood 2008). In 2010, we wrote a big report on the history and status of breeder reactors worldwide – on all the money (more than 100 billion USD) and talent that had been wasted and on the danger represented by all the plutonium that had been separated to provide startup cores for breeder reactors that were never built (Cochran et al. 2010).

Some of these reports have been important contributions to national debates. In 2011, the UK finally decided to end its reprocessing program. It is hard for me to believe that France and Japan can continue to defy logic and economics and continue their programs for many more years. I have just begun to write an IPFM report on why these zombie programs continue and possible strategies for accelerating their terminations.

In 2007, while I was fighting the Bush Administration's proposal to reprocess in the US, I wrote an IPFM report on *Managing Spent Fuel in the United States: The Illogic of Reprocessing* (von Hippel 2007). In 2016, while promoting a policy that future US naval reactors should be designed to use low-enriched uranium fuel, I wrote a report on the technical basis for a ban on the production of HEU for any purpose, including for fueling submarines and aircraft carriers (von Hippel 2016).

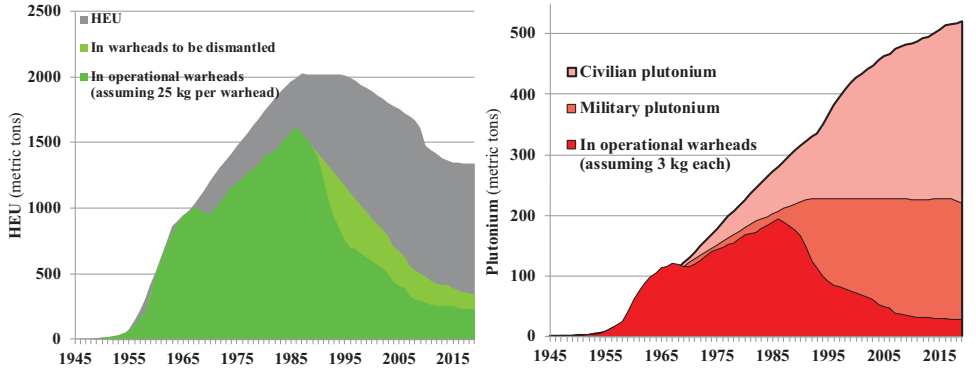

Figure 5. Global stockpiles of military highly-enriched uranium (HEU) and separated plutonium grew during the Cold War. After it ended, the quantities in weapons declined and about one third of the excess HEU was blended down to low-enriched uranium for power-reactor fuel. In the case of military plutonium, the planned disposal in reactor fuel of 68 tons of plutonium declared excess by Russia and the US stalled because of costs. In addition, France, Japan, Russia and the UK continued their civilian plutonium separation programs even after their breeder development programs failed to produce economically competitive reactors. (IPFM 2020).

TK: You worked hard.

FvH: When I get involved with an issue, I try to educate myself by writing about it. Then I use what I have written to educate Congress or another important target audience.

In the case of the French, Japanese and UK reprocessing programs, our reports were ammunition for their domestic critics. In France, Schneider and Marignac have become *the* sources of information and analysis for members of parliament skeptical about France's reprocessing program. The same is true for Tatsujiro Suzuki and Masafumi Takubo in Japan. Martin Forwood, the author of our report on reprocessing in the UK, was the leader of an NGO, Cumbrians Opposed to a Radioactive Environment (CORE), which sustained opposition to UK reprocessing nationally as well as locally. Cumbria is a large, sparsely populated, scenic county that includes the famous Lake District as well as the UK's Sellafield reprocessing complex.

TK: Going back to the necessity to educate the younger generation, what made you decide to start educating those people? Were you concerned about the future of nonproliferation?

FvH: It was not just nonproliferation but also nuclear arms control and reductions. There is always concern about aging experts.

I became aware of the generational issue from the very beginning, when I was writing about science advising. The first generation of people who were advising the US government on nuclear arms control were veterans of the Manhattan Project.

Then came their students, including Richard Garwin and Marvin Goldberger (Fermi's students) and Wolfgang Panofsky (Luis Alvarez's student) who became members of the President's Science Advisory Committee (PSAC) after President Eisenhower established it in 1957 in response to the Soviets orbiting Sputnik, the first artificial satellite. That involvement made them and the other people recruited onto PSAC sophisticates about government policy.

PSAC had a lot of influence under Eisenhower, Kennedy and Johnson. But its influence faded out at the end of the Johnson Administration after the government had regained its confidence in US technical superiority. Johnson and Nixon decided that deploying a ballistic missile defense could be dictated by the impact of the decision on the next election rather than by considerations of effectiveness or the stimulus it would give the Soviets to further build up their offensive forces.

In 1960, some of the second-generation advisors created the JASON Group of consultants, which spends two months every summer in La Jolla doing studies after agreeing with the Departments of Defense and Energy on research topics of mutual interest. This drew in a third generation.

But, while Drell, Garwin, Goldberger and Panofsky participated in the public debate as well as in advising the government, and Drell and Panofsky started an arms control course at Stanford, most of the next generation in the JASON Group did not feel the same responsibility to educate the public or even their students on nuclear-weapons issues. At one point early in my time in Princeton, I went to some of the Princeton JASONS and asked, "why aren't you giving courses on nuclear arms control?" They responded, "Our work in JASON has nothing to do with academia. We have to keep them separate." They

did not recognize the importance of educating the public and Congress – something that Garwin always understood.

I was one of the few in the next generation concerned about educating the public. So the question of who would come after was obvious and, when I started thinking internationally, I recognized it as an international challenge.

That is why we started what became the UCS summer school and our program's post-doc program. Our post-doc program is quite small. At any one time, we have one or two post-docs.

At the same time, Harvard and Stanford have about ten people every year. But they don't work with their post-docs the way we do. Applicants for their post-doc positions have to come with a well-developed research project. Their main interaction with the faculty and senior researchers is at seminars. And their tenure is usually limited to a year.

We've had good luck with what I call our apprentice approach. We work with our post-docs for two years – sometimes longer. We teach them how to write papers, and then, when they become known through those papers, they have opportunities to take positions where they can make a difference.

Often they already have activist backgrounds when they apply to us. Josh Handler, one of my very few PhD students, worked for Greenpeace for eight years and became a great expert on Russia's nuclear navy among other things. Now he is a senior analyst in the US State Department.

TK: So now you have younger-generation experts.

FvH: Yes, but the next younger generation of activist analysts, such as Alex Glaser, Li Bin, Zia Mian and M.V. Ramana are getting older, so we need yet another generation.

Fortunately, they are reproducing. I remember meeting one of Li Bin's students in Beijing. She exclaimed, "You're my grandfather!" *[Laughs]* In China, a student's academic advisor is like a second parent. Another of Li Bin's students, Tong Zhao, is already playing an important role in explaining China and the United States to each other in the area of nuclear-weapons policy.

TK: At Princeton, you have Sébastien Philippe.

FvH: Yes, Sébastien, our first student from France, was Alexander Glaser's PhD student. He is a both an excellent analyst and an effective activist. After President Trump was elected, Sébastien led in the creation of a graduate student group, Princeton Citizen Scientists, who organized to educate each other and then their fellow citizens on a variety of important public issues including climate change and the dangers of the continuing nuclear confrontation with Russia. The impulse was very similar to the one I saw at Stanford in reaction to the Vietnam War a half century earlier.

Before Sébastien came to us, he spent two years doing nuclear safety oversight over France's ballistic missile submarines. His first year at Princeton in 2012–13 was my last year on Princeton's teaching faculty and he took my arms-control course.

We have always worried about the loophole in the Nonproliferation Treaty's standard safeguards agreement that allows countries to remove nuclear materials from safeguards to be used in naval reactor fuel. How then could we prevent or detect possible diversion of enriched uranium from a naval fuel cycle to a clandestine nuclear-weapon program?

Brazil is the first non-nuclear-weapon state that has embarked on a serious effort to build a nuclear submarine. Sébastien wrote a course paper that he later developed further and published. He was invited to present his ideas in both Brazil and at the headquarters of the International Atomic Energy Agency in Vienna. His article is recognized as the first in the developing literature on the subject.

TK: So how did you get Alex Glaser?

FvH: A very interesting thing happened in Germany. It may have been an outgrowth of the early 1980 s movement in Western Europe that opposed the deployment there of US intermediate-range, nuclear-armed missiles. The US missiles were deployed in response to deployment of Soviet SS-20 missiles in the western part of the Soviet Union within range of Western Europe. Ultimately, in the 1987 Intermediate Nuclear Forces (INF) Treaty, the two sides agreed on a "zero solution" and eliminated all their land-based missiles with ranges between 500 and 5500 kilometers.

Probably because of the ferment in Western Europe over all these missiles, a group of physics students at Darmstadt Technical University near Frankfurt created a research program on nuclear disarmament. The named it IANUS, for the two-faced Roman god, Janus, because technology can be used for good or evil. They recruited a member of the physics faculty to be their nominal advisor but basically supervised their own research as a collective.

Their first PhD student was Martin Kalinowski.When it came time for him to defend his thesis, the head of the physics department reached out to me because the department was not convinced that Kalinowski's thesis was worthy of a PhD.

The thesis proposed a system of international controls on the production of tritium, which is used to "boost" the power of modern nuclear weapons. I said that it would be worth a PhD at Princeton. That may have helped tip the balance in Kalinowski's favor. Later, Martin became the first Professor of Science and Peace Research at the University of Hamburg, Germany. He then moved to the Comprehensive Test Ban Treaty Organization in Vienna where he is currently in charge of capacity building and training for the CTBTO's global monitoring network.

Alex Glaser was in a second cohort of IANUS students from Darmstadt. His thesis analyzed the options for converting the new FRM II research reactor near Munich from weapons-grade to low-enriched uranium (LEU) fuel.

The designers of the FRM II were a renegade group that did not accept the new norm of designing research reactors to be fueled by LEU. Instead, they used a high-uranium-density fuel that had been developed to enable conversion of existing reactors from HEU to LEU to make a more compact, high-neutron-flux core. Higher fluxes are achieved with higher-power reactors fueled by LEU but the Munich people were proud that they had achieved their relatively high flux core with a relatively low-power reactor. As Armando Travelli, the founding leader of the US Reduced Enrichment Research and Test Reactors program quipped, "they built the world's tallest dwarf."

Glaser developed his own computational tools for doing the neutronic calculations and came close to designing a new LEU core that would fit into the FRM II reactor. He then joined us as a post-doc and, when Princeton decided to search for another faculty member in our area, he applied and succeeded me on the faculty. He and Zia Mian also succeeded

Hal Feiveson and me as co-Directors of the Program on Science and Global Security and, along with Tatsujiro Suzuki, succeeded R. Rajaraman and me as co-chairs of the IPFM.

When I was on the faculty, my position was one hundred percent in the Woodrow Wilson School of Public and International Affairs. I was the first natural scientist on that faculty. Previously, all of the faculty members had been economists and political scientists. Subsequently, as its disciplinary makeup became more diverse, the faculty of the Woodrow Wilson School lost confidence in its ability to judge researchers in other disciplines and decided to have only joint appointments with other departments.

If that policy had been in existence when I joined the faculty, it would have meant that I would have had to be accepted as a physicist by the physics department. I don't think that would have been possible because I had stopped doing "pure" physics more than a decade before I joined the Woodrow Wilson School faculty in 1984.

In Alex's case, the proposed joint appointment was with the Mechanical and Aerospace Engineering Department. I was on the committee that appointed Alex as an assistant professor, and we debated what would be the criterion for making him a tenured professor. The engineers insisted he had to not just use physics in an intelligent way for policy but that he also had to make important original contributions to engineering. In the end, Alex did make such contributions. I still feel that technically-based contributions to arms control should have been enough, however, and worry that the tyranny of the disciplines may reduce the number of people in academia with saving the world on their agendas.

Disclosure Statement

No potential conflict of interest was reported by the authors.

Notes on Contributors

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