5

The City Plutonium Built

After the Army Corps of Engineers bulldozed the original ranch town of Richland, Corps officers and DuPont executives went to work repopulating Richland anew. Richland was to house plant operators, Matthias noted, "who must be kept under control for security reasons."[1] After witnessing the boozing, brawling single migrant workers in Hanford Camp, DuPont executives determined that the new operators' village would be dedicated to workers safely rooted in nuclear families in the new atomic city. DuPont and Corps employees bickered about what this new city would look like. The compromises they grudgingly made amounted to the creation of a whole new kind of community, one that banished single migrant laborers and minorities to the outskirts, displacing working classes to the cultural margins. They established a new regime that equated security with white middle-class families in a new upscale, exclusive bedroom community bankrolled by generous federal subsidies. After the new Richland took shape, it was widely promoted as a "model" community. In subsequent years, thanks to a similar alliance of federal subsidies and corporate control, many other exclusive, all-white, upzoned planned communities cropped up across the United States. The model was so successful, in fact, that Richland now appears unexceptional. Suburbs like the made-over Richland multiplied at such a rate in the postwar decades that it is now easy to overlook how novel it was in 1944.

General Groves had in mind a town akin to an army base—fenced, guarded, compact, gridded, with numbered streets and barracks-style dorms and apartments centered around a few utilitarian commissaries.[2] This was the kind of spare, fortlike town Corps engineers were already constructing at Los Alamos and Oak Ridge.[3] DuPont executives, however, rejected Groves' plan. They resisted putting up a fence around Richland because, they said, their employees would not live behind a fence. They assured Groves they had run company towns before and knew how to keep secrets and workers under control.[4] Instead of a fortress, DuPont executives dubbed Richland, in company-town fashion, a "village."[5] They hired an architect, G. Albin Pehrson, who sketched a city with gently curving streets spiraling around spacious single-family houses on large lots and a downtown business district with plenty of services and shops.[6] Groves pruned Pehrson's plan considerably. The plate-glass windows, the second grocery store, and the landscaped schools all had to go.[7] In fact, Groves didn't even want to call the hotel a "hotel," which to him implied luxury. Instead he renamed it the "transient quarters."[8]

DuPont executives did not readily submit to Groves' dictates. They wanted to build a settlement more substantial than an army base, more luxurious than a classic company town. They pointed out that in hiring for the world's first plutonium plant "they couldn't take a chance on junior men." They said they would need well-trained employees "of the highest type" to run the new plant.[9] Convincing senior DuPont employees and "good men" to live in Richland would be tough, they argued. Edward Yancey, a DuPont vice president, contended that "people out here would not be satisfied unless they had at least the bare essentials of normal, small cities."[10] "Normal" in this case meant the kind of infrastructure—housing, schools, stores—that middle-class professionals had come to expect in the East. Reasonably, DuPont managers wanted to build for themselves and their white, highly select employees a comfortable full-service city; even more reasonably, they wanted the government to pay for it.

But General Groves was a scrupulous manager who kept a close watch on the budget. Ideologically this should not have been a problem. DuPont executives shared with Groves a disdain for what they called "hegemonic" big government. They also disliked government planning, social welfare spending, and, generally, most New Deal programs. Irénée du Pont was an influential member of the governing board of the American Liberty League, which channeled corporate dollars into opposing New Deal spending to combat the Depression.[11] The Liberty League claimed that, in sheer panic, the Roosevelt administration was destroying capitalism and American democracy and that the president would soon make himself a communist dictator.[12] Instead of government interference led by the irrational passions of the electorate, DuPont leaders championed private stewardship of free markets led by clear-thinking corporate elites.[13]

Laissez-faire ideology, however, collided with DuPont's history. The company had emerged as a financial powerhouse by serving the U.S. government as a military contractor during World War I, when DuPont's annual profits escalated eightfold, earning DuPont the moniker "Merchant of Death." DuPont also stood to profit handsomely in the new war by supplying the army and navy with explosives, synthetic rubbers, insecticides, and nylon. For DuPont, war was very good business. As Lammot du Pont put it in September 1942, addressing the National Association of Manufacturers (NAM): "Do business with the government as you would with any other buyer. If it wants to buy, it has to do so at your price."[14]

The more the U.S. government spent, the more DuPont stood to gain. New Deal social welfare went against the grain of DuPont corporate ideology, but government spending that promoted business, generated profits for deserving parties, and preserved unspoken class divisions—that was the desired future, and in planning the city of Richland DuPont executives sought forcefully to push this vision along.

Initially DuPont architects submitted designs for houses exclusively with three or four bedrooms because "the employees at this station will be of a higher than normal type." Matthias objected strongly to such luxury, writing that "a temporary village under war conditions . . . opposes every principle of war economy and is deleterious to the war effort."[15] But DuPont's Yancey held his ground. He predicted that 25 percent of the plant employees would be supervisors and technical staff—"like commissioned officers," he translated for Matthias. Men with higher rank, Yancey stated, would require larger houses. The telegrams went back and forth, Matthias and then Groves demanding that DuPont submit designs for smaller houses, DuPont managers steadily refusing.[16] DuPont executives appear to have had the upper hand. As the rift widened, they had Groves and Matthias come to meet with them in Wilmington, each trip requiring for Matthias several days of travel.[17]

What were they thinking? Edward Yancey was a DuPont vice president, in charge of the vast explosives division. Groves was masterminding the entire Manhattan Project, and Matthias was charged with constructing the world's first plutonium plant. The nation was at war, and these leaders were fighting over none other than whether there should be two or three bedrooms for tract houses in Richland. Why was the question of a few extra rooms so important?

Groves was concerned about justifying to Congress after the war the expense of the Manhattan Project. At the time, three-bedroom houses were a luxury reserved for a minority of American elites. DuPont was proposing to build a town of nearly uniform largesse in the midst of wartime rationing—an appallingly extravagant notion.[18] Yet DuPont executives held fast in part because they believed that meddlesome federal officers should butt out of DuPont's contracted business, but also because they made a forceful argument that the success and security of the plant depended on housing designs and urban planning.[19] Pehrson, the project architect, argued that they needed to maintain morale among the transplanted workers. "High morale," Pearson wrote, "cannot be achieved by crowding skilled and veteran workers into inadequate dwellings."[20]

On other planning issues DuPont executives also held their ground. Despite Army Corps of Engineers orders, no fence went up around Richland. Unlike at Los Alamos and Oak Ridge, residents did not wear security badges or pass through a guardhouse to get home. Groves wanted houses more cheaply nestled together, within walking distance of the town's amenities. Pehrson spaced the houses far apart, which increased the cost of sewer and electrical lines, as well as making the city residents more dependent on cars and bus service.[21]

Groves was shocked at DuPont's plan to locate houses of a certain class together by type, so that residents of Richland would be clustered in neighborhoods by rank on the corporate flow chart. In a society where popular rhetoric held that citizens were equal, this spatial dramatization of class was too much.[22] Over Groves' objections, however, DuPont laid out the best houses on the most desirable lots along the river for the top brass.

Yancey made only one major compromise. He agreed that one-third of the houses would be either low-cost prefabricated houses or duplexes, but he still insisted that most of these houses would have two or three bedrooms. The prefabs were small, cramped, drafty affairs, with plywood furniture, pipes that froze, and roofs that had to be tethered because they took off in the fierce desert winds.[23] For the same price, apartments or row houses could have been built that were more cost-effective, spacious, and durable.

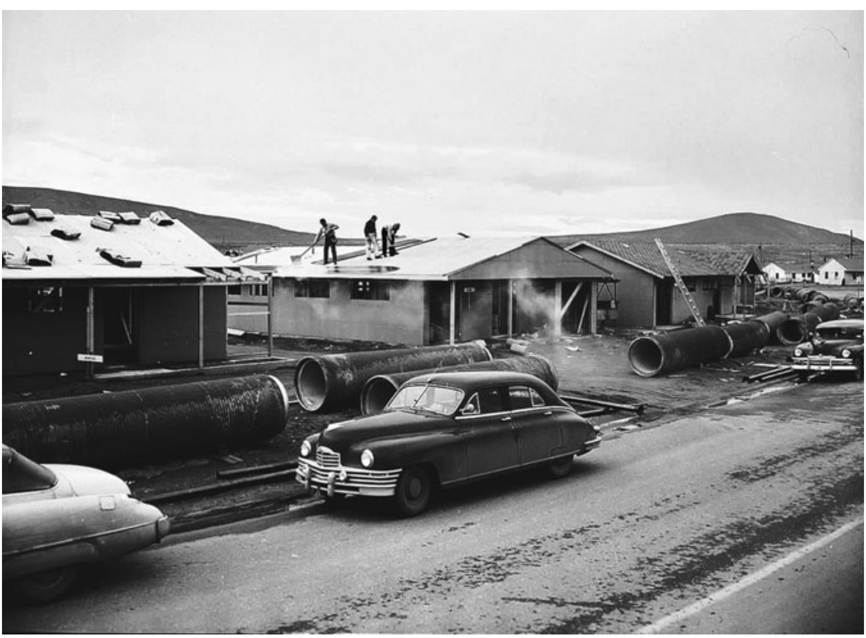
In fact, in this yearlong argument, Groves was right: there was no point constructing large, expensive housing in a sprawling layout when the "village" was supposed to be temporary (a fiction used to cover up what was projected to be the long-term project of building up the U.S. nuclear arsenal) and building supplies and labor were in short supply. Yet Groves, reputed to be a willful, arrogant "sonavobitch," largely gave in.[24] DuPont executives held their ground and built a community unique at the time on the American landscape—a wartime company town, paid for by the federal government, that resembled a private, upscale, postwar suburban development.

Clearly, for DuPont executives, freestanding houses bore a cultural meaning that overran practicality, even during a war, even on the Manhattan Project. DuPont managers' compromises in themselves point to this fact. The cheap prefabs for blue-collar employees were shoddy, but they sat on their own lots and did not look like working-class accommodations. The freestanding, suburban-style prefabs spelled middle-class respectability and tranquility, even if no middle-class people would live there.[25] DuPont managers glossed over the fact that 75 percent of plant employees were to be blue-collar workers.[26] Yet if most workers were blue-collar, why did DuPont managers argue so stubbornly for middle-class housing?

DuPont managers promoted Richland's master plan while engaged in a larger ideological battle on the national level for what they described as the survival of the "American way." Working through the DuPont-supported NAM, propagandists argued that, in contrast to New Deal social programs, American business would deliver a uniquely American "abundance," which would serve up a uniquely American freedom—the freedom to consume. NAM advertisers promised that in a laissez-faire economy, abundance would flow to all Americans, uniting the common worker with the middle-class professional in a shared, classless surfeit of consumer goods.[27]

In Richland, the concrete-and-drywall solution to this vision of a classless society was cheap, mass-produced working-class housing that *looked* middle-class. In insisting on middle-class housing, DuPont executives argued that only a community united in middle-class abundance would deliver plutonium safely and securely. Yet to run the vast plant they had to stock Richland with working people. So they simply called the proletariat "middle-class" and in that way co-opted it.[28] The scheme worked. Although Richland was a city with a working-class majority until the 1970s, it was seen and is remembered as a middle-class town of scientists and engineers, a homogeneous, monoclass society.[29] Disappearing the working class and recharacterizing Richland as "classless" helped muzzle the voices of labor and suppress unions, while coaching workers to identify with their managers in the interests of both national security and their own financial security.[30]

Once DuPont and the Army Corps of Engineers had settled on Richland's design, the city went up quickly, in less than eighteen months. DuPont managed to build swiftly by mastering assembly-line building techniques, in which workers were assigned simple, specific tasks and moved from site to site constructing a series of uniform houses. Prefab houses went up even faster. They came assembled in sections. Cranes lifted the walls and roofs off truck beds onto foundations, and crews bolted the walls together and attached the roofs.[31] Transforming a leveled terrain into a residential area in a matter of months was a



New construction in Richland. Courtesy of Department of Energy.

revolutionary new development, one that after the war shaped the emergent suburban landscape. Bill Levitt, the founder of Levittown, learned how to mass-produce communities as a wartime army builder on projects similar to Richland.[32] In this too—assembly-line residential developments—Richland was a trendsetter.

As DuPont executives increased the size of houses, they correspondingly raised the bar on who could live there. As the price of larger individual houses escalated, Groves, sweating over the rising tab, reiterated the need to reduce costs and so provide housing "only for those people who are required to live there for security reasons." To keep costs down, Groves decided that low-level workers would be barred from living in Richland.[33]

But where would the low-level workers live? Because of the massive influx of construction workers, housing throughout the region was impossibly scarce and expensive. The Corps and DuPont executives decided that unskilled plant workers who did not qualify to live in Richland would commute from neighboring farm towns, where they would live in existing housing or in new federally funded (FHA) housing, which, though rudimentary, Yancey pointed out, would suit these "service and low level employees" because they "will be people whose housing standards are none too high."[34] Groves and Yancey specified which lower-ranking plant operators—"laborers, janitors, and other manual workers"—would be excluded from Richland.[35]

This reiteration of Richland's exclusivity occurred shortly after news came in from nearby Pasco that the overtaxed little city, which had tripled in size with wartime construction workers, was a threat to public safety. In December 1943, Matthias penned in his diary: "The situation at Pasco with respect to crowding and general lack of control of workers is one which shows potential danger." Pasco had a "ghetto," one of the few places in the region where nonwhites could rent a shack, park a trailer, or pitch a tent. Pasco also had a strip of cheap eateries, bars, and bordellos. The "danger," Matthias reported, was that "irresponsible workers" were "flagrantly disregarding the local law." Matthias planned to get additional state troopers assigned to Pasco, and he worried: "If this condition is serious now, it will undoubtedly be more serious in the near future when this project begins to terminate employees who are undesirable." Something would have to be done, Matthias continued, "to see that these people actually leave Pasco and this area to avoid a concentration of undesirables and an unbearable load on the facilities, both social and law enforcing, of the Pasco area."[36]

Pasco's working-class volatility so near the emergent plutonium plant presented a major national security threat. Washington's governor, Arthur B. Langlie, went to see Matthias, worried about the problem. He and Matthias came to an agreement to eject laborers who were no longer needed, "particularly the negroes."[37] As work slowed down in 1944, supervisors first laid off African

Americans from the construction site.[38] Matthias ordered more state troopers to Pasco in 1944 to help disperse “vagrants” and unemployed drifters.

Pasco served as an example, one laced with a threat, of what Richland should not become. Part of the task of “securing” Richland involved quarantining it against the bellowing, brawling, shack-dwelling working classes and minority laborers of Hanford Camp and Pasco. Building respectable single-family housing with multiple bedrooms ensured that upright white family men, rather than explosive working-class bachelors, would work at the plant. DuPont officials won the debate over housing basically by making it a security issue. They successfully argued that the operators of the world’s first plutonium plant had to be securely embedded in nuclear families in an exclusive atomic city.

After the war, journalists piled into Richland. They had limited access to the plant behind the gates but could range freely in Richland, and they loved it. The *San Francisco Chronicle* described the “self-contained, shiny new village” as “Paradise.”[39] *Business Week* called it “utopia.” The *Christian Science Monitor* hailed it as “a model city . . . to be carefully studied by urban planners for years to come.”[40] Yet Richland was a puzzling creation in American society—a collection of what appeared to be private homes, private businesses, and grassroots organizations that were centrally planned, managed by a corporation, ethnically segregated, federally subsidized, and closely watched and controlled.[41] This model echoed deeply in postwar America as all-white, highly subsidized suburbs sprang up wherever prosperity allowed.[42] DuPont executives’ success derived from the fact that they focused not on building for a community but on building for individuals as loyal and valuable employees to the corporation, as consumers, and also as objects of security, safety, and surveillance.

By charting onto the landscape (invisible) zones of class and race, by offering financial security alongside military security, DuPont executives managed to hit these multiple targets without needing guard posts, identity cards, and fences, as at other Manhattan Project installations—without creating the appearance that Richland was a closed nuclear reservation for white male workers of a higher type. Oak Ridge and Los Alamos, fenced and patrolled, leaked nuclear secrets to Soviet agents. So far, no evidence of an espionage breach from Richland has surfaced in Soviet archives. Richland had no incarcerated people, just incarcerated space. It was quite an accomplishment.

6

Work and the Women Left Holding Plutonium

The plutonium plant also differed from Los Alamos in that it was not a lab but a bomb factory, a very large one. Few, however, of the common laborers from the Hanford construction site were hired as permanent employees. Instead, DuPont recruiters set out hiring anew two classes of workers—blue-collar operators and the white-collar supervisors and managers who would direct them. Access to knowledge about radioactive hazards was portioned out on a sliding scale. Those who worked most closely with radioactive solutions were often the most scantily trained and least informed.[1] Ignorance and anxiety rode shotgun up through the hierarchy, dividing workers by rank and gender. The higher up on the corporate hierarchy an employee was, the less that employee had to fear.

In hiring operators, DuPont had an attachment to values derived from the du Pont family's old-line Protestantism.[2] There was no talk of hiring black and Mexican American workers, whom the company had been forced to hire for construction. Some divisions of the corporation discouraged hiring non-Christians. With this selection process, the term that officials of DuPont and the Army Corps of Engineers used—"higher type"—takes on an Aryan weightiness. The first (classified) census of the new Richland revealed that all residents were white. The vast majority were Protestant. Fifteen percent were Catholic. Ten employees were Jewish.[3]

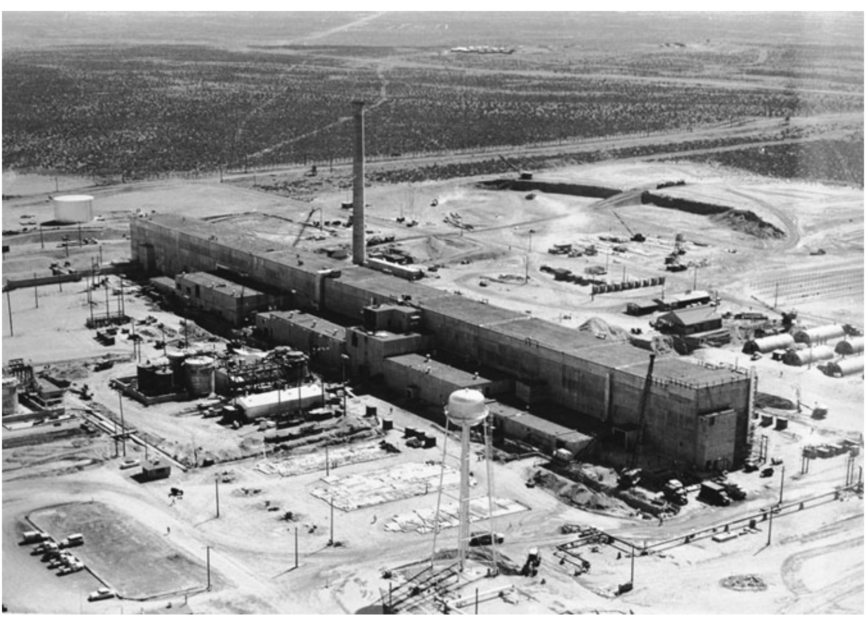
DuPont recruiters set up two categories of employees—exempt and nonexempt. Exempt workers were paid a salary and tended to be transfers from other DuPont plants. They had a higher education, worked in supervisory and technical positions, and were for the most part already "DuPont men."[4] The second category, the majority, was nonexempt workers, who were paid weekly or hourly wages for shift work. These workers tended to have no more than a high school degree. DuPont managers sought to hire these workers locally.

In Richland, I went to see some of the people they call "old-timers," hired at the plant in 1944. I met Joe Jordan in his comfortable ranch house, the furniture circa 1960, neat and mod. DuPont hired Jordan in 1941 after he graduated from Georgia Tech with a degree in chemistry. In 1943, Jordan got transferred to Chicago. There he reported to his new supervisor, who flipped on his desk a uranium fuel slug, used to power nuclear reactors, and laid out the whole Manhattan Project mission. Jordan's new job would be to take fuel slugs after they were irradiated in a reactor and dip them in a series of chemical baths to strip them down to grams of plutonium. The plutonium extract would be used to make a very powerful bomb.

For several months Jordan trained at the Met Lab at the University of Chicago. In October 1944, Jordan arrived in Hanford and toured the automated, remote-control plant under construction. As a chemist at Hanford's T plant, Jordan's job was to analyze samples of irradiated solutions along the plant's assembly line. Jordan oversaw a group of lab technicians who did the actual work of gathering the radioactive solutions, handling and measuring them, and moving the solutions through the production process.

When I met Jordan in 2008, he was ninety years old, one of those individuals whose longevity defied the talk about Hanford's radioactive legacy. Jordan was a little bent, but his step was quick. He had a full head of glossy white hair and a ready laugh. Jordan made old age look easy.[5]

As a college-trained, salaried employee, Jordan was in the minority. Most T plant workers clocked in for shift work in blue-collar jobs. DuPont sought people



T Plant, the ship-sized chemical processing plant at Hanford. Courtesy of Department of Energy.

who could be trusted to operate machinery and follow instructions precisely. In labs with special hazards, they needed people with more than "the usual attention to work."[6] As the recruitment drive started, there emerged a gendered division in hiring. DuPont recruiters hired men to staff the plant's three reactors, considered the most important and dangerous workplaces. Initially DuPont officials did not imagine hiring female plant operators at all because they feared genetic damage to women of childbearing age. Manhattan Project officials insisted, however, that because of the presumed labor shortage, "women should be substituted wherever practicable."[7] Work in the chemical processing plant, where workers would distill irradiated uranium down to drops of plutonium, was considered to be safer and less complicated than work in reactors.[8] That guess proved wrong. The chemical processing plants turned out to be as hazardous for workers as the reactors were.[9]

DuPont records offer no further explanation as to why chemical processing jobs were gendered female. Cost might have been a factor. It was cheaper to hire women because women were paid less and did not qualify for subsidized housing in Richland.[10] Jordan, who supervised many female lab assistants, said DuPont hired women because they were good workers. They did just as they were told and followed directions precisely. The best lab technician he knew was a woman who had been a short-order cook. She was good at following the same recipe, exactly the same way, over and over.

DuPont recruiters were looking for high-school-educated white women between the ages of twenty-one and forty, of "good health, pleasing personality, alert and intelligent."[11] In 1944, female applicants asked recruiters a lot of anxious questions—especially about the hazards of working in the mysterious plant. Locals guessed that DuPont was making chemical weapons. Rumors went around that people were being killed inside the plant and their bodies were being brought out under the ruse of removing Indian graves.[12] DuPont executives felt they had a "moral" obligation to disclose to their workers the hazardous nature of the plant's product. They maintained that even low-skilled workers could guess anyway, and full disclosure made for safer, more intelligent operations.[13] But Groves strongly objected to informing workers of the hazards.[14]

After accepting employment, women had to pass a health exam and a background security check. Unlike male operators, women were not sent for training in Chicago or Oak Ridge, but underwent a rushed six-week apprenticeship, consisting of only the essential skills and procedures, with no science or theory.[15]

Marge Nordman DeGooyer was one of the new DuPont recruits. DeGooyer grew up on a struggling farm in South Dakota, the kind of place where the farm can't provide an adequate living, so family members find work wherever they can. DeGooyer learned how to fly planes and worked as a crop duster, then a cab driver. In 1944, she followed her father, who was pursuing rumors of jobs, to

Woman on the job, Hanford, 1953. Courtesy of Department of Energy.

Richland. DuPont hired DeGooyer as a secretary, but a recruiter noticed her aptitude for math and told her that if she worked in the technical area she could get an education the likes of which no university in the world could provide. DeGooyer said she took that challenge.[16]

After a long bus ride to the plant, thirty miles past the entrance gates, DeGooyer arrived at the chemical processing plant, a massive "canyon" with no windows in its seamless concrete exterior. On her first day, the shift manager asked DeGooyer if she preferred to cook or sew. DeGooyer, confused by the question, replied that she didn't like to do either, but if pressed, she would cook.[17] So she was sent to the analytical chemistry lab to work with liquid chemicals, greenish "hot" solutions that the female lab assistants pipetted into beakers in exact, minuscule quantities.

DeGooyer was told how to do things, but not why. Her supervisor explained that the chemicals she worked with were dangerous, but he did not mention radioactivity. He also did not want the women to wear gloves because they hindered working quickly and precisely.[18] DeGooyer, however, was clued in to the dangers of her work by the behavior of her supervisors. She described how the chemists, "with their college degrees," would come to the door to give them new formulas. "They wouldn't come into our lab," DeGooyer remembered. "They'd stand on the threshold and hand the paper through the door, and then they'd run off."[19]

You can't blame the college-trained chemists for taking care based on their knowledge of the hazards, which security regulations prevented them from sharing with lab technicians. Chemists such as Joe Jordan who did analyses of the radioactive solutions knew a lot more than DeGooyer about the dangers involved. They also knew that because of the many problems DuPont had hiring workers to build the plant, the production of plutonium had fallen behind schedule. In order to catch up and have a bomb before war's end, in the summer of 1945 Groves ordered DuPont managers to shorten the cooling time for irradiated fuel slugs, thereby speeding up production. That meant workers pulled the highly radioactive slugs from underground cooling ponds after only a few weeks, rather than the two to three months necessary for the radioactive components to decay to safer levels. This "green" fuel sent up radioactive isotopes in great, toxic belches, the likes of which the planet had never experienced.[20] The decision to speed production to make up for lost time meant that the young lab techs were exposed to higher concentrations of radioactivity.

DeGooyer and the other lab techs measured and poured these highly radioactive solutions using bare hands. Spills were not uncommon. Each night as DeGooyer left work she placed her hands and feet in a counter. If her hands were not clean, she went back to the lab and rinsed them off, again and again. Radioactive solutions have a persistent quality that stands up to soap and scrubbing. DeGooyer got the nickname "Hotfoot Marge" because once the radiation monitors noticed that her clothes locker set the dosimeter ticking furiously. When they found that DeGooyer's work shoes were highly radioactive, they confiscated them and buried them in a radioactive-waste dump.

As I talked to DeGooyer, it was clear she was in pain. Her hand kept worrying a spot on the right side of her neck. She had a Band-Aid on her nose. "I've had cancer everywhere," she said as her hand flew around her body, "on my legs, hands, face, and then I had a mastectomy." DeGooyer's husband had also worked at the plant as a blue-collar operator on the F reactor—the reactor that over the years experienced the most leaks and other "incidents." While still young, DeGooyer's husband developed a problem with his heart valves. He had surgery and a long, incomplete recovery. Then he fell from a ladder and broke a leg, which mysteriously never healed. He retired early, and DeGooyer became the family breadwinner. She had a head for numbers and acquired a reputation at the lab for solving problems. Scientists sought her out to ask advice. Supervisors wanted her in their labs. DeGooyer worked her way up and eventually came to run the mass spectrometer at the plant. She was proud of that accomplishment.[21]

Before we parted, DeGooyer told me one last story. After news broke in 1945 about Hiroshima, a team of photographers came to tour the plant. They wanted to have a look at plutonium. DeGooyer's boss asked her if she would serve as a model. DeGooyer was flattered. She went to the bathroom, where she took off her coveralls and freshened her makeup. The photographers set her up at a glove box, into which she slipped her hands to hold a vial of plutonium solution. Then, to her horror, her boss told the journalists to leave the room, just to be on the safe side. He said they were not sure if the cameras' flash would make the solution go critical, sending out a lethal blue shower of neutrons. The photographers set their timers and hurried out, leaving DeGooyer alone to wait for the flash, holding the test tube, heart pounding. Years later, DeGooyer was most upset that her brave act was not recorded in the newspaper article. The photographers cropped her body from the photograph, which showed only her gloved hand holding the plutonium—a fitting parable of how many histories of the Manhattan Project have trimmed from memory the stories of the working people who took the most immediate risks.

7

Hazards

Defenders of the Manhattan Project medical record argue that in the 1940s researchers knew little about radiation's effects on the human body. Managers, they argue, placed workers such as Marge DeGooyer in harm's way unwittingly, and they were as careful as possible, given the wartime emergency.[1] With these arguments in mind, I set out to discover what Manhattan Project medical researchers knew about radiation and when they learned it. The answers show how managers and researchers discovered within the first years of research most of the critical dangers of the fission products they were creating. This realization, however, scarcely altered plant design, plant operation, or, most critically, the dumping of radioactive waste.

In the Atlanta branch of the National Archives, I came across a puzzling medical file for Don Johnson, a young DuPont chemical engineer. The file illustrates the vanishing qualities of the record of radioactive contamination, qualities that have since caused so many polarized views on the safety of the nuclear industry. In the fall of 1944, Johnson began to feel ill. He had nausea and severe gastric pain. His gums bled. His legs ached. He was fatigued and had night sweats, a mild fever, and, his Richland doctor reported, a pallor. The following week, doctors at the Richland medical center diagnosed acute leukemia. Within a few months, Johnson, age thirty-seven, who had been given a clean bill of health a year before, when he started work on the Manhattan Project, was dead.

DuPont officials acknowledged that Johnson had been exposed to radioactive sources at the Met Lab in Chicago and in Oak Ridge before coming to Richland, but at levels, they noted, below the then established tolerance. Researchers had set a "tolerance dose" of 0.1 roentgen a day in the thirties. They knew at the time that ionizing radiation from both gamma rays (electromagnetic waves of very short wavelengths), exposure to which comes from external sources, and beta and alpha particles (released from an atom's nucleus), exposure to which could come from ingested or inhaled substances, could damage cells, causing cancers and genetic problems.[2] Johnson's case caused a lot of anxiety in DuPont circles. His wife learned through a third party about Johnson's exposure to mysterious toxins and sued for compensation. DuPont lawyers were not about to admit liability, but they did recommend to General Groves that the federal government quietly pay her a settlement.[3] DuPont executives Roger Williams and Crawford Greenewalt, in charge of building the massive plutonium plant, had already been nervous about worker safety. Johnson's death elevated their anxieties.

DuPont managers were no strangers to workplace hazards or sick workers. In the early thirties, a DuPont chemical dye plant had an outbreak of bladder cancer among its workers. DuPont officials hired Wilhelm Hueper, a German scientist specializing in toxins, to figure out what was giving the workers cancer. Hueper isolated a new chemical agent, beta-naphthylamine, used in dye production, which, he said, caused bladder cancer in rats. Rather than pull the chemical from the line, DuPont officials took Hueper off the research project, and when he refused to drop the issue, they fired him. Fearful that Hueper would broadcast his findings, they assigned another scientist, Robert Kehoe, at the company's Kettering Lab, to carry out research that would discredit Hueper's findings. For the next twenty years, DuPont workers continued to use beta-naphthylamine, which caused bladder cancer in nine out of ten employees exposed to it.[4] For the subsequent two decades, DuPont officials harassed and censored Hueper in his work as director of the environmental cancer program of the National Cancer Institute.[5] Because of this experience, DuPont officials were more keenly attuned than Manhattan Project directors to the long-term consequences of workplace toxins and the threat of liability.[6]

In 1943, Williams and Greenewalt asked Army Corps of Engineers officers a lot of questions about the possible hazards of the reactors and processing plants they were designing.[7] The queries reveal their anxiety about sending forth into the earth's biosphere the world's first industrial-sized quantities of man-made radioactive isotopes. The executives asked: "What advantage would there be in hiring women beyond the age of menopause or older men? Would 0.1 rad [the daily tolerance dose at the time] be safe from causing genetic changes in offspring of workers? What is the natural mutation rate in humans—number of monsters, percent of spontaneously defective children; percent miscarriages?"[8]

In 1942, Groves had set up a Medical Section within the Manhattan Project with an eye to health and visibility. Groves and his chief medical officer, Stafford Warren, worried that workers would get so much contamination as to "produce physiological damage," which might undermine secrecy and production.[9] Ensuring production was both the main purpose of the new Medical Section and its essential shortcoming. As Hymer Friedell, a chief medical officer, put it, "the services of the medical organization are an accessory function. The primary interest is to maintain the health of the operators at a level which will in no way interfere with operations."[10] In other words, the medical division was there to keep workers healthy enough to produce, but not to solve the mammoth questions concerning the impact on human health of radioactive isotopes. In the steadily bloating Manhattan Engineering District bureaucracy, the medical research division was a needy stepsister, employing, at its peak, all of seventy-two medical officers to conduct research and to monitor and care for tens of thousands of employees, as well as to look after the environmental health of the surrounding air, rivers, lakes, and agricultural livestock and produce.[11] With few resources to spare, Stafford Warren instructed scientists to engage only in studies that would produce quick results and protect the agency from liability.[12] But Warren rarely had quick answers. His replies to DuPont executives' anxious queries about safe doses and genetic consequences were usually the same: *Researchers are studying these questions. We'll get back to you.*[13]

DuPont's top brass were not content with ignorance. By the 1940s, scientists had known for decades that radioactivity caused infertility, tumors, cataracts, cancer, genetic mutations, and general symptoms of premature aging and early death. Researchers in the 1910s and 1920s showed that X-rays produced cancers in animals.[14] In the twenties, American newspapers headlined the story of several hundred young women in New Jersey employed to coat watch faces with luminous paint that contained radium. The women had strange symptoms, as if they had sped into old age in a half dozen years. Their hair thinned and grayed, they became stooped and had to rely on canes, and their bones cracked with sudden movements. Their gums swelled and bled, and they lost teeth. They took to their beds too fatigued to walk in the park, go out on dates, or do the things other young women did.[15]

DuPont executives worried about the radium example, more so after September 1943, when Dr. Robley Evans published photographs of a radium worker with the lower half of her face consumed by a softball-sized tumor.[16] Evans reported that some of the autopsied radium workers had as little as 1.5 micrograms (0.0000015 gram) of radium in their bodies, minuscule amounts when compared to the tons of radioactive waste the plutonium plant would soon produce. A month later, DuPont executives sent the radium handbook to Groves' office and asked, again, for answers about the effects of uranium and its radioactive by-products.[17]

Natural uranium radiates only weakly, and a body has to be near it for long periods to incur damage. But when uranium is bombarded in a reactor, the result is a tremendous discharge of energy plus neutrons and new radioactive elements. This energy can affect the structure of any atoms it encounters. After the war, Atomic Energy Commission (AEC) scientists emphasized the "natural" radiation in the environment—from sources such as the sun's rays and minerals in the earth.[18] But there was nothing natural about the new radioactive isotopes produced in the Manhattan Project's reactors and cyclotrons, radioactive isotopes such as iodine-131, strontium-89, cesium-137, and plutonium-239. The new plutonium plant promised to generate these and many other man-made, hazardous isotopes in excess. In 1943, scientists could only worry what would happen when these new fission products entered living tissue, jolting with great energy the molecules, cells, and genes that support life.[19]

Not content with Corps promises, DuPont's Crawford Greenewalt started his own research programs, unique in the Manhattan Project, into the particular environmental panorama of the Columbia Basin. Greenewalt asked for a fish specialist to look at hydrology and habitats in the Columbia River before designing effluent pipes that would send radioactive waste into the river.[20] He called in a meteorologist to study the powerful winds that swept past the plant smokestacks.[21] DuPont executives requested their own medical health staff and asked for more and better doctors and researchers.[22] Corps officers found these safety precautions "excessively expensive and elaborate," but they paid for them.[23] At the same time, Stafford Warren contracted with researchers at several universities to carry out studies of the short-term effects of various radioactive isotopes on animals and humans.

At the Crocker Lab at the University of California, Dr. Joseph Hamilton was offered the job of researching how the fission products produced at site W (Hanford) would be metabolized in animal and human bodies as well as in plants, and what would happen when they entered soils. Hamilton eagerly accepted the assignment, apparently thrilled to be on the cutting edge of research on the biological effects of radiation.[24] Hamilton had long been one of many enthusiastic boosters of radioactive isotopes as a new diagnostic tool and cure-all for human ailments. In the 1930s, he stood in front of audiences and swallowed radioactive iodine to demonstrate how a few minutes later his thyroid set the Geiger counter ticking furiously.[25] In 1936, he and his colleague Robert Stone tested radioactive sodium on willing leukemia patients. In 1939, Stone treated wealthy cancer patients, who arrived drinking champagne in limousines, with neutron baths in the cyclotron; nearly half of these patients died within six months, suffering horribly from the side effects of radiation. In 1941, Hamilton injected six volunteer bone cancer patients with radioactive strontium, also with disappointing results.[26] With reputations as the leading researchers and promoters of radiobiology, in 1942 Stone and Hamilton were invited to work on the high-priority Manhattan Project in the medical division.

Hamilton set to work on the metabolism of radioactive isotopes, but his research agenda mutated strangely when an army general called to ask if it would be possible to poison an enemy population with radioactive by-products. Although Hamilton's lab was very short of money, staff, and especially time, Hamilton took a puzzling and costly detour in 1943 into this question of the "tactical" uses of radioactivity. On the general's suggestion, he investigated how Hanford radioactive waste could be used for "offensive purposes." Hamilton injected radioactive solutions into mice and turned solutions into smoke and food pellets for mice to inhale and ingest, trying to figure out the surest and swiftest ways to induce the mice to die.[27]

Manhattan Project security compartmentalized knowledge on a "need-to-know" basis, and Hamilton's reports went up his chain of command in the Medical Section, bypassing DuPont.[28] This security wall created a bizarre parallel correspondence within the Manhattan Project. In the summer of 1943, for instance, DuPont executives exchanged anxious letters with Groves about the health effects of workers' daily exposure to Hanford's radioactive isotopes, while Hamilton corresponded with Stone in Chicago about the best ways to use Hanford waste to "make everybody [in an enemy population] nauseated, vomiting and incapacitated within 24 hours."[29] While DuPont executives were worrying about air currents swirling in the topographic bowl around the Hanford plant, which created an inversion, trapping radioactive dust over local towns, Hamilton worked with a meteorologist to determine how they could best use the same inversion effect to confine radioactive dust in air currents over an enemy city. While DuPont officials grew anxious about the highly radioactive nature of Hanford waste, Hamilton was estimating the number of curies in a hundred pounds of the same waste, which, he imagined, could be spread on the ground, allowed to seep into well water, or turned into a gas for "offensive purposes."[30] The waste was so potent, Hamilton's assistants gushed, that "[radioactive] strontium smoke would be over a million times more lethal than the most deadly war gases."[31]

Hamilton, like many of his compatriots, was caught up in winning the war, but his research program inadvertently upended DuPont's concerns for public health. Instead of looking at ways to increase safety, Hamilton studied how to manufacture greater radioactive hazards. Instead of determining how to preserve life, Hamilton researched how best to bring about death. Hamilton's subordinates suggested building a plant specifically to process radioactive waste for weapons—a proposal that, considering the Mt. Vesuvius of radioactive effluent Hanford would soon produce, now reads as cruelly sardonic.[32]

At the time, however, Hamilton's results were encouraging from a military standpoint. A conventional bomb, Hamilton pointed out, is dropped, does its damage, and ceases to be destructive. Radioactive bombs, on the other hand, ensure destruction long after they are detonated. Hamilton reported, "A person who has become internally infected [with radiation] will be subjected to internal irradiation for many months after exposure," and "that a very large proportion of the long life fission products are retained for protracted periods of time in the lungs." He found that many of the radioactive by-products emitted at Hanford—strontium, barium, and radioactive iodine—were readily absorbed by the digestive tract and moved into the bone marrow.[33] In other words, radiation, once ingested by the enemy, was like a ticking time bomb buried deep inside the body. Hamilton reported optimistically that it was quite easy with relatively small amounts of radioactive substances inserted into the proper environmental conditions to incapacitate or even kill whole communities.[34]

Radioactive dust or smoke trapped by temperature inversions or dispersed by swirling currents, fission products unleashed in rivers and groundwater, radioactive particles dusted over crops—these were the scenarios that haunted the nightmares of safety-conscious DuPont executives who by 1944, as start-up approached, began to worry more audibly about the "super-poisonous" nature of the product they would soon produce.[35] At DuPont's pilot reactor at Oak Ridge, scientists were amazed at how "a minute quantity of hot material" could cause "widespread contamination."[36] In late 1943 and early 1944, DuPont executives joined others at Manhattan Project sites asking ever more urgent questions about safety and health.[37]

Mercifully, DuPont engineers had no access to Hamilton's hair-raising monthly reports on the offensive uses of radioactive waste. But they also had no real answers from the medical division about how to safely launch the world's first plutonium plant and dispose of its millions of gallons of radioactive gas and liquid. Despite the general sense of urgency, two years into the medical research program neither Hamilton nor his colleagues in labs in Rochester, Oak Ridge, and Chicago had useful answers.[38] Little wonder answers were missing: Manhattan Project researchers could not publish their work, discuss it at conferences, or even solicit the help of fellow scientists working on different areas in the Manhattan Project.[39] Meanwhile, Hamilton's program, most directly concerned with the problem of Hanford waste, had squandered a year studying the military applications of radioactive by-products.

In December 1943, Stone gently steered Hamilton back toward the Hippocratic Oath: "We have no authorization for investigating offensive radioactive warfare, but we have a responsibility to know as much as possible of the action of the dusts that might be around a plant resulting either from normal operations or accident."[40] Hamilton, with his characteristic perceptiveness about how best to achieve professional success, quickly recalibrated. Just three weeks later, he sent Stone a new proposal to study radioactive smoke and dust, much as his research group had before, but now in the context of an "accident or normal operations" at a project plant.[41]

Hamilton's yearlong research calculating how to induce a slow radioactive death reveals that researchers had a good idea about the killing qualities of the products and by-products Manhattan Project plants would produce, even before they produced them in industrial quantities. Hamilton's correspondence also shows that there was no real ideological division between military medical officers (such as Stafford Warren and his loyal deputy Hymer Friedell) and civilian research doctors (such as Stone and Hamilton). All were eager to serve the war cause in the most direct way.

Hamilton's foray into radioactive weaponry reveals, too, something about the nature of the Manhattan Project's medical program in the midst of a genocidal war: its cool appraisal of death and destruction, its surfeit of imagination about masses of enemies "nauseated, vomiting, incapacitated within 24 hours," and its deficit of imagination to envision the same scenario among Americans near Manhattan Project plants. Perhaps this initial martial gleam helps explain what followed in the history of medicine on the Manhattan Project.

8

The Food Chain

In 1943, Manhattan Project medical radiologists predicted that plutonium would not be a very dangerous material because plutonium differed from radium in that it emitted few gamma rays, the kind of radioactive energy that travels great distances and can penetrate through walls, clothing, and skin into the body. Instead, plutonium was an alpha emitter. Alpha particles do not travel more than the width of a hair and can be stopped by a sheet of paper. As a consequence, researchers estimated that plutonium would be fifty times less dangerous than radium.[1]

In February 1944, Hamilton received one of the first allotments of liquid plutonium, eleven milligrams, enough to begin lab experiments on the effect of this new isotope on the body. Hamilton's group started experimenting on mice, then moved on to rats, rabbits, dogs, and monkeys. The researchers smeared plutonium on skin and injected plutonium-laced solutions into blood and muscle tissue. As the first results were tallied, the picture of plutonium grew increasingly dismal. Hamilton discovered that once inside a body, plutonium lodged in the skeleton and bored into the vulnerable blood-cell-generating bone marrow. Hamilton had hoped to find ways to flush plutonium from a body, but he had no luck.[2] Plutonium, the researchers found, had an uncanny knack for bioaccumulation, concentrating in organs and insinuating itself into the biochemical processes the body uses to thrive. Thyroids, for example, greedily drank up radioactive iodine. Plutonium and strontium-89 imitated calcium and quickly migrated to the skeleton. Strontium-89 also traveled with speed and ease from placenta to fetus, from mother's milk to newborn.[3] John Wirth, the Oak Ridge medical director, was fascinated with how radioactive isotopes inserted themselves into biological processes. He marveled at the "ease with which it [radioactivity] seems to get about as though it were a living creature, trying to spread itself anywhere."[4]

Hamilton's exposed lab animals grew listless, their hair grayed, and their livers deteriorated. They developed lymphomas, bone sarcomas, and precancerous cells.[5] At Columbia University, researchers exposed mice to fast neutrons.[6] The mice lost weight, hair, and white blood cells. They became anemic, grew sterile, and developed cataracts. Their lungs became inflamed and clouded with bacteria. Strangely, the mice suffered these symptoms in different ways, no two alike. After thirty-four weeks most of the mice had died. On autopsy, the doctors could not determine a specific cause of death—not a tumor, a cancer, or organ failure—and attributed death to "a general malfunctioning."[7] Researchers found the random, vague qualities of these symptoms troubling. They had hoped to determine telltale signs that a body was approaching an overdose of radiation, but they discovered that different kinds of radioactive isotopes behaved in particular bodies in their own exceptional ways, and produced symptoms that were difficult to differentiate from symptoms in a body suffering from a more conventional illness such as pneumonia, anemia, or tuberculosis. It would be relatively easy, in other words, to mistake a death from radiation for a conventional one, or radiation illness for a general malaise and vague complaints of infirmity.

The researchers' experimental doses were high, such as an employee might experience during an accident or explosion. On a daily basis, most employees and bystanders would be exposed to far lower doses, but this exposure might continue for months, possibly years. Long-term, low-dose experiments took time and required the ability to measure minute levels of radioactive isotopes in the body, a skill Manhattan Project researchers had not yet mastered in 1944–45.[8] There were only a few studies that looked at the long-term effects of the new radioactive isotopes. Researchers at the University of Rochester conducted a two-year study of the effects of chronic radiation on mice, monkeys, rats, and dogs. The animals were given X-ray doses equivalent to the accepted tolerance dose for workers in the Manhattan Project. Much of the experiment failed, however, because epidemics of typhoid and tuberculosis overtook the mice and monkeys, killing them and skewing the results.[9] The researchers were looking for tumors, cancers, or disintegrating bones—symptoms suffered by workers exposed to radium and X-rays in the twenties and thirties. They were not looking for immune disorders, which might trigger a susceptibility to common illnesses. If they had, then the epidemics among the mice and monkeys might have been taken as results rather than as a sign of failed experiments.[10]

Meanwhile, a team of geneticists irradiated 73,901 fruit flies (genus *Drosophila*) starting at 25 rads (the annual tolerance dose for workers at the time) and finishing at 4,000 rads. Since the twenties, geneticists had been aware of radiation's effect on genetic mutations. In 1925, the geneticist H. J. Muller won a Nobel Prize for studies showing that X-rays caused damage to fruit fly chromosomes. Subsequent investigations determined that in all species radiation triggered mutations.[11] In Manhattan Project studies, researchers found that even the lowest doses directly affected the rate of mutations in offspring. The researchers moved on to mice and found that the higher the dose a mouse received, the better the chance for mutation.[12] The geneticists concluded their study by questioning the daily tolerance limit for Manhattan Project workers: "We are forced to wonder whether a human exposure of 0.1 rad/day is acceptable." The researchers doubted that any radiation dose was safe because of the random quality of chromosomal damage, which triggered in offspring changes ranging from superficial differences in eye color to a worrisome and vague "reduction of general vigor or of life span."[13]

Most Manhattan Project researchers were focused on the immediate goals of winning the war and minimizing the loss of American lives. They lined up potential casualties in nuclear weapons plants alongside the greater risks for battlefield soldiers and judged nuclear risks to be comparatively negligible. But the small group of geneticists working on the margins of the Medical Section took a different perspective. They reflected on the impact of long-term, large-scale deployment of atomic energy "in terms of society and the human race."[14] Their report, tossed in a large file labeled "Medical Summaries," displays an uneasiness about the way radioactive isotopes, so quick to lodge in the body and linger there, affecting biological systems, would, once distributed on an industrial scale, no longer remain an external feature of human existence, but would become a lasting detour (or cul de sac) on the path of human evolution.[15]

The consequences of these grim medical findings could be averted, of course, if humans minimized contact with radioactive isotopes. With that goal in mind, Manhattan Project researchers sought out the paths by which plutonium and other fission products might enter the body. The scientists found that these radioactive particles migrated outdoors, to the grasslands, into the rivers, and into air currents. The idea in locating the Hanford plant in the wide-open, sparsely populated Columbia Basin was to use the local territory as a vast sink into which engineers could dispose of hundreds of thousands and eventually billions of gallons of radioactive and toxic waste. With a vast reach of territory, the scientists figured, radioactive isotopes would scatter into the air, soil, and water to the point where they would be so diluted as to be harmless everywhere to everybody. The strong winds would carry away radioactive gases from high smokestacks. The swift, high-volume Columbia River would speed off liquid waste to the Pacific Ocean. The earth in the miles-wide buffer zone around the plant and the sandy sediment under the plant would easily absorb radioactive waste and make it vanish. The sink was an application of nineteenth-century notions of industrial waste disposal to twentieth-century garbage—one of those ideas that sounded good at the time, because radioactive garbage is undetectable by the senses. Passing one's eye across the rambling Columbia Basin made visible sense of the notion of the sink.

DuPont engineers did not approach the despoilment of the Columbia Basin cavalierly. Greenewalt realized quickly that Hanford was at the very nadir of the basin. Consulting meteorologists, Greenewalt learned that local air currents unfortunately would not evenly disperse Hanford's effluent. Warm air flowing over the top of the basin often formed a ceiling trapping cold air below, which then circulated and flowed liquidlike near the ground, heading south over the Columbia River toward Pasco and Richland, where a bottleneck of "high concentrations of radioactivity" could occur.[16] Greenewalt learned that when conditions were favorable, stable currents indeed held stack gases high, emitting them over many miles, but these emissions most often traveled southeast to the region's major population points—Richland, Pasco, and Kennewick—and on to Walla Walla, sixty miles away. At other times, downdrafts deposited emissions, hardly diluted, within a few feet of the stacks.[17] Frank Matthias learned of these disquieting scenarios in 1944, but by then he could do nothing about the plant's design or location. Instead, Matthias noted in his diary the desperate, optimistic belief that once the plant was up and running, engineers would hold up production while awaiting favorable weather conditions. Matthias and Greenewalt had a high tower built to forecast good weather for production.[18] Meanwhile, the plant ran around the clock in good and bad weather.

Hamilton had on staff two soil experts, R. Overstreet and L. Jacobson.[19] They tested the soils under the Hanford reservation and found that the soils in the Hanford area showed an amazingly high capacity for holding on to fission products. Overstreet and Jacobson packed soil into vertical glass columns and poured in radioactive waste from Hanford. They noted that 80–90 percent of the waste did not percolate down, but settled in the first few inches of topsoil.[20] These results were disconcerting because, like Greenewalt's meteorology studies, they directly contradicted the notion of the sink. If radioactive isotopes combined readily with Hanford soils, if most of the radioactivity settled in the topsoil, and if wind currents cycled inside the Columbia Basin toward population points, then the result would be not diffusion but concentration of radioactive isotopes in just the places where humans, flora, and fauna were most likely to come in contact with them.

Reflecting on this problem, Hamilton, writing from the floral splendor of Berkeley, California, penned to a colleague in dusty, dry Pasco: "There is one question which I think is very important that was probably not emphasized too strongly in the report, and that is the unhappy state of affairs that will take place should fission products in any large amounts ever come in contact with the top soil. Under such circumstances, unless the contaminated dirt is properly buried or otherwise disposed of, such material could be transported considerable distances by action of the wind."[21]

Placing fission products in contact with the topsoil is just what DuPont engineers were up to when Hamilton wrote his letter. DuPont engineers designed a waste disposal system in which they piped the most dangerous waste into underground storage tanks, while they mixed low-level waste with well water and poured it into depressions in the ground, creating open swamps and ditches of radioactive mud, liable to evaporate in the dry air and send particles airborne in one of Hanford's frequent dust storms.[22] The DuPont medical team took readings of the swamps and found the radioactivity to be high (6.5 millirems an hour). Stone, in Richland for a visit in February 1945, tried to put a stop to the practice, but it was too late. Workers continued to dump low-level waste into open trenches for decades.[23]

DuPont engineers also dug "reverse wells," deep holes into porous underground strata, to dump medium-level waste. Overstreet and Jacobson were concerned about this plan, too, and arranged to consult with DuPont engineers on the wells. DuPont engineers were happy to have the help and eagerly provided information and more soil samples. Overstreet and Jacobson saw problems in pumping waste into the ground near underground aquifers and foresaw that the soil would draw in and hold radioactive isotopes for as long as it took them to decay.[24] The two scientists experimented by growing peas and barley in contaminated topsoil. They found that plants eagerly drank up radioactive isotopes. Overstreet and Jacobson found to their surprise that there were higher concentrations of fission products in the plant roots than in the surrounding soils and that even relatively small concentrations damaged plants. "Contamination of the soil," the scientists warned, "may result even at very low levels in dangerous amounts of radioactivity in edible crops."[25]

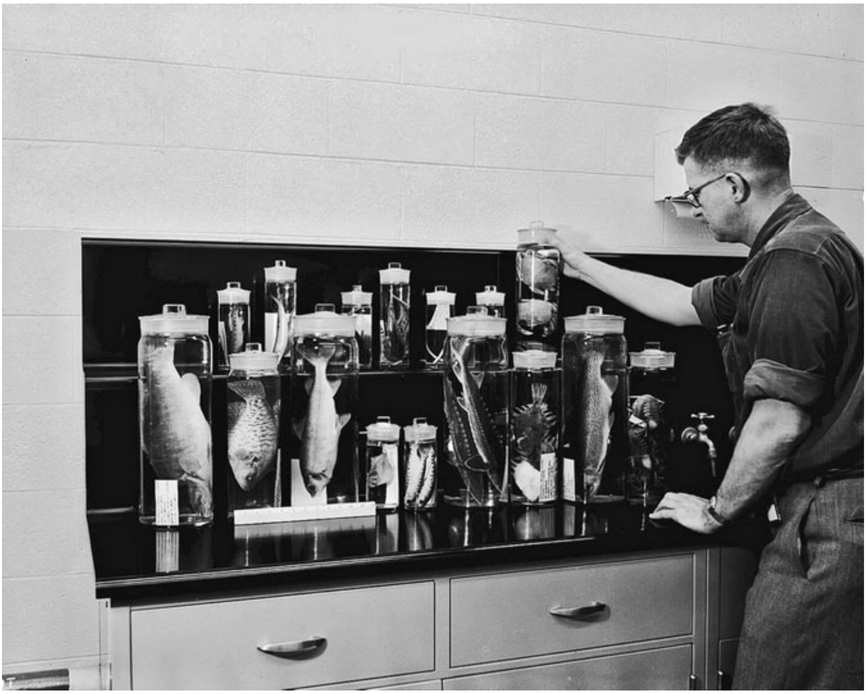
All of this news ominously contracted the diffusion theory upon which Hanford waste management was premised, but plant managers made no changes in design or practice. While Jacobson and Overstreet in Berkeley studied the problem of reverse wells, Stone visited Hanford and learned that they had already been installed. He wrote Hamilton: "They have no present intention of changing this [reverse well design] in any way unless tests of waters from various wells indicate that contamination is occurring."[26] Just a few months later, the first incident of radioactive contamination of drinking water occurred, as Overstreet and Jacobson had predicted. Even then, however, engineers made no changes to the reverse wells. The head of Hanford's Health Instrument Division, Herbert Parker, pledged only to monitor the wells more closely. In subsequent years, plant operators continued to dump radioactive waste into deep holes, and the soil studies were forgotten. A decade later, Parker characterized the Hanford site as one "admirably suited to the disposal to ground of large volumes of liquid wastes," as if Jacobson and Overstreet had never walked the earth.[27]

Symbols sometimes play larger in human imagination than complex realities do. When people from afar thought of the Columbia River Basin, they thought not about factories burping high-tech contaminants. Rather, they thought of salmon—the majestic, determined fish that made their way against the crashing waterfalls of the mighty Columbia to their spawning places deep in the abdomen of the arid interior West.[28] If something were to happen to the salmon, then the game would be up for the Hanford Engineering Works, for DuPont, and for the Army Corps of Engineers.[29] Plant designs called for large pumps to channel river water through the reactors to cool them. This volume of water was colossal: thirty thousand gallons a minute flowed through a reactor core. After the water became effluent, warm in temperature and hot in radioactivity, it was allowed to cool for a few hours and then pumped back into the Columbia River. Aware that the Hanford plant would be the only upstream polluter on the Columbia, Greenewalt requested in 1943 that an ichthyologist come to Hanford to study the effect of radioactive effluent on salmon that spawned near the plant.[30] A few months later, Lauren Donaldson started a program in his lab at the University of Washington where he radiated salmon, as eggs, as spawn, and as mature fish.

In a random file in the National Archives I came across a series of small photos, glossy three-by-five snapshots, of Columbia River salmon exposed to X-rays. At 100 rads, the fish in the first-month alevin stage, in which salmon fingerlings live off their yolk sacs, appear normal.[31] At 250 rads, there is something funny about the fingerlings. Scientists reported "evidence of disorganization." The photos show yolk sacs bulging, the fish thinning.[32] At 1,000 rads the bodies of the fish have shrunken radically, given over to a tumor-like growth in the abdomen. At 10,000 rads the fingerling's eye is blotted out, blanched from cataracts. The twiglike body holds up a swollen yolk sac. Inside bobs a shiny black growth. The fingerling swims mouth agape, gasping. At all levels of exposure above 500 rads, the fish soon died.[33]

But 500 rads is a high exposure, far higher than salmon would get swimming directly downstream from the plant's effluent pipes.[34] The first results, though sad to look at, were good news for fish researchers, showing that it took a high dose of gamma rays to harm the valuable salmon.[35] As Stafford Warren admired the complicated halters Donaldson had devised in his Seattle lab to pinpoint gamma rays on fish, researchers in Chicago tried something experimentally less elegant but more to the point: they dumped goldfish in various diluted solutions of Hanford waste and watched the fish as they sucked the effluent through their gills and fed on microscopic algae and plankton in the water. The Chicago researchers found that fish concentrated radioactive elements in their bodies at levels a shocking ten to forty times higher than the amounts in the water in which they swam. This was troubling news, since once inside the body, radioactive particles could do much more damage to vulnerable organs and cells than from outside the body.[36]

Donaldson replicated the experiment with Columbia River trout and salmon. On the high bank over the Columbia, each of the three reactors had large basins, where reactor effluent cooled before descending to the river. Donaldson set up



Fish laboratory at Hanford. Courtesy of Department of Energy.

fish troughs outside the basins and pumped in effluent mixed with clean river water in various dilutions.[37] Dumped directly into reactor effluent, the fish died. But in diluted water, the fish initially thrived, multiplying rapidly and outgrowing the tanks. Richard Foster, Donaldson's assistant, sacrificed some of the salmon. His autopsies showed that the fish behaved just like peas, barley, algae, bone marrow, and thyroid glands: they sucked in the radioactive isotopes hungrily, so eventually the concentration of radioactivity in the bodies of the fish exceeded by up to sixty times that of the water in which they swam.[38]

In the summer of 1945, Foster reported that the fish in the test troughs had external parasites and bacterial infections. Then Foster reported that on two days—July 27 and again on August 31—the fish died in mass "kills" in effluent diluted with three parts river water.[39] At the time, racing to produce plutonium before the war ended, the reactors were issuing as much as 900 curies a day into the river. Foster had no idea about the production speed-up and consequent spike in radioactivity in the river, as this was classified information. He puzzled over the substance in the effluent that was lethal to fish. Apparently he never figured it out. Perhaps if Foster had talked to the mice and monkey researchers, who by then had communicated with the doctors treating the TB outbreak at Oak Ridge, the scientists together might have discerned a pattern of immunological weakness. As it was, however, only a handful of top Manhattan Project officials were getting the whole arsenal of medical reports from various locations, and these men were inclined to judge the results in the most optimistic light.

So Foster's fish studies were filed away, as were Overstreet and Jacobson's soil reports, buried near the troubling studies on fruit fly genetics, meteorological surveys, and the metabolism of plutonium in mice and dogs. All these reports landed in the vast textual reverse wells of the Manhattan Project, into which information went and never came out.[40] If anyone had had the time and stamina in that harried wartime era to read all the reports, he or she might have noticed that the studies showed researchers across the medical research division coming independently to similar conclusions: that radioactive isotopes sought to attach themselves to living organisms, making their way up the food chain. This was bad news for those creatures at the top of the chain.

9

Of Flies, Mice, and Men

By early 1945, Manhattan Project leaders knew quite a bit after these first years of research. They knew the parameters of damage from exposure to various radioactive isotopes and the pathways those isotopes took into the body. They learned that the most troubling radioactive isotopes were those with long half-lives, and that once they were in the soil and in living organisms, they were difficult to detect and dislodge. Once those isotopes had made their way into bodies, the researchers learned, their radioactivity destroyed cells; caused cancers; resulted in problems in the immune system, the digestive system, and the circulatory system; and accelerated aging and death—all in random, unpredictable ways. They grasped that this research must be closely held, for once contractors and employees, already worried about "unknown amounts of product in the body," found out about the studies, they might panic.[1]

In the summer of 1944, DuPont's Roger Williams wrote to General Leslie Groves in just such a panic. Williams noted that in the previous months they had come to an astonishing realization—that the "most extreme health hazard is the product itself." "It is now estimated," Williams wrote, "that five micrograms (0.000005 grams) of the product [plutonium] entering the body through the mouth or nose or by skin absorption, will constitute a lethal dose. The poisonous effect of the product is cumulative, i.e., product entering the body is permanently absorbed and effective, like radium."[2] In the margin next to this passage, a Manhattan Project medical officer, probably Hymer Friedell, wrote, "Wrong."

That was the contested issue—how large a dose was "lethal." Williams was writing based on preliminary research results from Manhattan Project labs, and at least from rumors of research like Hamilton's on mice and dogs and Donaldson's in-house work on fish.[3] Williams concluded that if plutonium and other radioisotopes accumulate in sensitive areas of the body—bone marrow, thyroid, liver, kidney, lungs, and spleen—then even the smallest dose stood a chance of damaging cells and triggering the growth of cancerous tissue or genetic mutations. Manhattan Project medical officers, however, looked at the same results another way. Researchers blasted the bodies of fish, mice, and dogs with increasing doses of radioactive isotopes and noted that the lab animals succumbed only after very high doses. At medium doses, the scientists detected cellular changes and a certain weakness in the "material specimens." At low doses, they could detect no changes other than the presence of radioactivity in tissues, organs, and bones.[4] Extrapolating from these experiments, they reasoned that there was a "tolerance dose," below which it was reasonably safe for humans and animals to dwell. This was the only conclusion Army Corps of Engineers officers could draw in order to continue their unswerving course toward winning the war with nuclear weapons. If they were to conclude, as geneticists insisted, that no dose was safe, then the whole nuclear enterprise was folly.[5]

Although the lab results were grim, the experience in the new nuclear zones was less so. Workers were not falling ill, at least not in epidemic numbers. There was no great spike, though they watched for it, of stillborn babies or babies with deformities.[6] Animals and birds did not disappear from the sites.[7] Fish continued to swim up and down the Columbia River, even through exceptionally warm water that was "milky in appearance."[8] It's true that there were fewer fish from one inspection to the next, but the cause was "impossible to account for."[9] There was an outbreak of tuberculosis at Oak Ridge, along with cases of workers with skin ailments that refused to heal, which Warren learned were "definitely related to work" at the Oak Ridge plant.[10] Several uranium miners mysteriously died.[11] Two soldiers were rushed from Hanford to a Walla Walla hospital for kidney pathologies in the summer of 1945.[12] And there was a rash of employees whose lab reports were couriered about Medical Section offices. Medical personnel discussed whether to reassign these workers to safer work or terminate them "to protect the interest of the Government and Contractor against possible claim for compensation."[13] But these cases are just footnotes in the highly cleansed, declassified files, relatively minor incidents in the larger scheme of the vast project.

When, just to make sure, Manhattan Project doctors injected plutonium into eighteen unwitting human subjects and polonium into five more unsuspecting patients, first at Oak Ridge and Rochester, then in San Francisco under Hamilton's direction, the previously healthy, "normal" subjects did not die.[14] Their white and red blood cell counts dropped dramatically, and tests showed that their bodies accumulated plutonium with greater efficiency than the bodies of rats and mice, but the human subjects lived on, and that, too, was promising news.[15] The researchers measured radioactivity in urine and feces, but they did not record how the subjects felt with 50 micrograms of plutonium-239 in their bloodstream or 18.5 microcuries' worth of polonium slipped into their food and descending through their digestive tract. Symptoms and treatments were not the point. The researchers hoped to learn how to measure ingested doses by studying the subjects' urine and feces. This was a "medico-legal" research question related to guessing exposures and thus liability for workplace damages.[16] Family members later told of the intense pain, weakness, depression, vague complaints, and malaise that clouded the subjects' lives afterward, but the human subjects carried on ("very nearly a normal individual," as Hamilton boasted about his "experimental material," the house painter Albert Stevens), and that was a medical triumph as well.[17]

What did Manhattan Project leaders do in the workplace with the research results? They simply carried on, almost as if there had been no research. Robert Stone recommended to DuPont doctors in the fall of 1944 that they completely exclude premenopausal women from work in the plant.[18] Army Corps officers, however, stipulated that DuPont hire women because they feared hiring racial and ethnic minorities.[19] And so in 1944 DuPont recruiters placed young women in the most hazardous jobs in the chemical processing plant.

Once the reactors started up in the fall of 1944, DuPont executives worried about an explosion spreading radiation to the populous Hanford Camp.[20] They sought permission from General Groves to tell workers that they were exposed to radiation on the job and to hold practice evacuation drills.[21] Groves was more worried, however, about security and retaining workers. Groves asserted that if hourly workers learned of the potential dangers, they might quit. To make his argument Groves pulled out a trusted rhetorical device: shifting the scale from DuPont's local and individual concerns to the affairs of the nation ("the best interests of the United States"). The deployment of scale was a common tool in the Manhattan Project—the hazards at nuclear plants were described as no greater than those of the chemical industry and the risks "compatible with the overall urgency of the Manhattan District."[22] Most famously, Groves used scale after the war, arguing that the death of more than two hundred thousand Japanese civilians at Hiroshima and Nagasaki "saved [American] lives."

Manhattan Project workers were subject to regular "medical surveillance." Doctors had permission to inform employees of medical abnormalities only if the maladies were not related to radiation. To contain this knowledge within the trusted group of plant doctors, DuPont managers built up a full-service, low-cost medical clinic in Richland.[23] This kind of New Deal–style medical program directly contradicted DuPont's conservative philosophy, but in this case DuPont managers argued that a subsidized medical program for Hanford employees and their families would be advisable both to maintain control over the plant medical staff and to cover up the distinction between occupational and regular illnesses. The service plan would pay for both and thus "avoid embarrassing situations" and patients' "undue alarm." Writing with that knowing wink of Manhattan Project officialdom, a DuPont manager concluded, "The important value of this feature can be readily understood."[24]

Left in ignorance, however, workers worried "continually" about the reason for the urinanalyses, the blood tests, and the teams of safety monitors passing through the sterile-looking cement halls with ticking equipment.[25] Workers guessed that something was awry, all the more so because of the secrecy, mystery, compulsive cleaning regimen, fences, gates, alarms, and guards. So once Groves decreed that workers would be left in the dark, those workers had to be convinced that they were safe, and in this way public relations gradually overtook public health.

Instead of education about jobsite hazards, in 1944 Matthias started an annual extravaganza, called the Safety Exposition, that repackaged the dangerous plant as a beacon of safety. The Safety Exposition combined entertainment with exhibits promoting jobsite safety. To get workers to attend, the exposition featured concerts, dance troupes, door prizes, and a beauty contest electing a Safety

Hanford Safety Exposition, 1952. Courtesy of Department of Energy.

Queen. The chief purpose of the event, Groves emphasized, was to "build up morale" so that workers would stay on the job.[26]

In the fall of 1944, when DuPont engineers started up the first B reactor, six months behind schedule, Groves was in a great rush. By that time, it was clear that Germany would be defeated. Manhattan Project intelligence also reported that German physicists would not produce an atomic bomb.[27] Nonetheless, Groves raced to produce a bomb before the war ended so that he would not be left with a $2 billion tab and nothing to show for it. In his haste, Groves demanded that DuPont engineers begin transforming spent uranium fuel into plutonium before the processing plant was finished. DuPont engineers had designed the processing plant for safety, with robotic devices, underground chambers, and massive cement walls to shield workers from dangerously hot radioactive solutions. Beginning the processing early would mean working in "make-shift laboratories," DuPont's Roger Williams pointed out, exposing workers to radioactive hazards in "chance-taking" operations.[28]

In resisting Groves' urgent demands, DuPont had a problem. In 1943, Crawford Greenewalt had promised Groves that he would have the entire plant finished by the end of 1944. As I have shown, however, discriminatory hiring practices had slowed construction progress, and by the summer of 1943 Greenewalt knew he would miss this deadline, as he had failed to meet the earlier construction targets for the first reactor. DuPont managers repeatedly tried to delay the completion dates, with Groves resisting: "I am still unwilling to accept such a setback." For DuPont executives, the construction delays were nothing but "embarrassing," which gave them little room to negotiate when Groves asked for shortcuts that sacrificed safety.[29] Consequently, in the fall of 1944 DuPont executives agreed to manufacture plutonium before the processing factory was finished, employing young women in makeshift labs, with all the extra hazards that would entail.[30]

Groves was still unhappy. By February 1945, the processing plant, finally up and running, was only producing 250 grams of plutonium a day. Desperate for a bomb, he ordered DuPont managers to speed production by pulling irradiated uranium fuel rods out of the cooling ponds after only five weeks, rather than the three months required to allow short-lived radioactive isotopes to decay. That decision meant that the plant issued four times the usual amount of deadly radioactive isotopes, all of which spilled onto the ground, into the Columbia River, and into air masses that floated south and east over the Columbia River, across farmland, and then on to Walla Walla and Spokane. The most troublesome short-lived radioactive isotope was iodine-131, a problem because it selectively deposits in the thyroid.[31] Because of the shorter cooling times, plant releases of I-131 from the stacks soared in the first half of 1945, from a few hundred curies a month in January to 75,000 curies a month by June.[32]

Herbert Parker, in charge of radiation monitoring at Hanford, noted that iodine vapors built up on surfaces downwind from the stack, but Parker was not one to get easily alarmed. He added that the extraordinarily high releases were not a "critical hazard." "In the interests of morale," he concluded, "it may prove more desirable to restrict the evolution of fumes under certain atmospheric conditions."[33] Not surprisingly, Parker's mild recommendation went unheeded. Emissions of I-131 climbed the rest of the summer and soared even higher after the war ended—inexplicably higher, since all managers had to do was hold irradiated fuel cells in the cooling bins an extra month, presumably not a problem because Japan had already surrendered.

Once released, the plumes of radioactive iodine traveled great distances largely undiluted. In December, Parker's monitors recorded levels of radioactive iodine on shrubs and trees in Richland and neighboring Kennewick that were six times higher than the already liberal tolerance dose.[34] In Walla Walla, they found that ground contamination from radioactive iodine equaled that of the soil right next to the processing plant.[35]

Repeatedly there was an institutional impenetrability, as if research on the biological effects of radiation was conducted in isolation from plant operations. Why did Manhattan Project managers bother with research if they were likely to ignore the results? There are some clues as to what they were thinking. In 1960, Matthias wrote Groves about the genesis of the fish program. Matthias erroneously attributed Greenewalt's fish program to Groves, calling it "a brilliant tactical move." "I am convinced," Matthias continued, "that we would have had a very bad time with the fish people after August 1945 if we had not been able to demonstrate so conclusively that we had considered the salmon problem a serious one and had produced much evidence to show the effects were not serious."[36]

Likewise, in the summer of 1945, Herbert Parker was reluctant to begin regular urinanalyses of Hanford workers because at other Manhattan Project sites, such tests had "led to considerable alarm" among those who received positive results. Nonetheless, Hanford workers worried about plutonium in their bodies. It would be good for "plant morale," Parker reasoned, to begin a testing program, but if the results were positive, then he would have an even greater morale problem. Parker worked his way out of this snare by devising a plan to test workers after long weekends.[37] Testing after several days' leave gave workers time to urinate the most radioactive samples safely into their toilets at home—another brilliant tactical move.[38] With urinanalysis, workers felt safer, especially when the results were negative, and that was good for morale. Like the early environmental studies, medical research had a validating public relations function, useful when dealing with nervous workers toiling on the hazardous frontier of the atomic age.

At other times, Manhattan Project officials deployed medical research because of concerns with liability. Take the case of Donald Johnson, the DuPont engineer who came down with acute leukemia after just eighteen months of working with radioactive substances. During his employment, Johnson's urine and blood had been monitored. Medical Section doctors could confidently show that Johnson had received doses no higher than the tolerance dose at the time. Johnson's first autopsy showed significant radioactive contamination, but the second set of tests came back negative. Stafford Warren, chief of the medical section, was happy with the second report, and, in a rare recorded moment he revealed the urge not to see by ordering that the report of the first, troubling autopsy be purged from the files. Without that report, there was no evidence that Johnson's leukemia had anything to do with radiation.[39]

When Johnson's wife later attempted to sue for compensation, she did not know that her husband's case would never—could never—come to trial. In June 1943, DuPont and the Army Corps had made a secret deal with officials of the Washington State Department of Labor, who pledged to redact from workers' files information that would threaten the plant's secrecy. They also agreed that workers' lawsuits would not go to civil court but would be heard before a special tribunal consisting of representatives of the federal government and the contractor.[40] In the tribunal, the federal and corporate counsel, thanks to the medical research division of the Manhattan Project, would have submitted a wealth of carefully selected and edited reports by reputable doctors at prestigious universities, making for a bulletproof defense.[41]

By the spring of 1945, Matthias, Greenewalt, and other officers and corporate managers assigned to produce plutonium had accomplished a great deal. In the course of two years, they had built a series of factories and the world's first industrial reactors for plutonium production. They had demolished three towns and built in their place two new cities and a labor camp from the ground up, the larger city, Hanford Camp, already bulldozed as well by mid-1945. They had created Richland, a new kind of community of white nuclear families, subsidized by federal coffers, managed by corporate lawyers with a planned economy and carefully controlled access. They had also created a medical and environmental monitoring program that produced worrisome but classified studies. In the public realm, on the other hand, public health and public relations programs successfully placated anxious workers.

In just two and a half years, Manhattan Project leaders furiously invented new technologies, new communities, and novel ways of living that would radically alter postwar American society. One fact, however, General Groves and his staff did not learn. They did not know in 1945 that many of the secrets they had worked to contain had already left the country. The Soviet allies, who were a major target of Manhattan Project counterespionage, already knew a great deal about the American bomb and the cities created to build it.

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