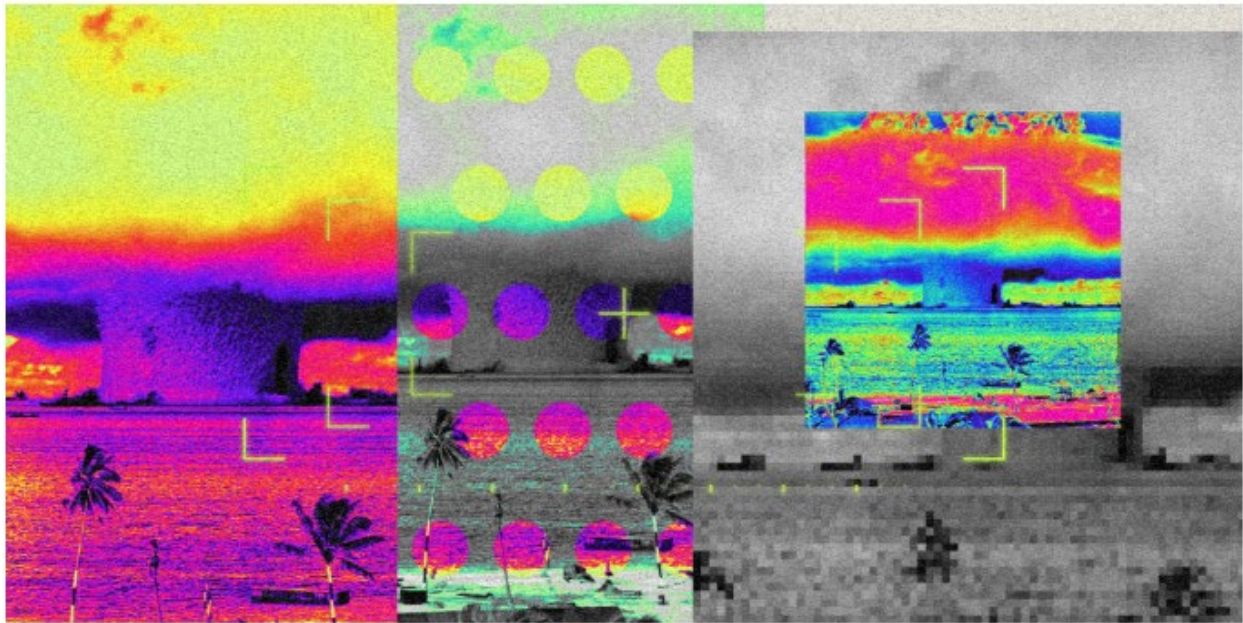


Lessons from Los Alamos

An interview with Dr. Siegfried Hecker, the former Director of the Los Alamos National Laboratory

by CARSON BECKER



Dr. Siegfried Hecker is an American nuclear scientist and the former Director of the Los Alamos National Laboratory, a role he held from 1986 to 1997. Born in Europe during World War II, he emigrated to the United States in 1956. He earned his PhD in metallurgical engineering from Case Western Reserve University in 1968, after which he joined Los Alamos as a postdoctoral fellow.

Following the collapse of the Soviet Union, Hecker assumed a leadership role in post-Soviet lab-to-lab cooperation between the US and Russia. In the chaos of the 1990s, the security of the Soviet nuclear arsenal was dangerously uncertain. It is a notable achievement that the vast arsenal of the former USSR, with its 40,000 nuclear weapons and 1 million nuclear personnel, did not find its way into the hands of international terrorists. Hecker documents this period in the book *Doomed to Cooperate*, which features the perspectives of over 100 Russian and American nuclear scientists.

Between 2004 and 2010, Hecker was given access to North Korea's nuclear weapons facilities in order to confirm the viability of the program. Among other

things, he confirmed that North Korea had mastered plutonium production when Dr. Ri Hong Sop, the head of North Korea's nuclear program, presented him with physical samples.

I sat down with Dr. Hecker to discuss the North Korean nuclear program, the challenge of proliferation, and the evolution of nuclear energy. What follows is a transcript of our conversation.

CB: When I read about your life, it's very clear that one central moment was the Second World War — this terrible disaster that befell Europe and drove you to the United States as a boy, and that also extinguished those little pockets of the German nation throughout Eastern Europe that your family comes from. Do you often reflect on this history?

SH: It certainly shaped my life. I was born during the Second World War, in 1943, while my father was stationed with the German Army in what is now Ukraine. I wound up being born in Poland. Then, of course, for the Germans and German-speaking people, everything went pretty poorly from 1944 on, so my mother had the job of getting our family to someplace where we could live and be reasonably safe. Eventually she took us from Poland through Croatia and Slovenia, back to Austria proper, where I grew up until I was 13. Both the war and the fact that my father never returned from the Russian front — and then growing up without a father, in barracks in Austria with no running water and no central heat the entire time I lived there — certainly shaped the rest of my life.

CB: What do you recall about the deprivations of the postwar era?

SH: Actually, I didn't know that people lived very differently than we were living. We were in this little town of 4,800 people in the Austrian Alps called Rottenmann — the town of the Red Man — and most of the people around us, particularly the ones who lived in the barracks, were just as poor. So I didn't realize that I was deprived. You just deal with it. I played soccer, I skied on what were essentially wooden boards, and when I look back on those 13 years, I'd say I had a pretty happy childhood.

CB: What was your journey to the United States like? Did you travel by train, by airplane, by boat?

SH: Not by airplane. This was 1956; I had just turned 13. From Rottenmann we took the train up to Bremerhaven, the port in Germany, and from there we went on an old US naval ship called the USS General Langfitt. Oh God, that was a miserable, miserable trip. But after five days or so, we survived and arrived in New York Harbor. We had uncles in the United States, and my older brother had gone ahead of us — specifically to Cleveland, Ohio. So we took the train from New York City to Cleveland, where my brother, who was five years older than I was — he was a little over 18 by then — was waiting with my uncle to pick us up.

CB: Your career spans 75 to 80 percent of the atomic age. What were your

impressions of those early years of the nuclear era?

SH: In Austria, I never thought much about this. When you live the sort of life we did, what you care most about is how you make it to the next day and how you can go out and play with your friends. So for those 13 years, I never thought much about the nuclear era. Of course, I'd heard that the Americans had dropped these atomic bombs and that it ended the war. And when I came to Cleveland at the age of 13, I must say I also didn't think all that much about the postwar atomic era we were in.

The first time it really came to my mind was the Cuban Missile Crisis. I still remember being at Case Tech — the Case Institute of Technology, as it was called — when we heard about the Cuban Missile Crisis. From then on, it started to stick more in my mind. But it still wasn't central to my thinking and my concerns about the future. That didn't happen until I came to Los Alamos as a summer student, after finishing my undergraduate degree at Case Tech. At that time it was called the Los Alamos Scientific Laboratory.

I didn't come to Los Alamos because of the bomb, or because of its fame from the Manhattan Project. I came for two reasons. One was that the brochure that attracted me showed there was skiing at Los Alamos. Let me just say there was not much skiing in Cleveland, Ohio, so from age 13 until then, when I was 21, I hadn't skied much, and the thought of going to a place with mountains was very attractive. The other was simply the fame of Los Alamos as one of the best scientific laboratories in the world. I wasn't thinking bombs; I was thinking science.

CB: How does the American national laboratory system work?

SH: It was all set up because of the Manhattan Project. As the film Oppenheimer showed, General Groves wanted the scientists to wear uniforms, and Oppenheimer was more or less resigned to that. But his super scientists said, "There's no way we're going to wear Army uniforms." So Oppenheimer and his colleagues managed to get the University of California to operate the laboratory, and that really developed the blueprint for the national laboratory system. At that time there was also Argonne, outside of Chicago, and Oak Ridge — they weren't called national laboratories then — and Los Alamos. Those three contributed in a major way not only to the Manhattan Project but to the future of science and the way one runs science. The University of California continued to run Los Alamos from 1943 until 2005. A number of other laboratories were created, and the whole system now comprises 17 laboratories managed under the Department of Energy.

The key aspects were looking for the best possible science, having a university connection, which always brings in new blood and new thinking, and tackling something of critical importance to the nation. For the Manhattan Project, that was clearly the bomb, and afterward it was nuclear weapons and deterrence. But it was also nuclear energy and so many other things critical to the nation's future. That's what the national laboratory system turned out to be. It's changed some, of course, over the last 10 or 20 years, but that was the design.

CB: When did you first witness a nuclear test?

SH: I've actually never witnessed a nuclear test, if by "witnessed" you mean seeing something like an atmospheric test. The United States signed the Partial, or Limited, Test Ban Treaty in 1963 with the Soviets and the British, agreeing not to test anywhere except underground, and that was before I came to Los Alamos. So I never saw an atmospheric test. Later, as director of Los Alamos, I of course participated in some of the underground nuclear tests, which by then we conducted at the Nevada Test Site.

CB: Would you like to lay eyes on an atmospheric test? Is that something you regret?

SH: No.

CB: No? Why not?

SH: Because putting all that radioactive material up in the atmosphere just doesn't sound like a good idea. Under the circumstances of the Second World War and the Manhattan Project, and then the Cold War with the Soviet Union and the race to stay ahead, as I look back, it was all understandable. This country wanted to make sure that it stayed ahead, and nuclear testing was an absolutely essential part of that. The easiest way to test was in the atmosphere, and it's also where you learn the most, because you can make all kinds of measurements that tell you a lot about how a bomb worked. So I can understand why it was done. But it was a very good thing that at least those three big nations decided to stop atmospheric testing.

CB: During that period there was an enormous push to reduce the risk of nuclear weapons, and yet since then we've had proliferation in India, Pakistan, North Korea, and supposedly Israel. How do you explain the thinking of the cohort of scientists that were pushing test bans when you began your career? Why were they so concerned?

SH: Of course I can't speak for what the key people were thinking at the time. But as one looks back, and from what I've read, the Soviet Union and the United States were racing against each other to make sure neither fell behind, yet they realized that unless there were some restraints, this race would endanger the whole world. The Cuban Missile Crisis scared not only John F. Kennedy but also Nikita Khrushchev. From that experience, and from the realization that they now had hydrogen bombs — what we call two-stage thermonuclear weapons, a thousand times more destructive than the atomic bombs used at Hiroshima and Nagasaki — they were concerned that we might put an end to the world as we know it. So they realized there had to be restraints, and that's how the test ban treaty came about: restraints in terms of shaping the arsenals, but particularly because of fallout and global health concerns.

If you look at how the arsenals grew in the '50s, '60s, and into the '70s, they still grew quite substantially. Nevertheless, the two sides talked about, and eventually signed, treaties to limit nuclear arms. What also struck them was that it's really important

not to get too many fingers on the nuclear trigger, and that's where the idea of nonproliferation came from. They said: look, we stand at this precipice against each other, and if we now get five or 10 — or, as John F. Kennedy said in the early 1960s, 20 or 25 — nuclear powers, that's simply not a situation you want in this world. That's what made them want to take part in limiting nuclear weapons around the world.

What's fascinating is that the initial drive to stop the spread of nuclear weapons actually came from non-nuclear-weapon states. Ireland, of all places, began through the United Nations to say, "Look, it's to the benefit of all of us non-nuclear countries that others not develop nuclear weapons." So, more or less, we had a consensus that more nuclear weapon states are bad news.

As you indicate, some other countries still developed nuclear weapons. But to me, one of the most important achievements of the Non-Proliferation Treaty and the movement behind it is that today we have fewer than 10 countries in the world with nuclear weapons. There are what we call the P5: the United States, Russia, China, France, and the United Kingdom. Then the two that declared themselves nuclear powers are India and Pakistan — and I've spent a lot of time working with India and Pakistan, because at one time I considered that the most dangerous nuclear region in the world. Then North Korea declared itself a nuclear power with a nuclear test. So those are the eight. And then there's the one we don't know about — at least the US government says we don't know — which is Israel. A lot of people in the world think Israel has nuclear weapons — certainly the Iranians do — but the US government, for various reasons, says we don't know whether Israel has them or not.

And over the years there have probably been some 15 to 20 other countries that at one time or another explored getting their own nuclear weapons. Believe it or not, that started with countries like Switzerland and Sweden, right after the Manhattan Project, around the 1950s. Then they decided this was really not a good idea, and of course they backed off.

CB: Do you have any particular insight into the South African nuclear program, the only former nuclear power?

SH: South Africa is a really peculiar case. The answer is no, I've never had any firsthand connection with South Africa. I think the main reason is that by the time I became really interested in the rest of the nuclear world, with the dissolution of the Soviet Union, South Africa was giving up its nuclear weapons program, including dismantling the five or six nuclear devices it had built. I've studied their program a lot, both technologically — the path they chose to nuclear weapons, which was highly enriched uranium — and politically, in terms of why in the world South Africa would want nuclear weapons. There are some very good books on that subject. But I haven't been personally involved.

CB: If you look at the actual science of the bomb, why are uranium and plutonium

the only elements that have been used to construct a nuclear weapon? In your book *Hinge Points*, you mention there's a theoretical case for other elements sustaining a nuclear reaction.

SH: Yes, there are some others. These elements are in what we call the actinide series of the periodic table, and uranium and plutonium are the two most practical fissile materials — or at least some of their isotopes are. Others, like americium or curium, are such low probability that we haven't worried too much about them. So the focus has been on uranium — specifically the uranium-235 isotope. That's what enriching uranium means: Mother Nature gives you only 0.7 percent of the 235 isotope; the rest is primarily uranium-238. So you have to throw away most of the 238 and concentrate the 235. Uranium-235 was the Hiroshima bomb, so you can make a bomb with it. Plutonium-239 is the primary weapons isotope.

And by the way, even though you can use both, it turns out plutonium is a much, much better element for a bomb — if there's such a thing as a good bomb. Plutonium is by far the most potent, and therefore, if you want to build a bomb, the most desirable. You can certainly use uranium-235, as Hiroshima showed, but if you want to make a small, potent bomb, plutonium would be the first choice.

CB: And plutonium is not naturally occurring, right?

SH: Actually, it is. It was created in the Big Bang, through what's called the r-process, as all the other heavy elements were. But because it's radioactive, it transmutes into other elements. Plutonium-239 has a half-life of 24,100 years, meaning half of it transmutes into something else in 24,100 years. Some other isotopes, like plutonium-242 and plutonium-244, have much longer half-lives. So while plutonium was created in the r-process, it fades away over a billion or two billion years, and only minute traces of plutonium-244 might be found in nature. So one typically says plutonium is man-made — and the material we use for bombs or in reactors is man-made.

CB: With regard to the enrichment process, where does one acquire centrifuges and how do they work?

SH: The idea with the uranium you put into a centrifuge is to separate the heavy isotope from the light one. As I mentioned, 238 is the prevalent isotope, and it's heavier. We want to separate it from uranium-235, the lighter isotope, which is fissile — in other words, it works for bombs. First you turn the uranium into a gas by combining it with fluorine, which gives you uranium hexafluoride: six fluorine atoms along with one uranium atom. You put that gas in a centrifuge that spins very, very rapidly. The heavy material goes to the outside, the light material stays toward the center, and then you siphon off the light material. You have to do this over and over again to get from 0.7 percent up to, say, 80 or 90 percent.

These machines spin at enormously fast rates, and uranium hexafluoride is a pretty corrosive substance. So you need centrifuges that are fast-spinning, high-strength,

and corrosion-resistant, and all of that makes centrifuge technology quite complicated. There was a man named Gernot Zippe, one of the German scientists taken to Russia after the Second World War, who helped the Russians develop these centrifuges. Eventually they let him go, and he also brought that capability to the United States. It's much more difficult for, say, the Iranians or the Pakistanis to learn it — but they did learn it. Those capabilities can be learned, and centrifuges can be built. Iran and North Korea have demonstrated that, even though people think of them as technologically unadvanced countries — which isn't true of either one. I've been to North Korea, and let me tell you, they're not technologically backward. They've demonstrated they can make centrifuges.

Just to give you another case, since you mentioned South Africa: when South Africa was doing this in the 1970s and 1980s, it decided it didn't have the technologies it needed, so it developed its enrichment capability in a different way.

CB: Let's go back earlier in your career. You trained as a metallurgist. Tell me about that part of your education and how it applied to your early nuclear career.

SH: Metallurgy is what I chose at Case Tech, where I went to school. I started in nuclear physics, but I was from a very poor immigrant family. After a couple of years in nuclear physics, I said to myself, "My God, I'm not learning anything that will get me a job, and I'm going to have to get a job after four years. My parents can't afford to send me to graduate school." One of my colleagues said, "Hey, Sig, we could go into metallurgy, because in metallurgy you can actually get a job after four years." So I switched to metallurgy and finished my four years.

Then came a really defining moment in my life. First of all, I got married after undergraduate school. And by that time I had decided I didn't just want to get a job — I wanted to go to graduate school — and that I would get a summer job at Los Alamos. So 1965 held two defining moments: I married my wife, Nina, who had once been the Polish girl next door, and I went to Los Alamos, where I got my introduction to the laboratory.

The connection to metallurgy was really fascinating. That's when I was introduced to the most complex and enigmatic metal of all: plutonium. I joined a part of Los Alamos that was essentially a materials science and technology organization, and within a couple of weeks of arriving I was doing experiments on plutonium in glove boxes. That started my affair with plutonium 61 years ago. The metallurgy has really paid off, because plutonium is still a very complex metal that we don't fully

understand, and it's the key, central part of nuclear weapons — whether you can reproduce them or extend their lifetimes. Even today I still go to Los Alamos occasionally as an unpaid guest scientist to help with understanding plutonium and how we deal with the primary issue of today from the American standpoint: How do we extend the lifetime of our nuclear weapons, or how do we remanufacture them? The key to that is plutonium.

CB: What are the "known unknowns" when it comes to plutonium?

SH: The most complicated part, related to what I just said, is the aging of plutonium. Consider what we typically think of as aging. If you take a hunk of iron, it ages from the outside in — it rusts, or oxidizes. Plutonium also oxidizes, much, much faster than iron, so it has a very reactive surface. That's a major challenge. But plutonium doesn't just age from the outside in; it also changes from the inside out, because it's constantly bombarding itself. Because it's radioactive, it's transmuting into other elements like americium and neptunium, and into isotopes of uranium, and it generates helium through this radioactive process. What that aging process does to the structure of the plutonium, and how it affects plutonium's nuclear performance — we'd really like to be able to find that out, but we can't without nuclear testing. So understanding that is today's primary challenge in the nuclear weapons business.

CB: You took some time away from nuclear to work in the auto industry, right?

SH: After I finished my PhD at Case, which I went back for, in 1968, I returned to Los Alamos as a postdoc. After finishing the postdoc, in 1970 I went to the General Motors Research Laboratories just outside Detroit, Michigan, and worked in the auto industry.

I was at General Motors for three years, and I had a great time. They gave me everything I wanted. I could do fundamental work and sheet metal stamping work. But my wife didn't like Detroit. And the General Motors people — I was about 28 years old — wanted to put me on a management track. They said, "Siggy, you would make a really good manager here at General Motors." I said, "I'm a research guy. I don't want to do management. There's no way." With Los Alamos calling every six months asking, "Are you ready to come back?" I finally said in '73, "I'm ready to come back."

I slowly moved up in the leadership at Los Alamos and eventually became leader of one of the big divisions, Materials Science and Technology. Then I said, "I don't want to do this. I'm really a researcher." So I gave up the division leadership — it was a division of 715 people — and we helped found the Center for Materials Science, to get back to the science. That was in July 1985. And then, lo and behold, somehow I wound up being chosen by December 1985 as the fifth director of the Los Alamos National Laboratory — something I had never thought of doing and never wanted to do. But it happened, and that's how I became director of Los Alamos.

CB: When you became director of the Los Alamos National Laboratory, what was your primary mission?

SH: This was January 1986, and we were still in the Cold War, so the primary mission was still the US nuclear arsenal — making sure it was safe, reliable, and effective. What I also thought was really important is that we never know what another country can do technologically. From the beginning of the Manhattan Project, and from the association with all those great scientists and with the University of California, I believed it was crucial for the laboratory to guard against technological surprise. In other words, always keep looking: What else is out there?

What's new in the scientific world, and could there be defense-related applications, vulnerabilities for the United States, or advantages for the United States? So in 1986, what was on my mind was taking care of the US nuclear arsenal and continuing to explore the frontiers of science in every possible way. But then the world changed.

CB: When the world did change, you traveled quite extensively in the former Soviet Union, beginning, I believe, in 1992.

SH: That's correct.

CB: Could you describe how that came to be, and describe your travels in this collapsed empire?

SH: As I mentioned, I became director in January 1986. Several things happened that year that really affected the rest of my life. One was the Challenger explosion later that January. Then in April, Chernobyl blew up, and that reinforced the importance of safety, especially in the nuclear world. Then in October 1986, President Reagan and General Secretary Gorbachev got together in Reykjavik, Iceland, and said, "Let's get rid of nuclear weapons." I'm sitting back in Los Alamos saying, "Wait a minute! How's that for job security? They're going to get rid of nuclear weapons, and here we are."

What played out over the next few years — with Reagan and Gorbachev, and then George H. W. Bush and Gorbachev — is that the world changed. The Soviet Union came apart. As it was coming apart, it occurred to me, and to many of my colleagues and many people in the academic world who had followed the Soviet Union and then Russia, that you now had this huge nuclear superpower coming apart at the seams in every possible way. It split into 15 independent nations, and they had a lot of the nuclear infrastructure the Soviet Union had built — particularly Kazakhstan, where the Soviet test site, Semipalatinsk, was located.

At the height of the Cold War, they had an enormous number of nuclear weapons: 41,000. In terms of fissile materials — highly enriched uranium and plutonium — they had somewhere around 1.4 million kilograms. It takes roughly five kilograms or so of plutonium to make a bomb, or, for more modern versions of the Hiroshima-type bomb, maybe 20 to 25 kilograms of highly enriched uranium. They had 1.4 million kilograms. They had a million people in their nuclear complex, and that complex was spread across the 11 time zones of the former Soviet Union. That was a potential recipe for disaster. So my whole thinking at that point became: What in the world can we do to work with the Russians and the other countries of the former Soviet Union to make sure we don't have a nuclear catastrophe?

CB: To what extent was the Soviet laboratory structure replicated from the American one?

SH: Until 1992, or just before, that was yet to be found out. No Americans had been inside the Soviet nuclear weapons laboratories, although there had been exchanges in Soviet science, particularly nuclear reactor science. I was the first to make a

major visit to a Soviet nuclear weapons laboratory — the equivalent of Los Alamos, in a town called Sarov. Its structure was indeed very much like ours at Los Alamos, although they didn't copy it from Los Alamos. They developed it themselves after the Manhattan Project. Their Los Alamos, Sarov, was set up in 1946, and they detonated their first atomic device in 1949.

The interesting analogy is this. In the American weapons complex, we have Los Alamos, which was the first, and then Lawrence Livermore Laboratory, which was set up mostly because Edward Teller was unhappy with how fast Los Alamos was proceeding toward the hydrogen bomb. He managed, with a number of colleagues including E. O. Lawrence, one of the great American scientists, to set up a second, competing laboratory. The general thinking was: this nuclear weapons work is important enough, and innovation in it is important enough, that you can't have just one lab. You need competition — later we called it peer review, but it was competition. And that's exactly what the Soviets had. They had their Los Alamos in Sarov and their Livermore in a town called Snezhinsk, out in the Urals. Once I got to visit and got to know these people, it was almost identical. They were so competitive with each other. We used to say in the United States during the Cold War that the Soviet Union was our adversary, but Lawrence Livermore was our enemy. That's exactly how the Russians had it.

There's also a third US laboratory, then and now: Sandia National Laboratories, which has two campuses, one in Albuquerque and one in Livermore. The Russians have a laboratory like that too, called the Institute of Automatics. Interestingly, on my first trip in 1992, I visited both their Los Alamos and their Livermore, and when I asked about a Sandia, they said, "No, we don't have a Sandia." It only took a few months before, yes, they had a Sandia, and we wound up with cooperative programs with them as well.

CB: Did you deal much with the arsenals in Ukraine, Belarus, and Kazakhstan following the collapse of the USSR?

SH: The United States did, of course, and the Department of Energy did, but the main effort there was really in the Department of Defense. Secretary of Defense William Perry — whom I later had the good fortune of co-teaching with at Stanford, after he'd gone back to his Stanford roots — personally played a major role in having the arsenals in those three countries shipped back to Russia to be disassembled. So the Department of Defense gets the major credit for the actual nuclear weapons and for shipping them back. But the Department of Energy and its laboratories — again, Los Alamos, Lawrence Livermore, and Sandia — did much of the technical work.

One of the really neat things was that Sandia, as it worked with the Russians on how to get these weapons back from, say, Belarus to Russia proper, had to be concerned about potential terrorist attacks and other safety and security issues. So the Sandia folks developed Kevlar blankets, which the Russians then put over their nuclear devices to ship them back. We worked closely together on those kinds of activities for many, many years.

CB: I want to ask you about someone who was very much responsible for proliferation during that period: A. Q. Khan of Pakistan. What do you know about him, and what should we understand about what he did?

SH: I never met A. Q. Khan. I have been to Pakistan, and as I indicated, I worked quite a bit with the Indians and the Pakistanis and visited both their military and civilian nuclear complexes. The A. Q. Khan story is one of particular concern. You had a very clever Pakistani scientist who went to work for the European consortium that was developing centrifuges. He was actually a metallurgist, as am I by training, and metallurgists are important in enrichment-related technologies. He worked there for several years, and then he stole them blind: the blueprints and all the different capabilities. But what was especially important is that he learned how to do it firsthand, the tacit knowledge of working in a centrifuge facility.

Then he brought that home to Pakistan. Prime Minister Bhutto had decided some time before that Pakistan would have to build a bomb, because India had detonated a nuclear device in 1974. They called it the Smiling Buddha and said it wasn't a nuclear bomb but a peaceful nuclear explosion. That turned out not to be true, and the Pakistanis knew that. A. Q. Khan was not the principal person in Pakistan's nuclear weapons design — that was another Khan. But as we said, you need either uranium or plutonium, and A. Q. Khan helped them down the path to a uranium bomb by getting centrifuges built, running a centrifuge facility, and producing enough highly enriched uranium for Pakistan to have the bomb — I'm not sure exactly when, maybe the late '80s or so.

What we do know is that in 1998, India decided it wasn't going to rest on the laurels of that one peaceful nuclear explosion and conducted five nuclear tests — at least, we think five. The Pakistanis were fully prepared. They had the highly enriched uranium A. Q. Khan had helped them get, and they conducted six tests, as far as we know — one for India's 1974 test and five for 1998.

To finish the A. Q. Khan story: after he brought the technology from Europe and helped Pakistan develop the capability, he decided to become — as I think Time magazine called him — the "Merchant of Menace." He started selling these capabilities all over the world to make money. There's no question that he made the initial introductions to Iran and Libya, and to some extent to North Korea. So in terms of nuclear proliferation and the worst offenses, one really has to point to A. Q. Khan, the Merchant of Menace.

CB: Tell me about North Korea's nuclear program. As you said earlier, it's seen as a backward country, where, as you well know, it's actually quite sophisticated. Why did they use this nuclear brinkmanship for so long, and how did they develop it into a viable weapon?

SH: Let me see if I can shorten it to something manageable. Around the time the Soviet Union was breaking up, Kim Il Sung, the founder of the North Korean nation — who was quite a pain for the United States and the Western world for decades — decided that with the Soviet Union breaking up, he couldn't count on them. The

North Koreans had never liked the Chinese, so he couldn't count on them either. So he turned to the United States and asked: Could we come to an accommodation with the United States—in other words, normalize relations? What I believe happened is that he seriously pursued that objective of working with the Americans to normalize relations. And not only he, but his son Kim Jong Il and his grandson Kim Jong Un did so too.

But being sufficiently paranoid, sitting there in North Korea — and they had reasons to be paranoid about the Japanese, given what happened in the first half of the 20th century, and now they had the South and the Americans there — they said: if normalization doesn't work, we'll have a dual-track strategy, and that means developing nuclear weapons. We'll pursue both and hope it works out on the normalization end, but there are things that have to happen with the Americans. Being sufficiently concerned — and they are indeed a small country surrounded by enormous powers — they continued on the path toward nuclear weapons.

Whenever they did something like launch a missile or conduct a nuclear test, the Americans had to make a decision. One president after another — starting with George W. Bush, then Obama, then Trump — simply never believed the North Koreans would either refrain from developing nuclear weapons or get rid of them. Meanwhile, the North Koreans were asking how much the Americans were willing to do, and whether they could trust them enough to normalize relations. We never got there. In each case — and these are what I call the hinge points, the title of my book — when the Americans had to decide what to do about North Korea, they chose not to continue down the path toward normalization, but instead to come back and try to shut down North Korea's nuclear weapons program. That was unsuccessful. For 30 years, North Korea built the bomb, and we watched them do it. I was there in North Korea for seven visits, every year from 2004 through 2010, and they showed me things they wanted me to use to convince the American government that they really did have the bomb.

CB: Why was it that the intelligence agencies in the Bush administration, according to your account, didn't seem to want much to do with you?

SH: No, actually — and I was there during all of those administrations — they appreciated the information I brought back. I think the technical information was not only appreciated but highly valued, because I saw the centrifuges. Nobody had ever seen the centrifuges, so that was an enormous revelation for the Americans. On one of those visits, I actually held their plutonium product in my hand, in a glass jar — and I'm still here to tell you about it, because once the plutonium is in a glass jar, the alpha radiation doesn't get out. So they valued that; I think they appreciated it. But when it came to taking that into the political world to make political decisions, they decided to go in a different direction.

I met with Condoleezza Rice in the Bush administration, with Hillary Clinton in the Obama administration, and with Mike Pompeo after that. I made my reports, and they seemed to appreciate them. But as I try to say in the book, none of those administrations made technically informed risk-management decisions, and that's

what they needed to do. They had to take the technical information I brought back — and of course what they collected in every other possible way — and translate it into political decisions. That's where, as my book shows, we failed.

CB: Could you describe the Yongbyon facility? What does it look like, and how did you get there from Pyongyang?

SH: North Korea sort of took me back. You asked me about growing up after World War II — it took me back to my childhood in the barracks of Rottenmann in Austria. Really poor countryside, with a lot of buildings that looked like the barracks I grew up in. Then we went through the town of Yongbyon, crossed the river, and entered their nuclear complex. That reminded me a lot of going into the Russian facilities, which I had been in many dozens of times. It was all old; it looked old. But through my discussions with them, I found it was all functional. What I learned is that the North Koreans may not be at the forefront of world science, but they are very good engineers, and that's what it takes to build a bomb. So they had a complex that was old and looked run-down — they had vegetables growing in the yards between the technical buildings because they needed to feed their people — but it was functional.

Particularly through my discussions with Director Ri Hong Sop, I came back and concluded: what they showed me was plutonium, and if it was plutonium, in that form, they could make a bomb. That's what I reported when I came back. This was right after the 2003 invasion of Iraq, and our country's focus was elsewhere. I tried to tell them, "Look, you'd better pay attention. They've got the plutonium; they can build a bomb."

CB: Can you tell me more about Director Ri Hong Sop and your relationship with him?

SH: Before I went, I was told that you really can't trust the North Koreans — they're going to pull the wool over your eyes. It's interesting: I was still at Los Alamos in 2004, and I did get approval to go, although it was not an official government visit; I went with my Stanford colleague John Lewis. But even though I got approval, the CIA refused to brief me about North Korea. So I had to learn what I could from anybody who knew anything about North Korea, and I was told, "Look, you can't trust these guys. They're going to pull the wool over your eyes."

By 2004, however, I had been to all of the P5 nuclear weapon states and their nuclear facilities and had dealt with all of those people. I've worked with nuclear technical people all my life. Still, I was on guard when I met Director Ri Hong Sop, and I thought it was just a fantastic visit. He was straightforward. That's one of the things you get when technical people come together: you can't just BS your way through. When you get to technical matters, something is either right or it's not, and so we walked through it. I asked him all of these questions, and he just answered. He gave me information I thought was really valuable — and I wasn't collecting; I was just trying to understand.

CB: How does the International Atomic Energy Agency work, and whose interest

does it ultimately serve?

SH: It was set up in 1957, and it was actually an outcome of President Eisenhower's 1953 Atoms for Peace speech. The idea was for the International Atomic Energy Agency to help countries develop the benefits of peaceful nuclear energy, but also to do the monitoring needed to make sure that countries receiving the benefits of peaceful cooperation don't turn them toward military purposes. So it's truly an international organization, and in my opinion it has been enormously successful: we don't have 20 or 30 or 40 nuclear states. We have fewer than 10.

CB: So when a country seeks to acquire civilian nuclear energy, it would presumably go to another country, like France, the United States, or Russia, for that technology, and the IAEA comes in as an inspector?

SH: It comes in as the inspector. The other countries would also, of course, have an interest. For example, if we help South Korea with nuclear energy, we want to make sure it doesn't use that technology to build a bomb, and we build that into our atomic energy collaboration with the South Koreans. Under our Atomic Energy Act of 1954, there's something called a 1-2-3 agreement — a nuclear agreement that we have with a partner country — that spells out what it may and may not do. Then we put export controls on top of whatever we're willing to send. So the country that partners with another country also has some responsibilities and some privileges. But on top of that, there's the IAEA, which acts as the international inspector.

CB: In this century, we as a country have now fought two wars on the premise of restricting nuclear proliferation. Obviously this was not the case with North Korea, although one could argue we came quite close, especially in 2017. In the cases of Iraq and Iran, to what extent do you think the claims that the nuclear weapons threat was imminent were accurate?

SH: In Iraq, there was no question that Saddam Hussein was trying to acquire the ability to make fissile materials to build a bomb, and so he was building a reactor. It was actually the French who were building the reactor for Iraq, and from what we knew of French technology, that reactor would have been very good for making weapons-grade plutonium. When it was clear the reactor was being built, the Israelis went in and took it out, so they took care of the plutonium path to the bomb. Saddam Hussein didn't fully give up; he still worked around it and tried to redevelop a path to the bomb. But by the time the US went in, in 2003, Saddam Hussein had lost most of his capability to build a bomb. So my view was that he wasn't close. My view at the time was also that it was a real mistake for the US to go in under the

guise that he was going to have a nuclear weapon. He wasn't close, and indeed the aftermath showed that he was not close.

Iran is a totally different story. Iran has been putting in place the pieces it needs to build a nuclear weapon since the days of the Shah, more or less from the mid-to-late 1950s. The Shah actually told his technical people, "Get me as close as you can, but make sure it doesn't show, so that we can deny it." That went all the way up through 1979 and the Islamic Revolution. Then the ayatollahs, as best we know, first said,

"No, these nuclear weapons are immoral. We're not going to go there." Then they got into the war with Iraq in the 1980s, and Saddam Hussein used chemical weapons — he gassed the Iranians. At that point, from the best we can reconstruct, the ayatollahs said, "Maybe we do have to put the pieces in place for a nuclear weapons capability again," and that looks like it started in the mid-to-late 1990s.

My view of it all is that the policy the entire time, whoever was leading the Iranian government, has been to put the pieces in place so they'd be ready if they decided they needed the bomb. That's what happened, and they took pretty big steps in 2003, in 2007, and even somewhat later. Those were steps toward uranium enrichment with centrifuges, and somewhat later they also started building a reactor for plutonium production. They always seemed willing to talk, particularly with the Americans, about restraining that capability, and in essence that's what the Obama deal — the so-called JCPOA, the Joint Comprehensive Plan of Action — was in 2015. It restrained the Iranians and moved them backward, but they never gave up during that entire time.

Trump stepped away from that deal, but he didn't have a plan B for what he would do, so the Iranians got closer and closer again to the point of being ready. That's essentially where they've been. Now, with the bombings in 2025 and 2026, they're somewhat farther from that goal, because a good part of their infrastructure has been destroyed. Have they given up? In my opinion, the answer is no. They haven't given up for the last 70 years or so, and it's not going to happen now. In other words, I think some sort of peace will have to come before they give it up, and it is indeed a dangerous situation. But in my opinion, Iran so far has also decided it's not in its interest to actually take that next step. One of the main reasons is Israel. They were always afraid of what Israel would do once it saw them taking that next step, and that's indeed what has happened.

CB: It seems the progression of nuclear technology slowed down in the 1970s. Around that time, the US-Soviet arms race was slowed through treaties. What do you think happened in the '70s with nuclear technology, both civilian and military, that caused this slowdown?

SH: The drive in the nuclear weapons laboratories, whether here in the United States or in Russia, to keep making nuclear warheads smaller and lighter was always there, and some major improvements were indeed made in the '60s and into the '70s. Certainly, one of the main technological restraints on nuclear weapons was the end of nuclear testing. However, we continued to look at what other interesting concepts were out there in the universe, so to speak, that might have military implications.

At Los Alamos, for example, we looked at pure fusion weapons. A hydrogen bomb is a fusion bomb, but we need an atomic bomb to trigger the fusion reaction. Is there some way to do without the plutonium or uranium for the fission bomb and actually make fusion? Well, the sun knows how to make fusion, and Lawrence Livermore Laboratory has now demonstrated that it can make fusion with lasers, on a very, very small scale. We explored various concepts in the 1980s particularly, and into

the 1990s — ways to make fusion, directed energy weapons, and so on. But in the end, what helped was the political will to restrain the system.

CB: Many countries feel their security is at risk, and we've seen an uptick in nuclear rhetoric. Countries like Poland, South Korea, Saudi Arabia, and obviously Iran are talking about nuclear weapons in a way they haven't previously. It seems the nuclear question is being reopened. In a world where middle powers turn to nuclear weapons, do you think we'd be safer, or would it be a far more dangerous world?

SH: It's a far more dangerous one. As I look back over these 81 years since 1945, what has developed is what I call a global nuclear order: no use of nuclear weapons since Hiroshima and Nagasaki; a limited number of countries — in other words, a limited number of fingers on the nuclear trigger; no nuclear terrorism; and quite a bit of nuclear energy. You simply can't have that unless you cooperate, and if you put more fingers on the nuclear trigger by adding other countries — be it Poland, South Korea, or Saudi Arabia — it just makes the world more dangerous. We've been fortunate. It's been a very difficult process, cooperating while also competing over these 80 years, and I can't imagine what it would be like with 20 or 30 countries. The problems occur particularly at borders — that's where we get the trouble. You have Israel in the Middle East with all of its borders, you have the North Korea-South Korea border, you have the India-Pakistan border. So the fewer fingers on the nuclear trigger, the better off we are, and it would be a grave mistake to add more.

I've talked a lot with South Koreans and the South Korean government to try to persuade them that this isn't a direction they want to go. What I say is: look at yourselves compared to North Korea. North Korea decided it was going to build the bomb. So it has the bomb, and it has nothing else. You decided you weren't going to build the bomb, and what do you have? You have Samsung, you have Hyundai, you have all these incredible companies. You have nuclear power — you build the best nuclear reactors in the world. Why in the world would you want to jeopardize that by building nuclear weapons now? And that message has to go to every country. It's not that we don't want them to have nuclear weapons just for the sake of it; it's that it will make the world more dangerous.

CB: Is the choice always that binary — North Korea versus South Korea, the bomb versus prosperity? Is pursuing the bomb really that costly a decision for a smaller country?

SH: It's not only the financial cost, but everything else that goes with it, including international relations. In South Korea's case, let's suppose we said, "If you build nuclear weapons, we'll cut you off totally." That should convince the South Koreans it's not a place to go. However, what if a US administration said, "Okay, go ahead, we won't hold it against you"? Then that's a different situation.

Is it binary? A lot of times it is, but never fully. India and Pakistan, for example, is very much a binary, but there's also China sitting out there, with all the China-India history, so there's a third element. You have South Korea and North Korea, but there's also Japan — go back to the Japanese occupation of the Korean Peninsula for 40-some years in the early 20th century — so there's a triangulation there too. So it's

not only binary, but the perceived need for nuclear weapons almost always starts from a binary. Another example is Argentina and Brazil, back when both had military juntas either running or influencing their governments; they were looking to build nuclear weapons. Argentina and Brazil are actually a very good example, because they themselves decided, "Hey, this doesn't make any sense," and they walked away from it.

CB: What do you make of China's nuclear rearmament, which seems to be underway?

SH: It's actually not rearmament. For China, it's a change in overall strategy. The Chinese were latecomers to the nuclear weapons business, but they did come on. First they had some help from the Soviets, but the Soviets cut them off, so around 1960 they went on their own. They detonated an indigenously built atomic bomb in 1964, and by 1967 they had detonated a hydrogen bomb. So they demonstrated they could do it, and then slowly, over the years, they developed a nuclear strategy you could call minimal deterrence: the idea that a few hundred nuclear weapons are enough to keep either the United States or Russia out of China. That's how it was for many, many years.

Then, maybe in the last 10 years or so, China made a decision. Of course I don't know the exact reason, but as best I can tell, its threat environment had changed, and its economic capabilities had changed in such a way that it could build more nuclear weapons. They had 300 or so over the years. The Soviet Union built an arsenal of 41,000; the United States had an arsenal of 31,000 at its peak; and the Chinese had 300. It looks like about 10 years ago they decided to expand their nuclear arsenal, and they certainly have the economic capacity to do so. They thought, from a political standpoint, it would put them in a better position to have a deterrent — and I would say not only against the United States but also against Russia, because that's never far from their minds, with the huge, long border they share.

Of course, this has caused real consternation in the United States. Various government officials have called it the largest nuclear buildup in peacetime. Well, it turns out that's baloney. If you look at the rate at which we built nuclear weapons in the '50s and the way the Soviets kept building them, the buildup in China is pretty small. However, we certainly expect these to be quite capable nuclear weapons. Today they may have around 600 or so — that's roughly the best estimate out there — and they may get up to 1,000 or so by 2030 or the early 2030s, while the US and Russia are still capped at about 1,550 actual weapons in the stockpile. So China may be moving in that direction, and it causes great consternation in the United States. From my standpoint, it's too bad, both for us and for the Chinese. They've been so successful in everything else they've done precisely because they weren't putting a lot of money into nuclear weapons or defense capabilities. How that will change, I don't know.

This interview has been edited for length and clarity.

About the Author

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