CHAPTER 2

LOS ALAMOS: A FIRST, BUT NOT THE LAST

Until the middle of the twentieth century, most atomic and nuclear discoveries had come from European minds, including those of immigrants to the New World. The top seventy nuclear discoveries and innovations of those fifty years[1] (1897–1948) originated in:

U.S.A.	26 discoveries	37%
United Kingdom	18	26
Germany & Austria	13	19
Switzerland	3	4
France	3	4
Russia[2]	2	3
Netherlands & Denmark	2	3
Italy	2	3
Japan	1	1
TOTAL	70	100%

Note: China, Korea, and S.E. Asia 0

1. Source: Charles Murray, *Human Accomplishments* (New York: Harper Collins, 2003), 184–87, 203–204.
2. The Soviet Union became a closed society in 1917. Many discoveries thereafter may have gone unreported in the open literature.

Middle Eastern countries	0
South Asia	0
Southern Hemisphere	0

An examination of the Los Alamos technical staff roster from 1943 to 1945 shows the national origin of the twenty-four intellectual all-stars, i.e., the directors, division chiefs, and their deputies, to have been:

U.K. and Canada	6 persons	25%
U.S.	5	21
Germany/Austria	5	21
Hungary	4	17
Other European	4	17

Thus, there never was an American nuclear cartel. Technology does not respect national borders, and in time, nuclear and atomic matters have ceased being even a European monopoly. We should not kid ourselves into thinking otherwise. By the summer of 1942, the European scientific diaspora had temporarily settled into Berkeley, Columbia, and the University of Chicago. Fearing Berlin's capabilities, these refugees and their American hosts were determined to beat Hitler to the nuclear punch.

In the beginning, nuclear cross-sections were at the heart of the puzzle. What was the probability of a given nuclear response to the bombardment of a nucleus by an incoming particle, usually a neutron? The answer came from experimental measurements. The standard unit of nuclear cross-section, 10^{-28} square meters, came to be known as a "barn," from the expression, "bigger than a barn door" (physicist humor, since the dimension was infinitesimally small). Once measured, cross-sections were then used to calculate the progress of a proposed nuclear assembly, chain reaction, or explosion. That data, in turn, was employed to calculate (correctly in the United States) the critical mass of uranium-235.[3] The Germans, in Berlin, miscalculated by a factor of ten, leading them to the conclusion that a portable bomb was not feasible.

In Chicago, Enrico Fermi was assembling a large pile of natural uranium (0.7-

3. The mass needed to sustain a chain reaction.

percent U-235) within a graphite matrix, which was necessary to slow down the cascading neutrons and thus promote their capture by the U-235 nuclei. On December 2, 1942, his "nuclear pile" went critical, producing slightly more neutrons than it consumed during each fission generation. Each neutron's gestation time was found to be about ten nanoseconds (10^{-8} seconds), and thus that interval became the unit of time in nuclear work. It was given the name "one shake," as in "one shake of a lamb's tail."

Fermi had created the world's first chain-reacting nuclear reactor. The secret of his success was the use of ultra-pure graphite. In Berlin physicists were attempting a similar experiment, but they used commercial-grade graphite; their reactor never went critical.

In June 1942, as Fermi labored in Chicago, the German armaments minister convened a conference of scientists, army officers, and munitions experts to review Germany's nuclear options. Albert Speer wanted to hear about recent nuclear fission developments and then the prospects for an A-bomb on a time scale acceptable to Hitler. Physicist Werner Heisenberg, already a Nobel laureate, led the discussion. He was enthusiastic, but the others, hearing estimates of a nonportable weapon and given no evidence of a chain-reacting experiment, wished to pursue other avenues. Speer closed out the subject in discussions with Hitler on June 23. The Fuehrer preferred to focus on more immediate prospects: rockets and jet aircraft.

Even so, physicists in Germany continued to tinker with nuclear visions for another half year. It was only the destruction of the Norsk Hydro heavy water facility[4] in Norway by ten dedicated Norwegian Special Forces paratroopers in February 1943 and the mind-focusing German defeat at Stalingrad during that same month that led Speer to reconfirm, formally, the end of any nuclear weapons work within wartime Germany.

In March 1943, the Allied pace picked up, and the action moved to Los Alamos.[5] The scientists relocated to that isolated New Mexico mesa not only achieved awesome scientific breakthroughs, they did so with a breathtaking speed while the engineers at their sides brilliantly coupled those discoveries into the industrial infrastructure and then into the military machines needed to win the war.

Once gathered, the scientists of Los Alamos immediately recognized the possibilities of plutonium as a nuclear weapon material. That element had been discovered by American Glenn Seaborg in Berkeley in March 1941, but it had not even been named when the Los Alamos talent first considered its possibilities. It was clear that "Material 49,"

4. Germany's source of heavy water (deuterium oxide), needed as an alternative neutron moderator in lieu of impure graphite. In postwar interviews, knowledgeable German scientists confirmed that the elimination of the Norwegian heavy water production facility was the key factor in terminating German A-bomb research.

5. This was the case even though the University of California had no formal contract to manage the Los Alamos laboratory until April 15, 1943.

as it was then known, would be a more efficient weapon fuel. Less of it would be needed for a critical mass; more yield would result from a given mass. On the other hand, there were problems. Plutonium generated too many neutrons spontaneously; it could not easily be brought to supercriticality. The solution: a spherical implosion, driven by high explosives, to both rapidly assemble and compress the new metal.

The requirement to accurately implode a ball of fissionable plutonium led to the engineering, machining, and testing of very intricate high-explosive lenses in the canyons of New Mexico. One such partially assembled system is shown in the photo section of this work. High-explosive lens technology was one of the real "secrets of the A-bomb" later appropriated by Soviet spies and Allied scientists after World War II.

Engineers needed to learn the metallurgy of plutonium; no one had ever cast, machined, or even handled this very dangerous metal before. The scientists needed to figure out its equation of state: its hydrodynamics as highly compressed plutonium metal turned into superheated plasma during implosion and compression. Then came the pursuit of neutron generators, the devices needed to flood the assembling core of a nuclear weapon with thousands of initiating neutrons at just the right instant.

These were the cutting edges of A-bomb technology honed in Los Alamos. Equally astonishing was the speed with which those nuclear concepts were brought to tangible reality. It was only at the end of 1941 that governmental papers were signed reflecting a serious U.S. interest in A-bombs. General Leslie R. Groves was not put in charge of the Manhattan Engineering District (as the A-bomb project was called) until September 1942. Fermi's chain-reacting "nuclear pile" did not go critical until December 1942. Robert Oppenheimer and the first scientific staff members did not arrive in Los Alamos until March 1943. At the earliest, the autumn of 1942 should be considered the starting point for America's serious efforts to achieve a nuclear weapon. Yet within three years of that start, A-bombs were falling on Japan. Could we make such quick progress today? And what does that tell us about the speed with which others can join the nuclear club if they are serious about doing so?

Science was important during World War II, but equally startling were the muscular achievements of American industry in producing the critical materials—enriched uranium and plutonium—needed for America's weapons. It was not until General Groves was put in charge, in the autumn of 1942, that the Army Corps of Engineers began to acquire land near Oak Ridge, Tennessee. Construction of the Oak Ridge gaseous diffusion facility on a hundred-square-mile patch of the Tennessee Valley did not start until the end of that year. It cost $500 million[6] to build, employed twelve thousand workers, and began to produce weapons-grade enriched

6. Six billion 2008 dollars.

uranium within two years. Little Boy detonated over Hiroshima thirty months after groundbreaking at Oak Ridge.

Only after Fermi's chain-reaction experiment succeeded did work start on another, even larger materials facility, this one along the Columbia River in Hanford, Washington. A 780-square-mile site was to be the home of America's plutonium-production reactors and reprocessing facilities. The first reactor at Hanford went critical after midnight on September 27, 1944, but by dawn the power level had fallen to zero; the reactor had quit operating. DuPont's engineers[7] had foreseen the problem: xenon poisoning. That gas, a fission byproduct, had built up in the reactor during its early hours of operation, absorbing the neutrons needed to maintain the chain reaction. Bypass tubes, designed into the reactor's core by foresightful engineers, drew off the disruptive gas, and the reactor resumed operation. Within four months of going critical, plutonium metal was being delivered to Los Alamos. This mysterious disabling of a reactor, its reasons, and cure were among the secrets passed to the Soviets by their agents in the United States.

The first American plutonium-based bomb, Fat Man, was fired as the Trinity event in New Mexico on July 16, 1945, ten months after reactor criticality had been achieved. No followers in the nuclear parade have ever moved that fast, but it can be done.

The technology and industrial effort were impressive, but they still only addressed two legs of the wartime challenge: the third was weaponization. The "gadget"[8] had to be converted into a weapon that could fit into a B-29 bomb bay, could be maintained and armed by military personnel, could be transported safely from assembly point to target, and that would work reliably once it got there. While those requirements may sound mundane, they are not simple. Few weapon systems, from automatic rifle to A-bomb, have made the transition from tested concept to operational weapon in less than two years. The first American H-bomb was tested conceptually in October 1952, and a portable version was tested on a barge in February 1954, but an operational weapon was not dropped from an aircraft and fired until May 1956—three and a half years after the first test.

The warriors of 1945 dealt with the challenges of weapon maintenance and arming by sending no less than the senior military officers from Los Alamos, qualified weapons engineers, to accompany the gadget from New Mexico to the skies over the target. In the case of Little Boy, navy Capt. William Parsons flew aboard the *Enola Gay*. Because of

7. The Army recruited the DuPont Corporation to build and operate the facility at Hanford. The company continued to operate it safely for the duration of the war.

8. To maintain security, even inside the Los Alamos fence, Oppenheimer directed that the word "bomb" never be used. The world's first nuclear weapon was to be referred to as "the gadget."

Little Boy's linear design, Captain Parsons could arm it after takeoff and then assure its well-being until weapon drop. Similarly, navy Cmdr. Frederick Ashworth accompanied Fat Man from Tinian to target, but his mission was a little more dicey. Fat Man, being a spherically-imploded device, could not be armed en route; it was ready to fire as the host aircraft, *Bock's Car,* started its roll down the runway.

Safety was addressed simply enough: by being very careful. The first American (and Soviet) A-bombs were quite delicate and dangerous. As noted above, an aborted *Bock's Car* takeoff could have resulted in disaster. In a crash, the high explosive in Fat Man would have exploded, scattering plutonium across the island. Some nuclear yield might have resulted as well. The entire war in the Pacific rode on those four Wright Double Cyclone 2,200-horsepower propeller engines as that B-29 began its takeoff roll on that August morning, but those engines had been cared for meticulously—everything worked as planned.

Reliability rides on the seemingly trivial, easily overlooked by designers in the laboratory. For example, the environment in a B-29's bomb bay would change drastically en route to Japan. Temperatures would drop from the tropical August heat experienced on takeoff, to forty degrees below zero Fahrenheit during the four-hour ride to Japan. Fat Man's components would shrink; the rattling of the engines might jar loose a connection. Any misalignment between detonators and high explosive would have rendered Fat Man inoperable. Thus, seemingly minor adjustments were essential en route to the target. It was this concern for reliability that weighed heavily against any U.S. decision to stage a demonstration test with advance notice to the Japanese. President Truman's interim committee on bomb use, meeting in Washington on June 1, 1945, noted: "An atomic bomb is an intricate device, still in the developmental stage. Its operation will be far from routine. If, during the final [airborne] adjustments to the bomb, the Japanese defenders should attack, a faulty move might easily result in some kind of failure. Such an end to an advertised demonstration of power would be much worse than if the attempt had not been made at all."

As it was, Allied scientists and engineers, pilots, and crew chiefs pulled it off. As a team they were ready to strike Japan within weeks of the Trinity test, instead of two years.

In this new twenty-first century, intelligence officers and policy planners debate the time required for a given nation to develop a nuclear striking arm. This is not a new pastime. At the time of the first Soviet nuclear test, in August 1949, the U.S. intelligence community was publishing estimates of five years until the U.S.S.R. could go nuclear. Unfortunately, the Soviets had fired their first device the previous week.

There are a few morals to be drawn from the above tales:

1. Technology does not respect national boundaries; the word travels fast; nuclear secrets do not keep. (Nuclear cross-sections are published and available at the MIT bookstore. They accompany the nuclear weapon designs that now proliferate on the worldwide web.)

2. Any well-industrialized society with the intellectual firepower, economic resources, and government determination can join the nuclear club less than three years from "go." (Think Germany, Taiwan, Brazil, etc. It's a long list.)

3. This time span can be shortened if the society of interest has plutonium-producing nuclear reactors or uranium-enrichment machinery already in place as part of its energy economy. (Think Japan, India, or the Koreas.)

4. It may take a little longer if the would-be nuclear power lacks a full industrial base, but national will counts for a great deal. (We speak of Iran here as well as Pakistan and, once again, North Korea.)

CHAPTER 3

THE RAIDS ON JAPAN

How did they do that? How could the wartime United States have entrusted the world's first A-bomb, a delicate and temperamental gadget, developed at staggering cost, to a novice B-29 crew? How could the United States be sure that Japanese fighters would not rise up to attack the unescorted *Enola Gay*? B-29s could operate at thirty thousand feet, but so could the new Japanese Zero interceptors. The answer to both questions is the same: practice. The United States lulled the Japanese defenders into complacency, and they trained their own American crews by making innocuous trial runs over a dozen Japanese cities during the summer of 1945. Repeated three-aircraft missions at first dropped only propaganda leaflets. Then came comparatively harmless attacks with single blockbusters known as "the pumpkin." It was only in August that the lethal U.S. nuclear attacks began.[1]

ATTACK ON TOKYO

The crisis for Japan started on the evening of March 9–10, 1945, the night of the great Tokyo firebomb raid. During previous months, the U.S. Army Air Forces had made sporadic bombing attacks on the Japanese homeland, with minimal results. Industrial production had continued after perhaps a thousand deaths in Tokyo—tragic but manageable for the Japanese government. Then Maj. Gen. Curtis LeMay arrived. He was put in charge of the 73rd Bomber Wing based on Saipan. General LeMay devised a radically different approach to the destruction of Japan; it started with a massive, low-level incendiary attack on the nation's capital.

LeMay struck at midnight. Three hundred B-29s based on Saipan dropped 8,500 bombs that, in turn, dispersed a half-million canisters of incendiary fuel. By dawn, sixteen square miles of eastern Tokyo were completely destroyed, eighty-eight thousand people were dead, and the survivors were burned and disfigured refugees. War from the air would never be the same.

1. See appendix B for a full listing of the 393rd (Nuclear) Bombardment Squadron's missions over Japan.

In June, General LeMay began the step-by-step incineration of the entire Japanese homeland. Five hundred aircraft armadas of B-29s, now based in the Mariana Islands, made weekly attacks on the smaller and more remote cities of southern Japan. By the end of June, eighteen such municipalities had gone up in flames.

Given these dreadful and massive attacks, the Japanese air defense forces "learned" not to waste precious gasoline and pilots on the "harmless" three-aircraft mini-raids taking place elsewhere. The leaflets fluttering down from the sky were laughably bad translations into Japanese, and the pumpkin was just one bomb, although it was the size, shape, and weight of Fat Man. At 10,000 pounds, the pumpkin delivered a whopping 5,500 pounds of explosives to its target, but that was pretty insignificant to the Japanese when compared to LeMay's massive firebomb attacks. Yet, the American pilots were learning their routes on those flights. They were practicing release procedures with a dummy Fat Man. In early July 1945, Japanese Lt. Masataka Hakata entered these three-aircraft formations into his operations register. He noted their odd flights patterns: dropping one bomb, turning, and zooming away. To him and the Japanese air-defense hierarchy, they seemed harmless enough to be ignored.

THE JAPANESE SCIENTISTS UNDERSTOOD

By the beginning of World War II, the Japanese had a modest nuclear program under way. As early as October 1940, as scientists in Britain were organizing their thoughts within the MAUD report, Colonel Suzuki of the Japanese Army and Professor Sagane of Tokyo Imperial University were producing a similar twenty-page paper for the army general staff based on the early fission discoveries in Europe. The Suzuki-Sagane paper concluded that the construction of an atomic bomb was possible and that Japan might have adequate uranium in-country to build one.

In May 1943, the project was given structure (Prof. Yoshio Nishina was put in charge) and a home (the Aviation Technology Research Institute in Tokyo). Professor Nishina was a world-class physicist, fifty years old at the beginning of World War II. During the prewar years, he had developed close relationships with Niels Bohr and Albert Einstein. The initial Japanese A-bomb venture was known as the "N Project" (for Nishina, not nuclear). The scientists involved settled on thermal diffusion as the means for collecting weapons-grade U-235.

Two tons of high-grade uranium ore would be needed for the N Project's research phase alone. Professor Satoyasu Iimori was to find it. His initial hopes lay within Japan's Fukushima Prefecture, but the uranium mines there turned out only small quantities of low-quality ore. Army commanders throughout the empire were given orders to look for better material. Professor Iimori even turned to the Germans for help. During the summer of 1943, as the Americans began to turn the tide in the

Pacific, this global search had produced enough uranium to start work. By the end of November 1943, Prof. Tadashi Takeuchi's isotopic separator was ready for its first test; by January 1944, Japan's N Project had produced a small, rice-sized crystal of uranium hexafluoride . By March, the thermal separator was ready to run, but the American B-29s were also closing in on the Japanese homeland. The first B-29 flew over Tokyo on November 1, 1944. The firebombing of that city four months later burned the entire N Project to the ground. Professor Nishina and his scientists escaped with their lives, but that part of Japan's nuclear weapons project came to an end.

Meanwhile, in another part of Japan, inter-service rivalry was assuring a second look at this problem. Earlier in the war (July 1942 to March 1943), the Imperial Navy's Research Committee on Nuclear Physics Applications had concluded that "It should be possible to make an atomic bomb, but probably difficult even for the U.S. to achieve during the war." At that time, the navy decided to turn its attention to radar, but later in 1943, as the war took turns for the worse, the Japanese Navy's Fleet Command returned to the A-bomb as a possible route to salvation. It sponsored the "F Project" (for fission) at the Imperial University of Kyoto. Professor Bunsaku Arakatsu was put in charge; high-speed centrifuges were his preferred route to U-235 separation. That was the right approach, as Pakistan's A. Q. Khan came to show a quarter-century later, but in 1944, the technical challenges were too great and the supply of uranium hopelessly small. Professor Arakatsu understood that his machines needed to spin at 100,000 rpm if they were to separate U-235 (in gaseous hexafluoride form) from U-238 effectively. The best he could achieve was 40,000 rpm. Professor Kiichi Kimura was put in charge of finding more uranium for the F Project, but he came up empty-handed.

Kyoto would become a safe haven during the war. American Secretary of War Henry Stimson was a man of letters; he considered Kyoto, Japan's onetime imperial capital, to be a cultural treasure. Much to the chagrin of General Groves, Stimson declared Kyoto to be off limits to bombing. But even with this free pass, no centrifuge at the F Project ever got up to speed, and no enriched uranium was ever produced.

Then came Hiroshima. On July 16, 1945, Fat Man was tested in New Mexico; on July 22, at Potsdam, President Truman and the Prime Minister Churchill made the final decision to use the A-bomb on Japan as soon as possible and without prior specific warning. On July 24, they advised Stalin of the Trinity test. His response: "I hope you make good use of it against the Japanese." On July 26, the leaders of the United States, Great Britain, and China issued the Potsdam Declaration, setting forth a demand for Japan's surrender. That document included a clear, but not A-bomb–specific, warning of "the utter devastation of the Japanese homeland" to come if the Allied demands for unconditional surrender were not met. The proclamation closed with the warning that, "The alternative for Japan is prompt and utter destruction." During the weeks that followed, there would be leaflets warning the population of target cities to evacuate, but otherwise the Japanese were taken by surprise.

At 2:27 a.m. on the morning of August 6, Col. Paul Tibbets taxied his B-29, the *Enola Gay*, onto a runway on Tinian Island, 1,500 miles east of the Phillipines. He and his two escort planes, one to photograph and the other with yield-measuring instrumentation, took off at 2:45 a.m. They assembled into formation over Guam and headed for Japan.

At 8:16 a.m., Little Boy detonated over the Aioi Bridge in Hiroshima. Destruction was beyond belief; it took well over twenty-four hours for the Japanese government in Tokyo to come to terms with what had happened. On August 8, the morning papers in Tokyo referred only to a "new type of bomb," but Professor Nishina knew better. On the previous day, Lt. Gen. Seizo Arisue had been put in charge of an investigating team to look into the attack on Hiroshima. His lineup would include Professor Nishina from the N Project in Tokyo and Professor Arakatsu from the F Project in Kyoto. Those scientists and their associates correctly identified the event as nuclear; they got the yield right by noting the distance of power-line insulation burnoff from ground zero; and, by examining bomb debris,[2] they identified the lethal ingredient: U-235. Unfortunately, a little knowledge can be a dangerous thing. The Japanese scientists knew of the huge infrastructure needed to separate U-235 from uranium metal. They had spent years trying to achieve this result, and thus they concluded (correctly) that the United States could only have one such weapon. By implication, Hiroshima was a one-shot demonstration. Too bad if you lived there, but the Japanese Empire should not take the event too seriously. The Americans could not have another U-235 A-bomb.

On August 9, as General Arisue's committee was assembling its report, Nagasaki was hit by Fat Man. Working in real time now, the scientists got the yield right, again based on insulation burnoff, but they found the bomb debris to be quite different from Hiroshima—it contained plutonium. Japanese scientists had read of this material, and they understood large quantities could only come from a nuclear reactor. They concluded (again correctly) the Americans must have a plutonium-producing reactor in operation. If there were one such weapon, there must be more because a reactor can churn out plutonium at a prodigious rate. The likely message, from scientists, through General Arisue, to the cabinet: "Better take this one seriously; better accede to American demands; there are probably more plutonium bombs."

2. The specific fallout measurements were made by Professor Kuroda; his papers now reside at the University of Nevada at Las Vegas.

Or perhaps it was the message taped to the side of an instrumentation canister, dropped on the outskirts of Nagasaki several miles from ground zero, in conjunction with the August 9 attack. Luis Alvarez, Phillip Morrison, and Robert Serber, all Los Alamos scientists, had relocated to Tinian for the bomb drops. They penned a one-page personal message to Prof. Ryokichi Sagane, a friend from their prewar days together in Berkeley. Professor Sagane had returned to Japan in 1940 to co-author the initial Japanese A-bomb study noted earlier. The Alvarez-Morrison-Serber letter urged Professor Sagane to use his influence "as a reputable nuclear physicist, to convince the Japanese general staff of the terrible consequences which will be suffered by your people if you continue in this war. . . . Unless Japan surrenders at once, this rain of atomic bombs will increase manyfold in fury. With best regards . . ."

The canister with message attached was dropped on August 9. It was recovered by Japanese Naval Intelligence, although the note was not turned over to Professor Sagane until after the war.

THE END

On the afternoon of August 10, in the aftermath of Nagasaki, the emperor of Japan broke with history to call a true policy meeting of his cabinet. He would participate, not just preside, but there were no conclusions. The Japanese general staff continued to argue, and discussions dragged on for days. Fortunately, the American cryptographers were reading the minutes of those cabinet meetings, via the Magic intercepts, as soon as they were distributed to sub-cabinet officials. The Americans noted the emperor's unprecedented August 10 intervention. That afternoon, General Marshall, the army chief of staff, modified the U.S. Army's weapon-release authority. General Groves, manager of the A-bomb program, was no longer authorized to "drop bombs as made ready." By written message on August 10, General Groves was instructed "not to release [further A-bombs] over Japan without express authority from the president."

The next American Fat Man would have been available about nine days after the Nagasaki attack. On August 14, as a prelude and a prod, the Americans unleashed a seven-pumpkin raid on various parts of Aichi Prefecture (Nagoya and Koroma) in hopes the Japanese would take note. Such raids had immediately preceded the earlier nuclear attacks. Perhaps the Japanese got the message, for on the afternoon of August 14, the emperor again met with his cabinet. He ignored those military officers wishing to fight to the last Japanese man, woman, and child. The emperor commanded an end to hostilities; soon thereafter, he recorded a radio speech implicitly accepting the Potsdam Declaration.

At noon Tokyo time on August 15, 1945, the Japanese emperor's message was broadcast to his nation; it was picked up by U.S. listening posts in San Francisco.

President Truman immediately acknowledged receipt. With the insight provided by Magic, Truman considered the emperor's speech to be a full acceptance of the Potsdam Declaration. The war was over; surrender documents would be signed aboard the USS *Missouri* in Tokyo harbor three weeks later.

It is fortunate the Japanese leadership acted as it did, for it appears that another city-busting A-bomb would have been dropped within Aichi Prefecture, in the vicinity of Nagoya on Japan's main Honshu Island, on August 17 or 18. The weapon components and bomb casings were already on Tinian, only the plutonium cores were needed to implement that third nuclear attack.

After such a "strategic" assault on a major port city, America's General Marshall intended to then use his increasingly available A-bombs as tactical nuclear weapons in support of the planned November 1 landings on the Japanese homeland. The general had gone to New Mexico after the Trinity test to hear about A-bomb aftereffects. He concluded (incorrectly) that his troops would be able to function safely in the aftermath of nuclear attacks on the Kyushu beachheads. General Marshall would have had another nuclear weapon at his disposal *every week* during the September/October "softening up" time period. Fortunately, that maelstrom never came to pass.

With these events, mankind had crossed the nuclear threshold. The use of a few nuclear weapons, backed up by the threat of more to come, and the Soviet entry into the Pacific War at dawn on August 9 with its invasion of Manchuria, all combined to convince an exhausted government to do what the holders of the nuclear trump card wanted done.

CHAPTER 4

THE U.S.S.R. AND THE UNITED KINGDOM: UNINTENDED PARTNERS

Winters in Moscow are usually dark and cold, the stuff of Tolstoy, Zhivago, and Stalin, but December 1991 was different. During the summer of 1991, political thunderclouds had boiled to enormous heights over central Russia. Boris Yeltsin had been elected[1] to the presidency of a revitalized and sovereign Russian Federation. Mikhail Gorbachev, the teetering president of a sclerotic Soviet Union, had proposed an all-union treaty unacceptable to the communist establishment. The old guard attempted a coup, bungled it, then fluttered to the ground like so many autumn leaves. In the fall of 1991, the citizens of Leningrad voted to reassume their imperial name, and President Yeltsin banned the Communist Party. With the first snows came a true winter solstice. Youngsters were celebrating in the streets; the *nomenklatura* were planning their exit strategies; the grand old men were reflecting on their place in history.

There was no grander old man than Yuliy Borisovich Khariton. Born in the time of the tsars,[2] Khariton had been schooled in Russia, trained in Cambridge, and then returned to Moscow in 1931 at age twenty-seven to organize the Laboratory of Explosives as part of the Institute of Chemical Physics. In early 1939, Khariton and his fellow scientists read with interest the papers by Hahn and Strassman emanating from Berlin, the Meitner and Frisch explanations from Sweden, and then the Joliot-Curie's experiments from Paris. Khariton and his associates replicated the key research and then came to the same conclusions as their peers in Berlin, Paris, New York, and Chicago: a chain-reacting nuclear explosion was within the realm of possibility. In the summer of 1939, at a seminar

1. With over 57 percent of a reasonably bona fide vote.
2. In St. Petersburg, February 17, 1904.

in Leningrad, Khariton and his co-worker, Yakov B. Zeldovich, published three papers that set forth the steps needed to achieve an atomic bomb. Their laboratory director, N. N. Semenov, forwarded those conclusions to the Soviet minister of defense.

In early 1941, pursuing their earlier thoughts, Khariton and Zeldovich calculated the critical mass of U-235. They thought it would be about twenty-two pounds. Unbeknownst to the young Khariton, the KGB's Colonel Barkovsky was extracting a similar analysis of A-bomb prospects from the British War Cabinet files.[3] The British estimate of critical mass was twenty-five pounds of U-235. All indicators pointed to the same conclusion: a bomb, exploiting nuclear energy, was feasible. But then Hitler intervened. The Nazi invasion in June 1941 turned every Russian's attention to the survival of Moscow and Leningrad.

REFLECTIONS

A half-century later, Yuliy Khariton could look back on a wartime of crisis, a postwar race to catch up, an era of breakthroughs, and a denouement of bankruptcy and collapse. As he reflected on the role of Soviet science in the twentieth century, Khariton was proud of the results; he only regretted the secrecy. He wanted recognition for all, including credit to certain Americans for unknowingly giving help, but he also wanted to mark the boundary between espionage and Soviet science, and he wanted to be the one who drew that line. To open this window to the West, Yuliy Khariton sent for Danny Stillman in late 1991.

On December 7 and 8, 1991, Boris Yeltsin and the newly elected presidents of Ukraine and Belarus were meeting at the Bison Forest Lodge outside Brest to abolish the Soviet Union. On that same evening of the 8th, Danny Stillman and an associate from Los Alamos[4] were preparing to board Yuliy Khariton's personal railcar at Moscow's Kazan Station. They were to begin a 240-mile trip through the Russian winter to a place where no westerner had ever been—the one-time monastery town of Sarov, now the heart of the Soviet nuclear weapons complex.

EN ROUTE

Stillman and Krikorian were picked up at the Kazan Station by a security man who was a veteran of the Chernobyl disaster, accompanied by a gorgeous young female interpreter. They were a cheery and helpful pair, but the nighttime trip through the Russian winter—even in a Soviet hero's personal railcar—was grim. There were no dining facilities, although

3. Via his man in London, John Cairncross.

4. Stillman made it a practice never to travel overseas unaccompanied. On this trip to Russia, he was accompanied by Los Alamos chemist Nerses Krikorian.

escorts Demin and Kutyanina had brought the tea, wine, and cognac and the salmon, bread, and cheese needed to make it through the night. A Spartan restroom awaited all at one end of the car. The train superintendent, quite drunk, tried to evict Stillman and Krikorian into the winter snows outside Moscow, as *no* foreigners were allowed into the nuclear city hundreds of miles to the east. Fortunately, bureaucracy and rank prevailed.

At dawn, the train stopped ten miles outside its destination. There were the usual dogs, then the security checkpoint. Every train was emptied and thoroughly searched before proceeding through the fence line into Sarov. In time, Stillman, Krikorian, and their escorts were met by four men in a curtained van, backed up by an armed escort vehicle, for the ride to the institute's guest house. Although the facilities within Sarov were fairly new, built as a home for the cutting edge of Soviet technology, the city still felt like a prison. The guesthouse was equally Stalinesque in design and hospitality, with a watchful floor matron at one end of each hall, the communal shower at the other.

THE ALL-UNION SCIENTIFIC RESEARCH CENTER FOR EXPERIMENTAL PHYSICS

On the morning on December 9, immediately after their guesthouse check-in and still recovering from a cold and sleepless train ride, Stillman and Krikorian were escorted to the House of Science, a beautifully built modern two-story building that served as the institute's hospitality center. It was located down the street from the personal residences of the director and other senior staff. None of those duplex cottages was particularly impressive. By U.S. standards, they were 1940s ranch houses, set incongruously amidst tall trees and the snows of central Russia.

Stillman and Krikorian were greeted with full honors upon their arrival at the House of Science. Academician Yuliy Khariton, a diminutive man of eighty-seven years and not more than ninety pounds, was there to meet them. During their entire stay Khariton would not leave their sides other than for sleep. Khariton could not have stood more than five feet four inches tall. He was a charming and gentle man, an introvert, but also a dedicated communist. He always wore a coat and tie, with no hint of the informality that characterizes the U.S. nuclear weapons complex. Khariton spoke perfect English with a strong British accent, the product of his years at Cambridge. He wanted to use his command of the language to tell his side of the story, the saga of Soviet scientific chrysalis. During the days that followed, whenever Khariton spoke in larger gatherings, the room invariably fell silent out of respect.

The proceedings started with a late breakfast, followed by a tour of the House of Science, then a long session in the second-floor conference room. Without delay and without a flood of vodka, it was there that the nuclear tsar of the Soviet Union began his *tour d'horizon*:

During World War II, Soviet scientists followed Western nuclear developments closely, thanks to excellent espionage efforts within the United States and Britain. In February 1943, as the United States opened its laboratory at Los Alamos, the Soviet Defense Committee initiated parallel work within Moscow at what became known as Laboratory No. 2.[5] On March 10, 1943, Igor Vasilevich Kurchatov, age thirty-six, was put in charge of that organization. He assigned to Yuliy Borisovich Khariton the responsibility for A-bomb design. Within a month, Kurchatov and Khariton were examining a first-class stream of intelligence data originating from agents within Los Alamos and Chalk River, Canada.

Until war's end, the Kurchatov project was mainly academic: engineering a natural uranium reactor suspiciously akin to the Fermi pile (neutrons moderated by very pure graphite, cooled with water). The team at Laboratory No. 2 undertook research on isotope separation, and they conceptualized U-235 and plutonium weapons, but only with the bombing of Hiroshima and Nagasaki did Stalin come to appreciate the political significance of those weapons. In August 1945, Stalin put his security chief, Lavrenti Beria ("a terrible man"[6]), in charge of a special committee[7] with orders to build the bomb as soon as possible.

Beria's assistant, Avrami Pavlovich Zavenyagin ("quite a decent man"), immediately visited the ruins of Berlin, extracting papers of interest from the Kaiser Wilhelm Institute and locating the German stash of uranium oxide (over fifty tons), acquired through Belgium and by then stored within eastern Germany. That find accelerated operation of the first Soviet nuclear reactor[8] by a year. It first went critical on December 25, 1946, and it was during April of that postwar year that Khariton's A-bomb project was moved east, out of Moscow to the more secure village of Sarov. The new institute had a formal name, the All-Union Scientific Research Institute for Experimental Physics, but as with all secret Soviet facilities, it was to be known only by its number: Arzamas-16. That code derived from the institute's post office address in the city of Arzamas, forty-five miles to the northeast. A host of other names were used interchangeably to confuse outsiders: "Design Bureau 11," "Base 112," "Moscow Center 300," "Site 500," and so forth. By 1991, Arzamas-16 and its associated production facility had subsumed the ten square miles of the old city of Sarov into a secure hexagon of over eighty square miles of laboratories, factories, homes, schools, and remote, high-explosive test facilities.

5. Typical of Soviet obfuscation, there never was a "Laboratory No. 1."

6. Khariton's words.

7. Full name: the Special Committee and Technical Commission on the Atomic Bomb.

8. The Fermi replica in Moscow, known as F-1.

Khariton gave full credit to Klaus Fuchs, a German refugee who had fled to Britain and thence to the United States, for supplying invaluable insight into the design of the U.S. Fat Man. This, in itself, was a significant admission, since on March 8, 1950, immediately after Fuch's conviction and sentencing, the Soviet news agency Tass stated that "Fuchs is unknown to the Soviet government, and no agent of the Soviet government had any contact with him."

In 1991, Khariton echoed the observations of other Soviet intelligence agents with whom we met and talked in the 1990s—that Fuchs operated out of ideology. He never received money or any other tangible benefit for his efforts. Fuchs was led to believe that the three Allied powers (United States, United Kingdom, and U.S.S.R.) had agreed in 1941 to share any and all new weapons technologies on a timely basis. In Fuchs' eyes, the American bureaucracy was only slowing the flow of the technology promised to their Soviet ally. Fuchs felt he was bypassing those hurdles in support of a partner in whose ideology he truly believed. Khariton confirmed that Fuchs, "a good communist," had sent, via the Greenglass-Rosenberg courier system, fully dimensioned drawings of Fat Man. Khariton received these documents even before the Trinity test, thus accounting for Stalin's nonchalance when informed of Trinity by President Truman at the Potsdam conference during July 1945.

But then the conversation took a strange turn; Khariton inaccurately denied the existence of any other agents within Los Alamos or elsewhere in the wartime United States. In actual fact, the United States was awash with communist sympathizers and planted Soviet moles. One example, Ted Hall, was exposed by authors Albright and Kunstel[9] in 1997.

Hall's treachery first became apparent upon the release of the Venona transcripts in 1996. These were the messages between the Soviet embassy in Washington and Moscow center during World War II. Having saved copies, American code breakers began to decrypt these communications in the late 1940s, leading to the immediate arrests of the Rosenbergs and Klaus Fuchs, among others. The texts were not released to the public until after the end of the Cold War.

Hall was a world-class expert on implosion at Los Alamos, but there were others. The Venona transcripts and supplementary sources[10] make it clear that another agent lay hidden deep within the Los Alamos fence, under the code name PERSEUS.

From the U.S. production facilities, other Soviet sympathizers provided a parallel flood of technical detail. Those at Hanford warned of xenon poisoning and

9. Joseph Albright and Marcia Kunstel, *Bombshell* (New York: Times Books,1997).

10. KGB operative Anatoly Yatsov, deathbed conversations with Lona Cohen, all fleshed out by several investigative authors. See the discussion of PERSEUS further on in this chapter.

other reactor problems; those at Oak Ridge helped with diffusion barrier design. On October 27, 2007, President Putin of Russia confirmed these arrangements when he awarded, posthumously, the title of Hero of the Russian Federation to Soviet intelligence agent Zhorzh (George) Koval a few months after that agent's death, in Moscow, at age ninety-four. Citations at the award ceremony made clear that Koval and his associates had successfully penetrated the American factories and laboratories turning out the plutonium, enriched uranium, and polonium needed for production of the American A-bomb. They had collected and transferred descriptions of those materials, the technology needed to produce them, and the quantities being turned out. As President Putin put it in 2007, Koval's work, "helped speed up considerably the time it took for the Soviet Union to develop an atomic bomb of its own."

Koval was the perfect spy. Born in the United States in 1913 to Russian immigrant parents, he returned to Russia after the revolution. Schooled at the University of Moscow in chemistry and trained by the Red Army's intelligence arm, the GRU, he was then re-inserted into American life at the beginning of World War II. Being American-born, with no foreign accent, Koval was then drafted into the U.S. Army at age thirty. Armed with phony documents that showed him holding an associate degree in chemistry from a local community college, Koval (Soviet code name, DELMAR) was trained by the army in radiochemistry, then sent off to Oak Ridge, Tennessee, where he hit pay dirt in the collection of nuclear production technology. In time he was reassigned to other, more central Manhattan District facilities, which gave him insight into the entire U.S. nuclear materials production complex.

The postwar defection of Soviet code clerk Igor Gouzenko, in Ottawa, gave Koval cause for concern. The GRU urged him to stay in the United States, thereby running the risk of exposure, but in 1948 Koval was allowed to return home. He joined the faculty at the University of Moscow, taught chemistry, earned his Ph.D., and went on to enjoy a peaceful retirement.

Aside from the scientific facilities, Soviet espionage also penetrated the management of the American A-bomb program. A former AEC security official now confirms the presence of at least two GRU agents within the Manhattan District headquarters. As of this writing, one is still alive, living in Moscow and staying in discreet contact with his former competitors. The other is now deceased, but while alive he took credit for helping *both* wartime allies with their nuclear work.

It may be that Khariton was sincere in his disclaimers. Intelligence often makes its way to the user wearing a mask. Sources are seldom disclosed. One day an interesting memo shows up, or a senior official just seems to have a bright idea. Khariton admitted as much when he said Kurchatov often displayed "impeccable physical intuition." Thus, the Soviet claim that Fuchs "was our only spy" remains an article of Soviet cant, but it is not true.

The Fuchs A-bomb drawings were welcome, but the design was still carefully recalculated within the Arzamas-16 facility. Weapons boss Lavrenti Beria was suspicious of disinformation possibly fed into the Soviet system by U.S. counterintelligence. Beria made it clear to his underlings: a failed first test could only be the result of sabotage. He wanted the names of all responsible hands, in advance. That was the execution list in the event of failure.

MAYAK

By his own admission, Khariton knew of the slave labor used to build Arzamas-16. "There was little joy in watching the columns of prisoners who built the installation," he said, but this indignity did not seem to bother Khariton's conscience. As a good communist, he viewed forced labor by political unreliables as simply the price of overtaking the imperialists.[11] Even so, it was not clear that Khariton understood the broader cost, the full price paid by the Soviet people to produce that ball of plutonium first placed into his A-bomb. Only later, in the mid-1990s, did many leaders of the Soviet nuclear empire even meet each other.[12] It is doubtful they communicated during the 1940s. Whether Khariton knew it or not, that ball of plutonium was terribly costly: millions of rubles, tons of concrete and steel, hundreds of thousands of lives.

In April 1946, as many of the people within Laboratory No. 2 were being moved to Sarov, another decision was made: to open a fissionable materials production facility in the southern Ural Mountains at a place called Mayak. This plant would be code-named Chelyabinsk-40, later Chelyabinsk-65, in connection with the nearest industrial city. Mayak would be home to the "A" plutonium-production reactor, the "B" reprocessing facility (to extract plutonium from the irradiated fuel rods), and the "V" metallurgical laboratory, intended to cast and machine plutonium parts. For two years, forty-five thousand workers and uncounted numbers of prisoners worked to build these facilities. They dug an acre-sized pit, more than a hundred feet deep, just for the reactor. Prisoners died by the thousands during the construction that followed; those who did not were returned to Siberia for "extended terms" so they could not disclose the secrets of Mayak.

The "A" reactor went critical on June 10, 1948. Xenon poisoning was anticipated and was not a problem. Irradiated fuel rods emerged six months later, in time producing the first fractional gram of Soviet plutonium.

11. There is no record of any of those prisoners ever leaving Arzamas-16 alive.

12. At the History of the Soviet Atomic Program conference held in Dubna, north of Moscow, in May 1996.

The prisoners were not the only ones expendable at Mayak. Most young professionals on the scientific staff were exposed to hundreds of times the radiation dosage now acceptable within the nuclear industry. Few have survived. They cleaned up plutonium oxide and corrosive acids without benefit of facemasks or gloves. Time was everything. The Nazi invasion was fresh in everyone's mind; the American imperialists were deemed to represent a similar threat. Every good Russian simply did what he had to do.

FIRST LIGHTNING

By June 1949, Mayak had produced enough plutonium for RDS-1, the first Soviet A-bomb. (The initials stand for *Reaktivnyi Dvigatel Stalina*, "Stalin's Rocket Engine.") That device, internally an exact copy of Fat Man, was fired atop a steel tower west of Semipalatinsk[13] on August 29, 1949, fourteen months after the Mayak reactor first went critical. Once again, immediately before the test (known as First Lightning), Lavrenti Beria explained the stakes to Khariton. The scientific director of Arzamas-16 was to be executed if RDS-1 did not work. In later years, Khariton described Beria as "the personification of evil in modern Russian history," but he also gave Beria credit for being "a first-class administrator who could carry a job through to completion." Fortunately for Khariton, RDS-1 *did* work; it gave twenty-two kilotons, as did Fat Man.

When a nuclear device is detonated within the atmosphere, a plume of radioactive debris begins to spread, high in the atmosphere and downwind. An observer a hundred miles distant is in no danger, but an aircraft flying a thousand miles away, if properly equipped with filters and collection devices, can bring home samples. In the United States those samples go to the Air Force Technical Applications Center (AFTAC), where scientists and contractors pick through the debris to ascertain what was in the bomb and how it worked. Think of sampling your neighbor's chimney smoke; you can tell if he is burning firewood to stay warm, if he is cooking for his family, or if he is making steel. Similar analyses are possible from nuclear bomb debris. In 1949, U.S. Air Force weather aircraft, flying off the Kamchatka Peninsula, performed that collection; other bomb debris was found in navy rainwater collectors. Within a few days, both air force and navy scientists came to the same conclusion: the Soviets had tested a nuclear weapon on August 29. Wishful U.S. defense and intelligence officials did not want to hear that; they were forecasting a five-year hiatus before the Russians could test. The U.S. secretary of defense tried to claim a Soviet reactor had blown up. Thoughtful scientists at Berkeley proved otherwise. They confirmed the debris came from a bomb, utilizing

13. In eastern Kazakhstan.

plutonium, bred in a reactor that had been running for about a year. The debris was remarkably similar to that from the Nagasaki weapon. President Truman decided to rely on his scientific advisors, not the politicians; on September 23, 1949, he announced the Soviet test. The reactions, in East and West, were of earthquake proportions.

THE EXPANDING SOVIET NUCLEAR HORIZON

Once freed of the execution threat, Khariton's staff moved out on a broad intellectual front. Within two years, they completed a new A-bomb design that was half the diameter, two-thirds the weight, far more efficient in its use of fissionable materials, and twice the yield of Fat Man/RDS-1. Known as RDS-2, it was successfully tested on September 24, 1951. In time the Khariton team came to build bombs "ten times lighter" and skinny enough to fit into artillery shells. There followed a dazzling array of nuclear tests; within a decade, the Soviet Union had pulled abreast of U.S. nuclear technology in some important respects.

Even before the first Soviet nuclear test, Stalin turned his attention to the production and deployment of his new weapons. On March 9, 1949, he directed the construction of a nuclear weapons production facility within the Arzamas-16 complex. As a factory, it came to be known as Avangard; sixteen buildings operated quite independently of the physics institute. Avangard could produce twenty nuclear weapons per year. Ten thousand people worked at this new weapons plant and twenty thousand at the physics center, with another fifty thousand people needed to run the town's infrastructure. Those who think the assembly (and disassembly) of a nuclear weapon is simple should bear this scale in mind. Stalin's first nuclear weapons came off this production line in December 1951. Yuliy Khariton conducted the final inspections on each as it was accepted into the Soviet inventory.

THERMONUCLEARS

The first Soviet A-bomb was a great achievement, but even as Khariton and his associates were starting work in Moscow during that winter of 1945/46, the Soviet Special Committee was considering another possibility: thermonuclear weapons. Khariton was given the additional task of looking into the matter. His staff reported back in November 1947. They were unable to find an immediate solution to the problem of igniting a capsule of deuterium and tritium.

At that time, KGB agents were still meeting with Klaus Fuchs, as yet undetected by the West. He was living in England, working at Harwell. Fuchs provided no useful information about American H-bomb designs, but he did furnish critical thermonuclear cross-section data and perhaps much more. Based on those interviews, Khariton, Kurchatov, and their associates proposed a work plan for the development of a Soviet H-bomb. The Special Committee approved that arrangement in June 1948, eighteen months before Truman announced his intent to pursue similar technology in the United States. There is no evidence of any internal Soviet debate regarding the H-bomb decision. The new Soviet weapon-to-be was given the code name RDS-6. Competing groups were established at Arzamas-16 to pursue spherical "layercake" and linear "pipe" approaches[14] to the ignition of thermonuclear fuel.

In February 1950, immediately after the Truman announcement of a U.S. thermonuclear effort,[15] Yuliy Khariton was put in full charge of the Soviet thermonuclear program at Arzamas-16. Igor Kurchatov was his boss. Igor Tamm and Yakov Zeldovich were his deputies. Andrei Sakharov and other future weapons all-stars were, at that time, young assistants. Thus, Khariton would have been the logical recipient of any intelligence relating to the U.S. thermonuclear program.

In March 1951, Edward Teller and Stanislaus Ulam published their internal Los Alamos paper outlining the correct solution to H-bomb design (radiation implosion of a second stage). On June 17, the U.S. AEC approved that approach, authorized the assembly and test of a device employing those principles, and directed the production of the special nuclear materials needed.

On February 26, 1952, apparently unaware of the U.S. plan, the Soviet nuclear weapons ministry settled on the single-stage, spherically imploded RDS-6s concept as their best bet for achieving a successful H-bomb. The resulting design was to package layers of thermonuclear fuel (Li6D) around an improved fission core, and then implode the entire assembly with high explosive. In Sakharov's memoirs, these approaches are known respectively as "the first idea" (the use of Li6D as thermonuclear fuel, attributed to Vitaly Ginsburg) and "the second idea" (imploding a fission core and thermonuclear fuel as an integrated assembly, Sakharov's own invention.) Taken together, the package came to be known as the Layercake. RDS-6s, which was to be tested in June 1952, would require modest amounts of tritium and was expected to yield one megaton within a five-ton package.

The RDS-6s design process did not go well. On December 29, 1951, the Soviet council of ministers agreed to the postponement of the test date to March 1953. Significantly more tritium was allocated to the device in an attempt to offset falling calculated yields.

14. The former was given the name RDS-6s, for "spherical"; the latter RDS-6t, for "tube"
15. On January 31, 1950.

On October 31, 1952, the United States detonated Mike, a two-stage thermonuclear that produced 10.4 megatons of yield. Within a day, the fact of that test was known to Stalin. We believe he also learned of the approximate yield.[16] Beria and Kurchatov were not able to offer Stalin any explanation of how the American device worked. Since they did not know, they started to guess. A month after the Mike event, Beria wrote a memorandum to his associates (Kurchatov, et al.), noting, "Information has reached us that the USA has conducted experiments with articles [like Layercake]. . . . Tell [the staff at Arzamas-16] to put all their effort into ensuring the successful completion of the research and experimental design work connected with RDS-6s." But Mike was *not* a Layercake device; Beria had misdirected his scientific staff. In time this led to Beria's ultimate dilemma.

The Soviet leadership knew there had been a significant U.S. nuclear event in the Pacific; we believe they understood it to have been a multi-megaton detonation. At the same time, Beria's scientific staff was painting an ever-darker picture of the possibilities for RDS-6s—a growingly small fraction of Mike's yield consuming ever-larger quantities of tritium. If Stalin learned of all this, the Soviet nuclear weapons boss Beria would be a dead duck.[17] But then, in March 1953 two things happened: Beria postponed the testing of RDS-6s to the summer of 1953, and Joseph Stalin died under most mysterious circumstances at his dacha ten miles outside Moscow. Beria's fingerprints were all over the case.[18]

On June 15, 1953, physicists at Arzamas-16 signed off on the final design of RDS-6s, but those were Beria's last days of authority.[19] As device assembly and test preparations were underway, Beria's competitors in the post-Stalin struggle for power[20] brought about his arrest, imprisonment, and, on December 23, his execution.

RDS-6s was tested on August 12. The device performed as designed, delivering a yield of four hundred kilotons, but that was only 4 percent of Mike's yield. RDS-6s derived only 15 to 20 percent of its yield from fusion reactions, yet it had used up most of the tritium in the Soviet inventory. There was a great deal of Soviet crowing in public about "the first H-bomb dropped from an aircraft." That was Khariton's

16. Russian historians disagree. They claim the Soviets were unable to measure American test yields until 1954.

17. There were other reasons for Beria to fear for his life. Stalin's paranoia meant purges were always in the air.

18. See Thomas C. Reed, *At the Abyss* (Ballantine Books, 2004), 21–27.

19. Beria was arrested and imprisoned by his peers on June 26 and was then held in an army, not KGB, prison.

20. Malenkov, Bulganin, and Khrushchev were the competitors for power. Army Marshal Zhukov reported to Bulganin and effected Beria's arrest.

boast to his dying day, but in private, the physicists at Arzamas-16 had the feeling that RDS-6s was an expensive dead horse. As Sakharov wrote in his memoirs, "This device had run its course." The autumn of 1953 was a gloomy time at Arzamas-16.

Seven months later, on March 1, 1954, the United States conducted the Bravo event, kicking off the Castle test series in the Pacific. Bravo gave fifteen megatons, substantially larger than Mike and almost forty times the yield of RDS-6s. In his December 1991 conversations with Stillman, Yuliy Khariton admitted the Soviets collected yield data and bomb debris from the Castle tests in 1954, but the results, he said, were of no help. The only fact that emerged was that multi-megaton thermonuclear explosions were possible, and the Americans knew how to do it.

During the ensuing month, March 1954, scientists at Arzamas-16 broke into a frenzy of brainstorming. Frank-Kamenetsky proposed the use of two primaries, to blast the secondary capsule from each side (the "razor" design). Zavenyagin, a bureaucrat, not a physicist, proposed a dozen or more primaries. That approach came to be known as "the candelabra." Neither made much sense. Then, one day in late March or early April 1954, Khariton says his deputy and long-time physics partner, Yakov B. Zeldovich, "Threw open his office door and joyously exclaimed, 'We have to do it differently; we'll release radiation from a spherical device!'" But there is a strange contravention to this statement. In later conversations, Lev Feoktistov (whom we will come to in a moment) said, "I never did hear from Zeldovich a direct confirmation of this account, nor did Sakharov, by the way."

By the end of April 1954, the physicists in Khariton's thermonuclear division at Arzamas-16 were fully focused on the correct solution: imploding a secondary capsule with radiation from a primary, and then lighting the highly compressed thermonuclear fuel. Within eight months, a conceptual design was on the table; in February 1955, the initial design was complete, and the device was given a name: RDS-37. Nine months later, the weapon was air-dropped from a Tu-16 bomber, giving a de-rated[21] yield of 1.6 megatons. Windows were shattered in the nearby city of Semipalatinsk, with two fatalities, one soldier and one young girl.

Was Zeldovich really that smart? Was he the father of the Soviet H-bomb? We think not. To this day, the origins of that Soviet two-stage thermonuclear technology remain unclear. Khariton maintained it was a spark of insight at Arzamas-16, but until a credible Soviet scientist steps forward to claim credit—as their counterparts have done in the United States, United Kingdom, France, and China—we revert to our earlier observation about the "impeccable physical intuition" displayed by

21. By replacing some uranium components with inert material to limit radioactive fallout.

those seated at the far end of the intelligence pipeline. We believe the Soviets did not discover radiation implosion on their own—they had help. The only question remaining: whence cometh that help? It is our belief that the Soviet agent then still at Los Alamos provided the missing piece.

The "secret of the H-bomb" does not involve blueprints and drawings. Whereas A-bomb success depends on the technology of materials manufacture and high-explosive lens design, the key to the H-bomb lies in one sentence, two little words actually ("radiation implosion"), if the listeners are sophisticated scientists who have been reflecting on the problem and who enjoy significant computational support.

PERSEUS

Numerous authors, researchers, and archivists posit the existence of a yet-unidentified Soviet agent within wartime Los Alamos.[22] In 1942, this agent was given the code name PERSEUS by his New York recruiter and controller, Morris Cohen. Other experts on Soviet wartime espionage (for example, Albright and Kunstel) consider PERSEUS to be a myth, generated by the KGB to cover their tracks or to cover the work of three separate agents: MLAD (Ted Hall), STAR (Saville Sax), and PERS (unknown). We are of the view that PERSEUS was a real communist sympathizer/agent; he joined the Los Alamos Scientific Laboratory at its inception and remained there for decades until his retirement. In the mid-1990s, Stillman reported his suspicions as to the identity of PERSEUS to the FBI's special agent in charge of its Santa Fe office. Stillman reviewed the files and the supporting evidence with the Bureau's counterintelligence expert, but within weeks that agent was reassigned to the Wen Ho Lee case, and then became ill and was transferred to another site. Both the PERSEUS and Wen Ho Lee investigations died, botched beyond recognition, until the latter case returned to public scrutiny a few years later.

Since the man we consider to have been PERSEUS is now deceased, and since he can neither defend his family name nor refute our arguments, we identify him only by the initial code name given him by Morris Cohen: "Arthur Fielding." Until the Soviet KGB files are opened, no "smoking gun" is likely to appear. The actual identity of PERSEUS does not matter—his fingerprints are what count.

Mr. Fielding was born in the United States, but his parents soon emigrated, and he spent his younger years out of the country. Fielding returned to the United States to attend university, then left again to continue his academic life elsewhere. During

22. See the Venona transcripts, released in 1996; the Mitrokhin Archives; Michael Dobbs' interview with Anatoli Yatskov, *Washington Post*, October 4, 1992; Pavel Sudoplatov, *Special Tasks* (Boston: Back Bay Books, 1995), among others.

those difficult Depression years, as a contemporary of the Rosenbergs, he fell in with the young academic/intellectual crowd that saw communism as the most promising cure for society's ills. As World War II broke out, Fielding, too old for the draft, returned to the eastern United States to start work at a U.S. Navy facility. He soon joined one of the leading physics institutes in the United States and then, as Robert Oppenheimer was organizing the Los Alamos Laboratory, he was recruited to serve there. It was at that time, in 1942, that Fielding volunteered his services to Soviet recruiter Morris Cohen. Fielding worked and built an excellent reputation at wartime Los Alamos as a leader in the field of experimental physics. Like Klaus Fuchs and Ted Hall, Arthur Fielding initially served the communist cause out of ideology; all three feared an imperial U.S. nuclear monopoly at the end of the war.

Fielding stayed at Los Alamos as others returned to academia. He assumed significant responsibilities while his political loyalties remained murky. It may be the postwar Stalinist excesses and expansionism bothered him, or it may be the 1949–50 arrests of David Greenglass, the Rosenbergs, Klaus Fuchs, et al. gave him cause for concern. In 1950, Fuchs confessed and was sentenced in Britain to fourteen years in prison. At the same time, PERSEUS controllers, Morris and Lona Cohen, vanished from New York. (They turned up in the Soviet Union; their portraits now hang on the walls of the KGB museum in Moscow.) During 1950, Harry Gold, a member of the Rosenberg-Los Alamos spy ring, pleaded guilty and agreed to testify at the Rosenberg trial, and thus avoided execution; he got thirty years. David Greenglass, another courier, also copped a plea, agreed to testify, and got fifteen years. Ethel and Julius Rosenberg, along with Morton Sobell, went on trial in federal court in March 1951. All were found guilty. Sobell got thirty years; the Rosenbergs were sentenced to death.[23]

We believe that with these Cold War developments, with the arrest and conviction of so many of Arthur Fielding's fellow spies, and with the rupture of the courier chain connecting him to Moscow, Fielding suspended his Soviet connections. He turned his attention inward instead, to the new frontier of thermonuclear physics.

In January 1950, President Truman directed the U.S. AEC to proceed with a full thermonuclear program. Fielding was deeply involved in the hunt for ideas within the Los Alamos community. He exchanged memoranda and held discussions with Edward Teller, Stanislaus Ulam, Lab Director Norris Bradbury, and other heavy hitters of the thermonuclear world as those ideas took shape. On June 16 and 17, 1951, at a meeting of the AEC's General Advisory Committee, held at Princeton

23. The Rosenberg case remains contentious, though the Venona transcripts of Soviet wartime messages from the United States to Moscow leave no doubt as to their involvement. Whether they deserved the death penalty is another matter.

University, that committee, the AEC commissioners themselves, and a few outside gurus converged on the decisions needed to proceed:

1. Design, build, and fire an experimental device that would use the Teller-Ulam radiation scheme to implode a canister of liquid deuterium.

2. Start the production of lithium deuteride as quickly as possible.

3. Pursue a specific schedule.

Prior to the October 1952 Mike event, Fielding was appointed to a senior position within Los Alamos. From that roost he would be privy to every detail of the Mike event as well as the details of the subsequent 1954 Castle test series. He remained in place for years thereafter.

The question is, why did Fielding not provide the Soviets with details of Mike? Why did they spend so much time in the thermonuclear wilderness if they had such a good source within Los Alamos? The apparent answer: at that time they did not have such a source. Fielding was not a willing agent. During 1950, as the brutal face of communism became evident, we believe Fielding turned his back on that world. It was a time when another Soviet spy, Whittaker Chambers, came to a similar conclusion. Perhaps Fielding read and was touched by Chambers' best-selling memoirs.[24] Or on another level, the arrests of Fuchs, Rosenberg, et al. may have given Fielding great pause. Seeing his fellow spies disappear into federal prisons and execution chambers must have concentrated his mind. We believe that by 1950, Arthur Fielding had terminated his Soviet connection, until recalled to active duty.

As we have seen, after the Mike event, in December 1952, Beria sent his physicists barking up the wrong tree. On June 26, 1953, Khrushchev, Malenkov, et al. imprisoned and soon killed Beria to protect their own skins, but Beria's successors at the KGB surely remained puzzled, paying ever-greater attention to the secret of Mike. On March 1, 1954, the Americans conducted the Bravo event—fifteen megatons, with fallout everywhere. The radiochemistry from Bravo would have made it clear: that device bore no relationship to Layercake. The Americans had achieved a full multi-megaton event from a portable device . . . but how?

We believe a KGB asset made contact with Fielding during late March 1954. One approach might have been to his ego: "You are a bright guy, Fielding. You now have a bigger job at Los Alamos than Teller, and you were involved in his thermonuclear

24. *Witness* (Random House, 1951).

concepts. Surely you do not want Teller and Ulam to get all the credit in the history books. How did you do it?"

Another approach might be from the Dark Side: "We have a lot of history together, Mr. Fielding. The Cohens are our guests in Moscow. It could be quite embarrassing if they start to talk in public. We would like one small favor before we close the books on PERSEUS. Los Alamos did great things out in the Pacific last week. How did you do it?"

And/or the Soviets may have waved the tangible inducements that turned other U.S. citizens later in the Cold War. Fielding appears to have died a wealthy man; money may have been the clinching inducement to return (briefly) to the world of espionage.

For whatever reasons, Fielding's reply to his KGB contact could have been one simple sentence: "Edward Teller, Stan Ulam, and I thought up the idea of using radiation pressure to compress, and then light, thermonuclear fuel within an opaque capsule." That's all it would take. A short, top-secret, and highest priority message would make its way back to Moscow and thence to the desk of Yuliy Khariton. We believe that is how Edward Teller, inadvertently, came to be the father of *both* the U.S. and the Soviet H-bombs.

THE SILENT SOVIET SCIENTISTS

In thinking this matter through, we have come to rely on the statements—and non-statements—of three intellectual and moral titans of the Soviet nuclear world. The first is Andrei Sakharov, one of the most brilliant men of modern Soviet science. He frequently claimed credit for RDS-6s, the Layercake, but he has never claimed credit for originating the idea of two-stage, radiation-imploded, thermonuclear technology. (He was supportive once the idea was proposed, and that carried great weight.) Sakharov became a Soviet dissident, sent into internal exile for years, but in the 1980s, he was released. He served in the first freely elected Russian parliament until his death in December 1989. Neither of your authors had the good fortune to meet Sakharov, but the man left behind a trail of memoirs and a talented biographer, Gennady Gorelik, who has been most helpful in clarifying the nuclear aspects of Cold War history.

Our second source is German Goncharov, one of the bright young physicists and device designers at Arzamas-16 in the 1950s. He is still there, leading the theoretical physics department, but he is also the principal investigator of, and reporter on, Soviet nuclear history. *Physics Today*, the lead publication of the American Physical Society, turned to Goncharov to provide the Russian account of the historic Dubna Soviet nuclear history conference in its November 1996 issue.

Our third source is Lev Feoktistov, the designer of the first Soviet series-manufactured thermonuclear weapon, the man who was drafted from Arzamas-16 to open a second Soviet weapons lab at Snezhinsk (Chelyabinsk-70), and who was later admitted to the Soviet Academy of Sciences. Every Russian we asked said that Feoktistov was the defining tower of integrity in the Soviet nuclear world. Before his death in February 2002, Feoktistov wrote a small book, *Nukes Are Not Forever*,[25] that reflected on his life's work.

During March 1997, in the aftermath of the Dubna Conference, these three, among others, were invited to visit the Lawrence Livermore National Laboratory. On March 15, at the conclusion of a long and most productive week, those gentlemen, plus Livermore Lab Director John Nuckolls, spent an evening at co-author Reed's home. The resulting insights into Soviet nuclear history were illuminating.

What did these gentlemen have to say about the origins of the Soviet two-stage H-bomb? Sakharov, in his memoirs and biography, says, "Several associates of our theoretical divisions apparently came to the [radiation implosion] idea simultaneously." He then goes on to use the words "apparently," "it seemed to me," "possibly," and "it may be that," but Sakharov never identifies the originator of the idea. Biographer Gorelik confirmed that Sakharov never took credit for what came to be known as "the third idea" himself.

Goncharov corroborated this. "Sakharov clearly ascribes priority to himself [for Layercake] and Ginsburg [for the use of Li6D], but he disclaimed any credit for [radiation implosion]." In our dinnertime conversations, Goncharov went on to speculate that, after the Bravo results became known, "Khariton retired to his office and emerged a wiser man." Goncharov believes that wisdom came from a re-examination of Klaus Fuchs's 1948 intelligence paper, for, as recently disclosed by Goncharov, that paper does contain the first seeds of the radiation implosion idea: Fuchs refers to the possibility of a ten-fold compression of thermonuclear fuel due to radiation. Gorelik concurs in the view that the Fuchs 1948 paper contained the seeds of "the third idea," but we do not believe that was the only source of Soviet wisdom.

Feoktistov was more categorically skeptical. "We had neither drawings nor accurate data from the outside, but . . . we were prepared to catch hints and half-hints. I can't shake the feeling that in those times, we were not completely independent."

We believe Soviet agents reconnected with PERSEUS, received a few key words, and passed them on to Moscow, thence Arzamas-16, and thence to Yuliy Khariton. That very intelligent leader of the Soviet thermonuclear program reflected on them, a light went on in his talented mind, and at the next brainstorming session, he suggested "the release of radiation from a spherical source to implode a secondary," while attributing this insight to a deputy—who would never accept the credit. We have to

25. Published as part of the "Abolition 2000" campaign in Russia in 1999.

further conclude that Khariton's 1991 invitation to Stillman and Krikorian was part of a campaign to mask the very extensive and continuing role of technical intelligence in the Soviet nuclear weapons program. The Soviet nuclear veteran wished to build a bogus wall a half-century in the past. "Fuchs was our only spy" was the Khariton mantra, but to quote from Hamlet's queen, as a murder inquiry was hitting close to home, "Methinks [he] doth protest too much."

PARTING COMPANY

After their meetings in the House of Science drew to a close, Khariton escorted Stillman and Krikorian around his facility. What had once been an isolated Russian farm town, the site of an abandoned monastery, was now a bustling city of eighty thousand people, totally enclosed and utterly inaccessible to the outside world. As Stillman toured the town, his original impression did not change. It was a vast prison with marginal amenities for the privileged few. While they toured, Khariton reiterated his enormous pride in the scientific talent at Arzamas-16. He spelled out the achievements of each individual, and on bidding his guests farewell, he repeated his opening lines: "Never before has this history been told to any foreigner; the time was right to let the world know about the origins of the Soviet nuclear program." Then the mantra: "Except for some opening help from Klaus Fuchs, we did it all ourselves."

Khariton also understood that "the atomic age has come to define history," and, although he did not spell out the specifics, his handiwork set the stage for the war in Korea. This was a tale left for other Russian insiders[26] to tell five years later, but in summary, on August 29, 1949, the Soviet Union tested RDS-1 and thus became a nuclear power. A month later, Mao Zedong completed the communist takeover of China. In December of that year Mao came to Moscow, met with Stalin, discussed Korea, and sought agreement for Stalin to meet with Kim Il Sung, the leader of North Korea. Within a few weeks, the date was set; in late March, 1950, Kim Il Sung came to Moscow. During April the two men met and, after discussions with his generals, Stalin approved Kim's plan to invade South Korea. Stalin declined to commit troops to that venture, but he would allow the Soviet general staff to plan the attack. Stalin expressed confidence in his newly acquired bomb; it would give him immunity from U.S. retaliation. Two months later, on June 19, 1950, North Korea invaded South Korea. That war did not go as either Stalin or Kim planned. Stalin died before it ended; so did thirty-six thousand Americans, a

26. Vladislav Zubok and Constantine Pleshakov, *Inside the Kremlin's Cold War* (Cambridge: Harvard University Press, 1996).

million Koreans,[27] and another million Chinese,[28] all drawn into the Korean sinkhole as the Stalin-Kim plans went awry. When it was all over, the boundary between North and South remained essentially unchanged.

In his farewells, Khariton also neglected to mention Khrushchev's decision, in April 1957, to pass on Khariton's sophisticated nuclear technology to the People's Republic of China (P.R.C.) an aid package that was to include an actual atomic bomb.

MEANWHILE, IN THE UNITED KINGDOM

Within months of the 1938 and 1939 discoveries of nuclear fission and chain reactions, scientists were gathering throughout Europe and the United States to think through the next step: the possibility of a nuclear weapon. In Britain, reflections started in the spring of 1940 as Europe dozed through the so-called Phony War. Then came the May 10 Nazi invasion of France. With the arrival of a Churchill government on that same day, scientific investigations of nuclear weapons took on serious purpose. The MAUD report,[29] "On the Use of Uranium for a Bomb," was delivered to the war cabinet in June 1941. Colonel Barkovsky of the Soviet KGB picked up his copy three months later.

With the Nazi invasion of western Europe, the fall of France, and the Battle of Britain, all in the summer of 1940, the core of the British nuclear program relocated to Chalk River, Canada. Other parts moved to New York as elements of a "trade mission." Then, once the United States was militarily engaged, many of those scientists moved to Los Alamos, heart of the Allied nuclear weapons design effort.

British and Canadian scientists dominated the roster at Los Alamos, and their observers flew with the Nagasaki mission, so when the war ended, the British were privy to all the key nuclear weapon design concepts. On the other hand, they had not been involved in materials production. They had been promised otherwise, specifically at the Hyde Park conference in 1942 and in the Quebec Agreements between Churchill and Roosevelt in August 1943. Given Britain's initial leadership in the field of nuclear science as well as its unilateral transfer of that technology to the United States in 1940–1941, the government of Great Britain felt entitled to the secrets of uranium enrichment, plutonium production, and weapons assembly, but that was not to be. Franklin Roosevelt had entered into the Hyde Park and Quebec Agreements with Churchill during the war, but by the time of the Hiroshima bombing, both men had been removed from the world stage.

27. 415,000 South Korean and 520,000 North Korean military and civilian dead.

28. David Halberstam, *The Coldest Winter* (Hyperion, 2007).

29. Prepared by Sir George P. Thomson, Chair. Members: Marcus Oliphant, Patrick Blackett, James Chadwick, Philip Moon, and John Cockroft.

In the summer of 1945, upon the surrender of Germany and seeking a mandate to rebuild the postwar world, Winston Churchill called for new elections in Great Britain. None had been held for ten years; a British coalition government had joined hands to fight the war. The election of 1945 was conducted on July 5; the votes were not tallied for three weeks, but when the results came in, Winston Churchill had been swept from office. On July 26, 1945, Churchill's wartime coalition partner and deputy prime minister, Clement Attlee, took the reins of power. He brought with him a belief in the embryonic United Nations (formed in June of that year) and a fear of nuclear weapons as instruments of sovereign power. On October 24, the war's victors ratified the UN charter, and on November 9, Attlee came to Washington to meet with President Harry Truman and Prime Minister Mackenzie King of Canada to discuss international controls on atomic energy. A week later, the conferees published an agreed declaration calling for the UN to take control of atomic energy matters, to assure only peaceful uses, and to eliminate nuclear weapons from national armaments. Those ideas did not sit well with U.S. opinion leaders and were anathema to the U.S. Congress. Within months, legislation was drafted precluding the sharing of U.S. nuclear secrets with any other nation.

During those same postwar months, during February 1946, a code clerk defected from the Soviet Embassy in Ottawa. Igor Gouzenko exposed the Soviet network, extending from Chalk River to Los Alamos. Soon thereafter, Alan Nunn May, a British scientist working at Chalk River, confirmed his Soviet connections.

The U.S. House and Senate took action during July 1946, passing a bill known as the McMahon Act. President Truman signed it into law on August 1. With the passage of that act, the FBI took charge of security at all U.S. nuclear facilities.[30] The scope of the espionage problem soon became clear: the biggest leaks out of Chalk River and Los Alamos and into the Soviet system had been via British citizens and British-sponsored émigrés. With these disclosures the U.S.–U.K. nuclear relationship was hopelessly poisoned; with the passage of the McMahon Act, the door slammed shut.

A FEAR OF AMERICAN WITHDRAWAL

Other postwar political currents within the United States were giving British leaders even more cause for concern. Were the Americans returning to a policy of isolation? Were they once again withdrawing to the safety of the New World, leaving Britain to face the communist menace alone?

The U.S. Government had ended the Allied Lend-Lease program immediately upon the cessation of hostilities with Japan; it did not even await the formality

30. During World War II, that security had rested in the hands of the U.S. Army.

of surrender documents. A few younger American troops remained in Germany and moved into Japan to serve as armies of occupation, but for the most part, the Americans in Europe were being recalled and demobilized with frightening speed. At the same time, the Soviet armies were ignoring many an agreement reached at Yalta and Potsdam—they were extending their reach into eastern Europe.

In the winter of 1945–1946, Winston Churchill, by then out of office, came to the United States hoping to deliver a wakeup call. He met with President Truman on February 10, and on March 5, he delivered his now-immortal Iron Curtain speech in Fulton, Missouri. He warned of the Soviet threat to come. Some Americans listened, but many more were reflecting the same postwar fatigue that had removed Churchill from power in Britain eight months before. In the autumn of 1946, U.S. voters delivered a massive vote of no confidence in the Truman administration. Republicans gained twelve seats in the U.S. Senate, achieving a majority for the first time since the days of Herbert Hoover. They picked up fifty-five seats in the House of Representatives, again giving the Republicans control for the first time in a decade. Of greater significance to those watching from overseas, many of those elected to the U.S. House and Senate were staunch isolationists. Withdrawal from the quarrels of Europe was in the American air.

Once again standing alone, the British government decided, in 1946, to hedge its bets: to look into nuclear power and to start work on a nuclear reactor with plutonium-production capabilities. In January 1946, Attlee had asked John Cockroft, the professor who had been running the Chalk River facility, to take charge of a nuclear research establishment at Harwell. Attlee assigned the broader job of overseeing all U.K. development of atomic energy to Lord Portal, former chief of the British air staff.

Lord Portal wrote a paper for the prime minister on the matter of weapons; it laid out the options and was reviewed by an inner government circle to make the critical decision. That nuclear-weapon decision group, meeting in January 1947, was known as the Gen 163 Committee. It had but three members: Prime Minister Attlee; Hugh Dalton, chancellor of the Exchequer; and Sir Stafford Cripps, president of the Board of Trade. The makeup of the Gen 163 Committee makes it clear that nuclear policy hung not on science but on the economic conditions within Great Britain, struggling as it was to recover from the disaster of World War II.

The Gen 163 Committee met in early January 1947 to consider the Portal paper. It reached several conclusions: First, to proceed full-bore with the development of nuclear weapons. Second, it called for a bomb test within five years. Third, the committee decided, in a true stroke of genius, to put Sir William Penney in charge. There are indications that the Defence Committee of the British cabinet concurred in these decisions, but the matter was never brought to the attention of the full cabinet.

William Penney had been one of the British scientists working at Los Alamos. He and RAF Group Capt. Leonard Cheshire rode aboard *The Great Artiste*, the photo aircraft accompanying *Bock's Car* on its weapon drop over Nagasaki. Penney and his associates at Los Alamos had excellent insights into the design of Fat Man; upon their return to the United Kingdom in 1946, they prepared extensive memoranda on their recollections and understandings. In the words of a subsequent historian,[31] "[Penney's] modest, unassuming personal manner, with its mixture of heartiness and privacy, enabled him to command respect across a broad range, from the most temperamental cabinet ministers and civil servants to the casual and easygoing servicemen who carved out sites in the Australian desert." But as an indicator of the secrecy of the British decision to proceed into the nuclear arena, even Penney himself did not learn of his assignment until five months later.

The Attlee government decided on a stealth announcement of this program via a planted question in the House of Commons. On May 12, 1948, sixteen months after the decision had been made, the Honorable A. V. Alexander, minister of defence, responded to a question from a fellow Labour Member of Parliament: "Can the minister give any further information on the development of atomic weapons?"

Minister Alexander: "No, I do not think it would be in the public interest to do that." That is all that was said in public for years, although another assurance, that "all types of modern weapons, including atomic weapons, are being developed," was given privately to other MPs.

Relations with the United States warmed in the spring of 1949, as the United States sought overseas sources of uranium, controlled as they were by U.K. interests. Then, in the fall, relations cooled, as the decoded Venona transcripts began to finger Klaus Fuchs, among others, as Soviet spies. In January 1950, Fuchs confessed to his role as a leading Soviet agent inside Los Alamos. With that the U.S.–U.K nuclear door slammed shut a second time.

A FULL BRITISH PROGRAM

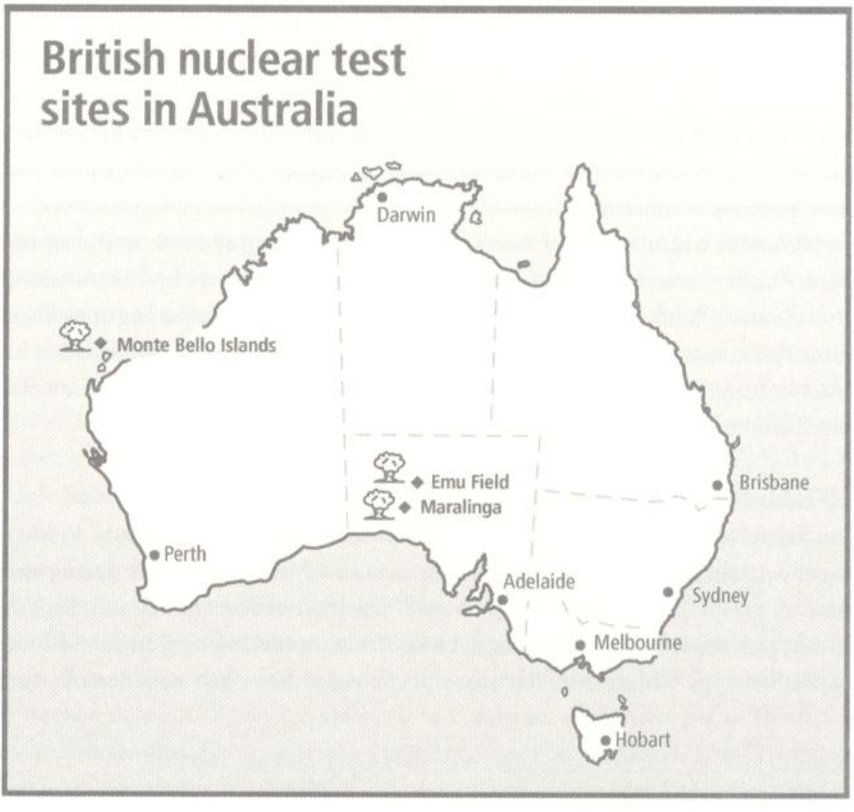
The first U.K. nuclear reactor, built at Windscale,[32] went critical in July 1950. It began to produce useful quantities of plutonium in early 1952, but during that interval, the question arose: "Where to test?" The preferred location was at the U.S. nuclear test site in Nevada. The needed infrastructure was in place, and the British would be happy to pay their fair share of the costs, but those negotiations were

31. Robert Milliken, *No Conceivable Injury* (Victoria: Penguin Australia, 1986), 25.

32. Located on the Irish Sea in northwest England and renamed Sellafield in 1957 after an unfortunate, though nonlethal, fire.

among the casualties of the Klaus Fuchs arrest and confession. The British then turned their attention to the remote provinces of Canada, a nation that had been part of the Allied wartime nuclear triumvirate, but in time the outback of Australia seemed like a better location. The prime minister there was fully supportive. When the Churchill government was returned to power, on October 26, 1951, the British nuclear weapons program was reinforced. Soon thereafter, the decision was made to test off the Monte Bello Islands, fifty miles to the northwest of Western Australia. On February 17, 1952, Churchill announced there would be such a test, "before the end of the year.

The first British nuclear test took place on October 3, 1952, five years and nine months after the decision to proceed and twenty-seven months after the reactor at Windscale first went critical. The device was known as Hurricane, a plutonium-implosion weapon modeled after Fat Man, but with improvements that resulted in a twenty-five–kiloton yield from a device that weighed about three tons (60 percent



Source: *Graphite Studio*

that of Fat Man). Hurricane was fired in the hold of a retired British frigate, the HMS *Plym*, anchored offshore. Canadian observers were invited to participate.

Over the next four years, there was a series of eight more A-bomb tests. The first two were conducted during October 1953, within the Australian outback at the Emu Field station. Those tests, conducted as Operation Totem, involved instrumentation improved over the rather hurried first shot at the Monte Bello Islands, thus leading to a better understanding of nuclear weapons physics.

THE THERMONUCLEAR CLOUD AGAIN APPEARS

The early 1950s became years of deep concern within Europe. In the shadow of the Communist conquest of China, the Russian nuclear test, and the seemingly endless war in Korea, the NATO ministers met in Lisbon in February 1952 to discuss the rearmament of Western Europe. They agreed to raise a ninety-division force and thus to return the West to a World War II footing. This was done in the face of an immense Red Army assembling within Eastern Europe. The British were already in the line of fire. Since June 1948, at the time of the Berlin blockade, three American bomb groups of nuclear-capable B-29s had been stationed in East Anglia. They were under the command of the irascible General LeMay. In the event of war, the British Isles would be a prime target, yet the British had no access to U.S. plans, no voice in the decision to use any nukes that might be brought to British soil. In time, successive prime ministers of the United Kingdom and presidents of the United States reached "informal agreements" on consultation and use, but the British Chiefs of Staff continued to worry. During the early 1950s, the United States could have pre-emptively attacked the Soviet Union without much fear of retaliatory strikes hitting the United States. The Soviets had only a handful of nuclear weapons and no intercontinental delivery systems, but the Soviets could have wreaked nuclear havoc on American bases in the United Kingdom

In the midst of this concern, at the end of 1952, the thermonuclear window began to open. That October, the United States fired the ten-megaton Mike device; on August 12, 1953, the Soviets detonated RDS-6s at four hundred kilotons. Sharing of bomb-debris data from "distant nuclear explosions" was allowed under the McMahon Act, so the United States, United Kingdom, and Canada exchanged such data. It implied an unsophisticated, one-stage Soviet design, but even so, William Penney found the results to be "sensational and revolutionary." During the summer and fall of 1953, Churchill opened thermonuclear discussions with his scientific advisor; the conversations continued within the government while British scientists focused on the immediate A-bomb experiments then underway in the Australian outback.

The political calm was shattered in February 1954, when the chairman of the U.S. Joint Committee on Atomic Energy[33] announced the impending test of "a thermonuclear device even more powerful than Mike." Those tests, the Castle series in the Pacific, broke open the door to practical, two-stage thermonuclear weapons. The United States had invited British observers to attend those tests at the Bikini Atoll. British aircraft sampled the resulting radioactive clouds, losing at least one aircraft in the process. Soon thereafter, serious policy discussions started back in the United Kingdom. On April 13, Churchill began to participate. In May, the British military reiterated their uncomfortable conclusions: U.S. nuclear forces could act unilaterally and without fear of retaliation for several years; in such an event the United Kingdom would be a prime target. With an adequate British nuclear capability, however, the Soviets might be deterred from such an attack on bases in the United Kingdom. The British military also reminded their political masters that holding such nuclear cards would strengthen British power and influence on world affairs. On June 16, 1954, the Defence Committee of the British cabinet decided to pursue the thermonuclear option. On June 29, Churchill confided that decision to his Canadian counterpart while seeking Canadian help with raw materials. On July 27, the British cabinet formally authorized the commencement of work on a British H-bomb.

DEVELOPMENT

The most immediate experiment, of great interest to both U.S. and British scientists, was the detonation of the Soviet RDS-37, a true two-stage, 1.6-megaton thermonuclear, in the Semipalatinsk area on November 22, 1955. By then, the Allies were quite accomplished at sampling other people's bomb debris. Analysis of the American tests in 1954 and the Soviet tests in 1955 provided a roadmap that a British historian[34] later described as "very influential" in the clarification of concepts. Thus it was that the wartime partners once again came to share nuclear secrets.

The United Kingdom resumed testing at the Monte Bello Islands on May 16, 1956; the test series was known as Mosaic. On June 19, the Brits fired a single-stage thermonuclear. It produced ninety-eight kilotons, twice the expected yield, and thus dictated the move of future tests into a more remote Australian outback facility known as Maralinga, or "Field of Thunder" to the local aborigines. The next year, the British moved their test operations to even more remote island sites in the Pacific,[35] testing their first two-stage, radiation-imploded device on May 15, 1957. Short Granite, as

33. A committee composed of House *and* Senate members, known as the JCAE.
34. Lorna Arnold, *Britain and the H-bomb* (New York: Palgrave Press, 2001), 94.
35. Christmas and Malden Islands, near the equator.

the device was known, operated successfully, but the results, at two hundred to three hundred kilotons, were not up to expectations. The British returned to Maralinga that autumn for some follow-up experiments, and then, on November 8, they got it right. A device known as Grapple X, fired at Christmas Island, gave 1.8 megatons. It had operated as planned. Five more tests in the megaton range were conducted in the area of Christmas Island during the year that followed, the objectives being to improve affordability, cut weight, and demonstrate to the Americans that Great Britain was a true thermonuclear power. The latter was essential in reopening the door to nuclear cooperation between the wartime allies. That goal was achieved with the passage of amendments to the McMahon Act, signed into U.S. law on June 30, 1958, which allowed the full exchange of U.S. data and nonnuclear materials with other friendly nuclear powers. Implementing agreements were executed in August.

On November 1, 1958, a tripartite[36] nuclear testing moratorium went into effect, developed in response to worldwide concern about nuclear fallout. It was not a treaty, simply a "gentlemen's agreement" to which the United States and United Kingdom adhered, closing down test facilities and some weapons work. The Soviets used the moratorium to gain a technological lap on the West; they unilaterally broke the argeement, with one day's notice, on September 1, 1961, in a dazzling display of new technology developed during the moratorium. (See chapter 5 for details.)

THE UNRECOGNIZED GENIUS

Unrecognized by many, digital computing was and remains the *sine qua non* of the thermonuclear age. Calculating the conditions necessary for thermonuclear burn is quite complex. Scientists' hands cannot do those calculations, nor can they be checked by small-scale experiment. Only *gedanken,* or thought-experiments, are possible, and those require extensive computational support. The first American H-bomb would not have been possible without the new Univac digital computers then under development in Philadelphia and accessible to the physicists at Princeton. (In Russia, the Arzamas-16 scientists were supported by acres of women punching desk calculators in Moscow.)

The British H-bomb was made possible by the 1952 arrival of the IBM 704, the world's first commercial digital computer. That machine is now an antique: powered by vacuum tubes, utilizing a magnetic core memory, and utilizing then-dazzling software—floating-point arithmetic. In the mid-1950s, however, as the British grappled with the thermonuclear problem, the 704 sped their deliberations by a factor of twenty and enabled the rapid post-test diagnostics of Short Granite

36. U.S., U.K., and U.S.S.R.

that led to Grapple X. In time, the 704 gave way to the transistor-driven 7040 that your authors used in the design of the American thermonuclear deterrent of the early 1960s. It is this struggle for computational power that lies behind the export-control battles with would-be proliferant states. Any intelligent college student, with enough enriched uranium, high explosives, and truck capacity, can build and deliver an inefficient but deadly A-bomb, but those without large-scale computers will not be admitted to the H-bomb fraternity.

Some Conclusions

Many have reported on the history of the Soviet nuclear weapons program after Dan Stillman's ground-breaking visit with Yuliy Khariton, and the British have been most forthcoming with their published histories. Through all of these revelations, a few lessons stand out:

- Technology moves fast: Only a year or two is required to go from a chain-reacting nuclear reactor to an exploding bomb.

- Technology is fungible: U.S., Soviet, and British nuclear technology all flowed from the same wellspring: prewar Europe. Junior states "borrowed" from their seniors, but in time all three thermonuclear superpowers came to learn from each other as they recruited each other's scientists and examined each other's nuclear-testing debris.

- The early American and British nuclear programs were carefully conducted. Health records confirm few casualties, although the environmental costs are still being weighed.[37]

- There were no production nuclear reactor accidents in the United States and only a minor (nonnuclear) fire at Windscale in the United Kingdom. The Soviet nuclear program cost thousands of lives, exploited prisoners, and left a generation marked for long-term illness.

37. The findings of Dr. Andrew C. McEwan, National Radiation Laboratory, Christchurch, New Zealand, in response to a request from the British Government for an independent survey of the effects of the U.K. nuclear tests on those individuals resident in the Pacific during the tests stated, "There is no evidence that the participants received any significant radiation exposures, and certainly no exposures that would give rise to any observable health effects." NRL Report 1981/9.

- It is the production of plutonium and enriched uranium that separates the nuclear men from the conventionally armed boys. The facilities needed to produce these materials are technically challenging, physically immense, and financially crushing, but it is only the lack of fissionable materials that maintains the exclusivity of the nuclear club today.

- Nuclear weapons are developed and deployed for political, not military, reasons. They are political enablers as much as they are weapons of war. The decisions to develop such weapons, both in the mid-twentieth century and in the decades that followed, have been made by senior politicians, acting virtually alone, with little or no input from—and often over the objections of—their military advisors.