Hanford's Nuclear Wasteland

by Glenn Zorpette, *staff writer*

Over the next 75 years, the U.S. government will undertake what has been called the largest civil works project in world history in an expansive desert in southeast Washington State. When the project is over, at a cost of well over $50 billion, there will be no sprawling rocket-launch center or string of advanced electricity-generating plants or other inspiring monuments to progress. What there will be, mostly, is radioactive detritus, millions of tons of it, ranging from contaminated soil to entire nuclear reactors. It will all be on a large plateau, buried in vast landfills or stashed away in a collection of nondescript buildings. And there it will stay, probably for thousands of years to come.

Such is the future of the Department of Energy's Hanford site, the original U.S. plutonium-production complex and the source of the plutonium used in the bomb detonated over Nagasaki, Japan, during World War II. From those early days of military and technological glory, the 1,450-square-kilometer Hanford site has slowly devolved into a nightmarish agglomeration of decaying, contaminated facilities that each consume tens of millions of dollars a year just to be kept stable or safe.

In 1989 the DOE began deactivating and cleaning up Hanford. At last count, there were about 14,300 contractor workers and 550 DOE employees at the complex, and an estimated 1,400 different places where environmental work had begun or was needed. At several hundred of these sites, liquid or solid nuclear wastes had been intentionally dumped: since 1944 the DOE and its predecessors are believed to have pumped 1.3 billion cubic meters of liquid waste and contaminated effluents into Hanford's soil.

Over the past seven years, the DOE has spent $7.5 billion cleaning up Hanford. It expects to spend at least $1 billion at Hanford every year for the next four decades. The cleanup has attracted far-flung interest, and not just because of the sums involved. "This is absolutely brand-new—not only to industrial society but to humankind," says Roy E. Gephart, a program manager in the environmental and energy sciences division of Battelle Pacific Northwest National Laboratory in Richland, Wash. "There will be difficult political, social and technical trade-offs as we approach cleaning up this site."

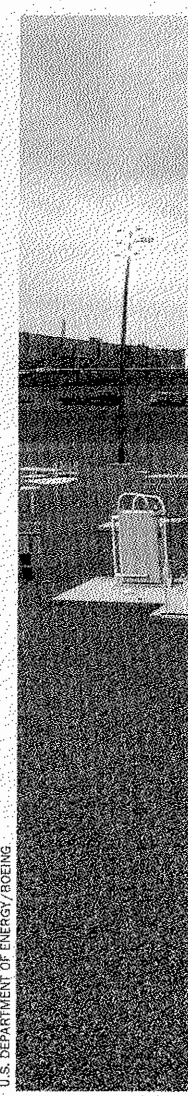
In an effort to determine how well the cleanup is proceeding, SCIENTIFIC AMERICAN examined several dozen recent reports and other documents, some not yet officially released, and conducted scores of interviews with cleanup workers, administrators and scientists at Hanford as well as with key DOE officials and others in Washington, D.C. The picture that emerges from this research is not encouraging. In addition to the contaminated soil and water, dozens of potential disasters vie for attention, including:

- 177 huge underground tanks of high-level nuclear waste, some of which have leaked or are building up heat or flammable gases;
- At least a dozen tons of dangerous plutonium, some of it in the soil or otherwise unsecured;
- Five gigantic and profoundly contaminated buildings where plutonium was extracted from irradiated nuclear fuel;
- 2,100 tons of irradiated fuel, in basins that in an earthquake could become lethal, radioactive dustbins.

Not surprisingly, questions have been raised about virtually every aspect of the Hanford project. They concern whether the work is being done properly and efficiently, how cleanup contracts are being written and the possibility that a mishap could cause a radiological disaster. The most significant accomplishment of the past seven years may be an arrangement that has enabled parties with conflicting interests—principally the state, the DOE and the Environmental Protection Agency—to begin working with one another. Unfortunately, adherence to the agreement has hindered planning and priority setting, several studies have found.

"We've been on this cleanup effort for six years, and we're still not out of the starting block," states a scientist who has worked at Hanford for two decades. "No program—for tank cleanup, groundwater remediation or anything else—has lasted more than about two years. We're not sustaining a long-term vision, and investment in that vision, long enough to make any progress."

Cold War Leftovers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Huge as the Hanford project is, it is just one piece—about a fifth—of a DOE program to close down a large part of its vast nuclear-weapons enterprise over the next century, give or take a few decades. Estimates of cleanup costs range from $230 billion to more than half a trillion dollars—well in excess of the $375 billion it cost, in current dollars, to research and build the tens of thousands of weapons that were assembled in the U.S. and to detonate the 1,000 or so that were tested. Government officials expect to spend fully 70 percent of the money on just five DOE sites, including Hanford.

The imprecision of the time and cost estimates results in part from the lack of agreement on how "clean" the former weapons sites will need to be on that far-off and probably chimerical day when they are formally declared rehabilitated. "There can't be

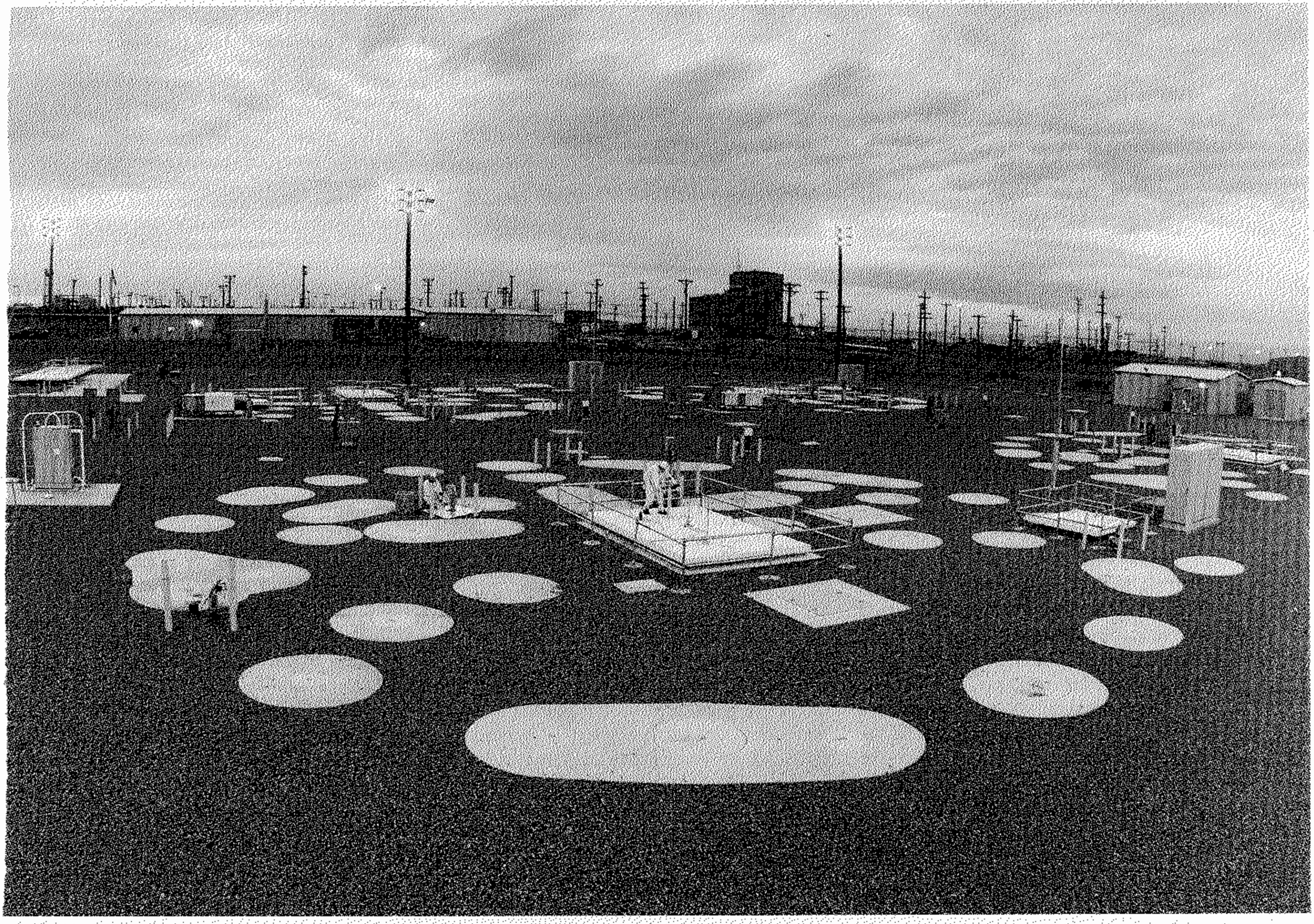
The U.S. is spending billions to clean up its nuclear weapons complexes. At one of the most contaminated sites, no one knows how much the project will cost, how long it will take or how much good it will do

cleanup in the traditional sense, like you clean up a kitchen floor or a hazardous chemical site in the civil sector," notes James D. Werner, director of strategic planning and analysis in the DOE's Office of Environmental Management. "The stuff we're dealing with can't go away until it decays. You can containerize it, solidify it, immobilize it and move it, but you can't make it go away."

Understanding how and why this colossal mess was created requires a bit of history. Starting with the Manhattan Project, the U.S. assembled an enormous industry for manufacturing nuclear weapons. A great deal of the enterprise was devoted to making plutonium, a basic element of nuclear weapons and the cold war's coin of the realm. The metal is derived from uranium, which was processed or fashioned into nuclear fuel at complexes in the states of Idaho, Kentucky, Ohio and Tennessee.

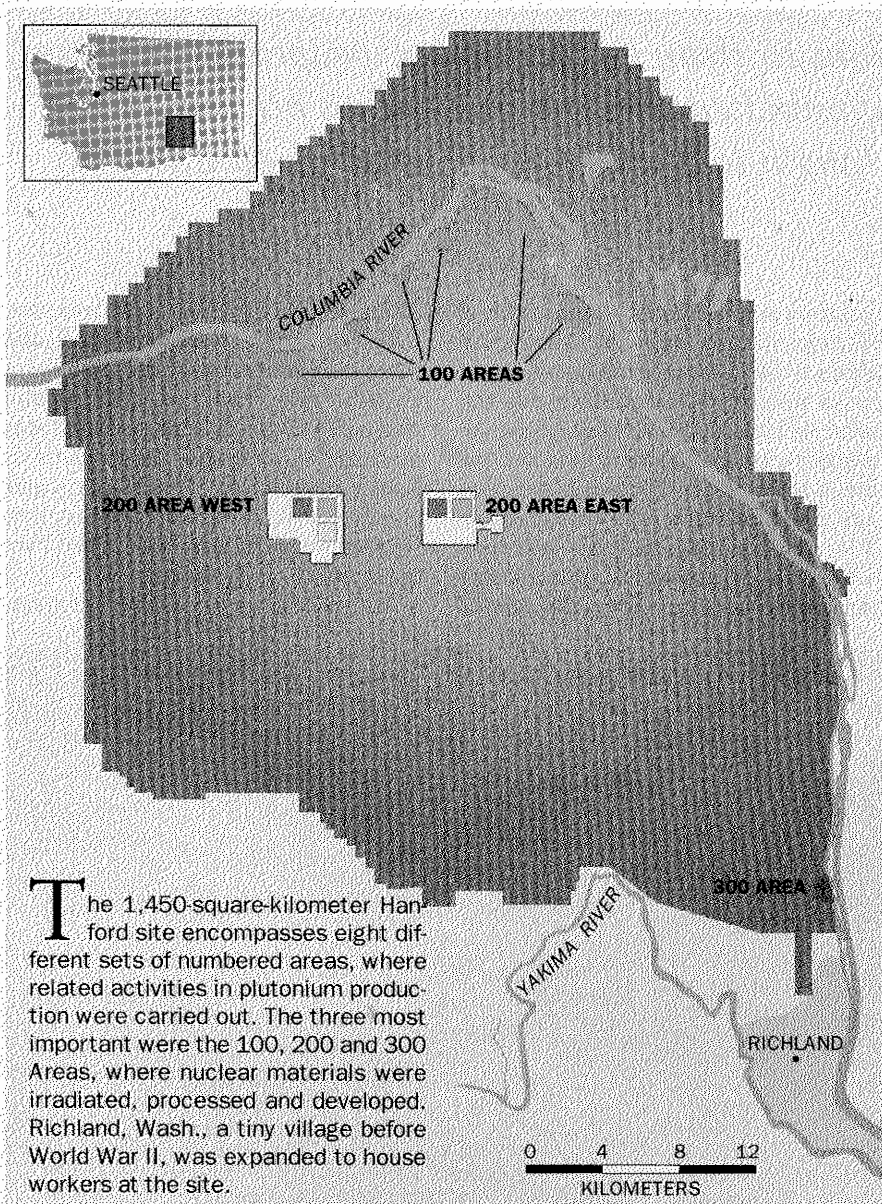
The uranium was irradiated and chemically treated to create plutonium at sites near Hanford, Wash., and Aiken, S.C.; the plutonium metal was machined into bomb components at Rocky Flats, Colo. Those parts came together with hundreds of others into finished weapons at a plant called Pantex in the Texas Panhandle.

At these sites, the cold war ethos em-



HIGH-LEVEL NUCLEAR WASTE TANK sits about three meters underground. Ports and risers admit instruments for monitoring and sampling of the waste. These entry tubes are normally sealed by the plates visible in the photograph.

How Hanford Became Contaminated: Some Examples



The 1,450-square-kilometer Hanford site encompasses eight different sets of numbered areas, where related activities in plutonium production were carried out. The three most important were the 100, 200 and 300 Areas, where nuclear materials were irradiated, processed and developed. Richland, Wash., a tiny village before World War II, was expanded to house workers at the site.

MICHAEL GOODMAN

NUCLEAR REACTORS
All but one of Hanford's nine nuclear reactors, which created plutonium in fuel rods, drew water from the nearby Columbia River, ran it through the reactor to cool it and then discharged the water back into the river. When fuel claddings ruptured, radioactive elements contaminated the water, which was diverted to the soil and flowed back to the river. All the reactors also had nearby burial grounds, where workers dumped solid objects, including some extremely radioactive ones.

REPROCESSING CANYONS
Five reprocessing canyons were built (three in 200 Area West and two in 200 Area East) to extract plutonium from irradiated nuclear fuel. Workers poured millions of cubic meters of relatively lightly radioactive and chemically contaminated wastewater into the soil. In the 1940s and early 1950s, more strongly radioactive wastes from one plant were injected hundreds of feet below ground. At the same time, large quantities of radioactive iodine were released into the air from two plants.

HIGH-LEVEL WASTE TANKS
A total of 177 tanks (91 in 200 Area East and 86 in 200 Area West) store 210,000 cubic meters of highly radioactive nuclear waste, a by-product of reprocessing. Sixty-seven of the tanks are known or suspected of having leaked an estimated 3,700 cubic meters of the intensely radioactive waste into the soil.

PLUTONIUM FINISHING PLANT
From this plant, wastes containing transuranic elements, such as plutonium and americium, were pumped into the ground. Many industrial solvents and other chemical contaminants were also discharged, including carbon tetrachloride, tributyl phosphate, aluminum fluoride nitride, and lard oil (the latter was used as a cutting oil in the machining of plutonium metal).

EXPERIMENTAL FACILITIES
A plutonium laboratory, nuclear-fuel fabrication facilities and six small test reactors all occupy what is known as the 300 Area. Waste and uranium-bearing liquids were sometimes discharged into the soil from the laboratories and facilities, as were contaminated coolants from the reactors.

phasized production above all else. Starting with the Atomic Energy Commission in the 1940s, the agencies that oversaw the weapons complexes were essentially unconcerned with environmental degradation. (Nor, it seems, did Congress pay it much heed.) The DOE and its predecessors answered to no outside regulators and, it is now known, obscured or lied about operations and conditions inside the complexes.

A turnaround began in the mid-1980s, when a series of landmark rulings in federal courts established the applicability of state and federal environmental laws and regulations to DOE activities. (Notably, however, the DOE continues to regulate itself where certain nuclear materials, such as uranium and plutonium, are concerned.) During the late 1980s, newspaper investigations began offering the first hints of the extent of the contamination inside some of the complexes, intensifying the pressure on the department to fundamentally change its activities with regard to the environment and safety.

For the DOE, becoming an externally regulated entity was difficult and sometimes traumatic. At the Rocky Flats complex near Denver, where the department's contractors machined plutonium, allegations of secret violations of environmental laws and dangerously deteriorating conditions prompted a federal raid in 1989 and a subsequent lawsuit against the plant's main contractor, Rockwell International. In a plea bargain, Rockwell paid $18.5 million, and the charges were dropped.

At about the time of the Rocky Flats episode, the DOE formally faced the inevitable by creating the Office of Environmental Management (which expanded on the existing Office of Waste Management). This year Environmental Management will receive $6.026 billion of the DOE's total budget of $16.3 billion ($3.4 billion still goes toward weapons work). In comparison, the entire 1996 budget of the EPA (not finalized at press time because of the federal budget impasse) is likely to be $5.7 billion. In effect, the DOE is being painfully transformed into a huge environmental agency that has so far shown little aptitude for its core mission.

Only lately, as part of Energy Secretary Hazel R. O'Leary's initiative to make the DOE more open about its past and present, has the department begun revealing the extent of its transgressions. The DOE and its contractors generated hundreds of thousands of cubic meters of highly radioactive and hazardous waste and billions of cubic meters of less radioactive effluents. The DOE now admits that enormous amounts of the liquids and solids were simply pumped or dumped into the ground. Most of the wastes contain both radioactive and chemical contaminants.

At some places where releases were intentional, scientists tried to estimate how much contaminant the soil above the groundwater could adsorb; operators were then supposed to limit discharges to 10 percent of that amount. Judging from the groundwater problems at most large DOE complexes, the technique was rarely or inadequately applied. In recent years, a series of liquid-effluent treatment plants have begun operating to clean up the discharges before they go into the ground.

There were accidental releases of waste, too. Almost all are attributable to carelessness: high-level radioactive wastes sometimes leaked from aging storage tanks into the soil, as did contaminated water from basins containing spent nuclear fuel or other materials. Millions of curies of potentially harmful radioactive materials were also released into the air and nearby river water at Hanford and other sites, sometimes intentionally.

Some of the damage is permanent; cleanup technologies either do not exist or could never make a dent in the level of contamination. For example, at Hanford, a plume of groundwater containing tritium, nitrates and other contaminants occupies at least 250 square kilometers and is leaching into the Columbia River, which runs for 82 kilometers through Hanford. It is practically impossible to separate tritium, a radioactive isotope of hydrogen, from water. The contaminated plume is only one of dozens below the site.

The DOE estimates that throughout all the weapons complexes, billions of cubic meters of soil, groundwater and surface water are contaminated. Along with their counterparts in the former Soviet Union, these are the grievously disturbed battlefields of the cold war.

Nightmare in 177 Tanks

The DOE has been working longest to stabilize and remediate Hanford, making the site a proving grounds of sorts for the many other complexes where work is less advanced—including those in the former Soviet Union. This year $1.353 billion of the Environmental Management budget, the largest share, will go to Hanford; by the end of this fiscal year, almost $9 billion will have been spent at Hanford on work designated as environmental. The lack of apparent progress, however, has prompted many observers to wonder where exactly the money has gone.

The simplest reason why so little progress is apparent is that, unfortunately, the remediation of contaminated soil and water is one of the least urgent items on Hanford's agenda. Of the many other, more pressing issues, the 177 high-level waste tanks are the biggest, most complex and most costly by far. One contractor has estimated that this job alone could cost $50 billion. Nevertheless, until quite recently, the tank farm was tended by some of Hanford's worst workers. It was "a Siberia for a lot of derelicts on the site," says Roger F. Bacon, Westinghouse Hanford Company vice president in charge of the tank program.

To instill discipline in the program, Westinghouse Hanford recently brought in Bacon, a tall, broad-shouldered former navy admiral and submarine commander who looks the part. Bacon, who wrote the forward to one of Tom Clancy's books, now has in the tank-waste project a mission far more daunting than anything ever dreamed up for a techno-thriller. The tanks, many the size of the U.S. Capitol dome, store 210,000 cubic meters of intensely radioactive, high-level nuclear waste. Almost half of Hanford's known accumulation of roughly 450 million curies of radioactivity sit in the tanks—a hellish mixture of liquids, gases, peanut-butter-like sludges and rocklike "salt cake."

Sixty-seven of the 177 tanks are known or suspected of having leaked an estimated 3,700 cubic meters of waste into the soil. Fifty-four tanks are continuously monitored, about half because they occasionally build up flammable gases inside—creating the possibility, though slight, of a radiation-releasing chemical explosion. The DOE spends $80 million a year just to maintain the tanks and keep them safe.

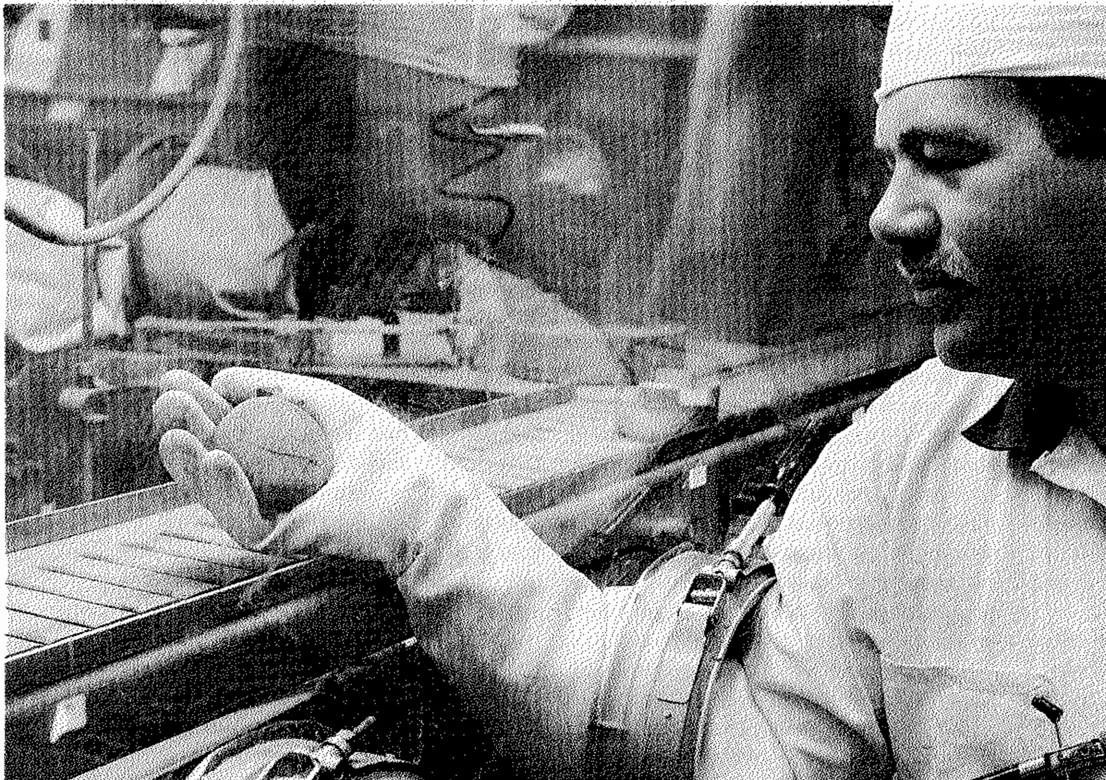
Almost all the tank waste was generated as a by-product of the isolation of plutonium from spent nuclear fuel. Single steel shells covered by reinforced concrete make up 149 of the tanks, including the 67 that have or may have leaked; the rest have more leak-resistant double shells. Although they were intended to hold some radioactive products with half-lives of thousands of years, the tanks were designed to last only 25 years—and were built without any means for draining the waste.

The first of the single-shell tanks were finished in 1944. By 1959, weapons officials at the DOE's predecessor agency knew that some of them had leaked. "Yet they kept building them until 1964 and kept introducing waste into them until 1980," notes Andrew P. Caputo, an attorney with the Natural Resources Defense Council, a watchdog group. "It's hard to explain this history in a rational way."

The tanks contain waste from three different reprocessing technologies. Intermittently, other chemical processes were used to mine the tanks of useful or troublesome isotopes. When some of the tanks started leaking, waste was shifted around from tank to tank—and, inevitably, mixed together—to avoid the leaking vessels.

The DOE is being transformed into a huge environmental agency that has shown little aptitude for its core mission.

The bottom line is that DOE officials do not know exactly what is in the tanks. That information is necessary for several reasons. A legal agreement with the state of Washington obligates the federal government to mix the waste with glass (a technique called vitrification) for eventual disposal in a high-level nuclear-waste repository. But the waste cannot be safely or efficiently vitrified until the DOE and its contractors know its composition. The waste's in-



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PLUTONIUM "BUTTON" was Hanford's sole product. Consisting mainly of the isotope plutonium 239, the buttons were sent to be machined into bomb parts in Colorado. The metal must be handled in glove boxes, such as the one shown here, because extremely minute quantities of the metal in the lung can induce cancer. Currently the DOE has no long-term plans for its plutonium.

gredients may be different even in different parts of individual tanks.

The "tank-waste characterization" program, which seeks to specify what is in the tanks, has been a lightning rod for criticism. "They've been doing this for 10 years and have spent $260 million, and only now are they at a point where they can take samples at a reasonable rate," says William R. Swick, senior evaluator for energy and science issues at the Richland bureau of the General Accounting Office (GAO). Sampling of the tanks is hindered by the high radioactivity and toxicity, which make access difficult and dangerous, and by the waste's multiplicity of physical states and ongoing chemical activity.

Deadly Bullion

Until recently, plutonium was Hanford's raison d'être, but now it is just another big and expensive headache. For 40 years, plutonium nitrate solutions were brought from the reprocessing facilities to the on-site plutonium-finishing plant, where the element was converted into dull, leadlike "buttons," about the size of hockey pucks, for further machining. Eleven tons of plutonium sit in storage at Hanford, much of it under tight security in vaults at the finishing plant. In addition, an estimated 1.5 tons are believed to be in waste dispersed in the soil around the site or in pipes and filters in its facilities.

Plutonium exists in many forms at Hanford. There are tiny scraps of it, and it is present in sludges and in 3,500 liters of nitrate and other solutions. At the finishing plant, workers have begun cleaning out countless air ducts, filters and "glove boxes" where the metal was extracted and handled. They are also bringing plutonium to the finishing plant from other Hanford sites, to consolidate the element in one place. Most of it will be baked into oxides or other reasonably stable, powdery forms for long-term storage. The work is slow and expensive because plutonium is extremely dangerous; a mere 27 micrograms in the lung can bring about cancer.

Workers must also be mindful of the metal's critical mass—which can be as little as 11 kilograms. If the critical mass is allowed to accumulate in one place, a spontaneous fission chain reaction known as a criticality can occur, releasing a lethal shower of neutron and gamma radiation. In the history of the U.S. nuclear weapons program, there have been eight known accidental criticalities and two fatalities, both in New Mexico in the mid-1940s.

Lately, there have been a few close calls (technically, "criticality infractions"). In late September 1994 a worker drained liquid from a tank at Rocky Flats, leaving five liters of highly concentrated plutonium solution in what the Defense Nuclear Facilities Safety Board called "a potentially unsafe geometry." There was also a near miss several years ago at the Idaho site, when some fuel bundles suspended in a pool fell to the bottom near one another.

During the mid-1980s, Hanford's plutonium-finishing plant was declared a serious earthquake risk. One analysis found that a temblor could rend a construction joint, possibly releasing plutonium compounds into the air. This threat has been pushed into the background by other risks and changing priorities.

Plans for disposing of the scavenged plutonium—not only at Hanford but also at Rocky Flats, Savannah River and Pantex—have been stymied by the DOE's inability to decide whether plutonium should be hoarded for possible future use. "The largest factor affecting the cleanup scope relative to plutonium is the absence of a national policy on whether some or all of the plutonium at Hanford is an asset to be maintained in inventory or a waste to be disposed of," wrote analysts Steven M. Blush and Thomas H. Heitman in a recent congressional report on Hanford's cleanup. The DOE spends about $82 million a year maintaining the plutonium just at Hanford's finishing plant.

Costly Canyons

The reprocessing plants, where plutonium was extracted from irradiated fuel before being sent to the finishing plant, are another financial burden. Hanford has five of them, each in concrete buildings called canyons. Some of the canyons are comparable in size to the Empire State Building, if it were lying on its side. Each has internal radiation levels ranging from slight to deadly. Their inner surfaces, air filters and duct systems contain large quantities of dangerous radioactive elements.

In one of the canyons, known as B-plant, room-size air filters may have collected as many as 100 million curies of radioactive cesium and strontium, SCIENTIFIC AMERICAN has learned. Such a vast accumulation of radioactivity will make demolition of the building—as required by an agreement between the federal government and the state—extremely difficult. A better estimate of the radioactivity is not available, because it is so high that "we don't have instruments to measure it precisely," a Hanford scientist admits.

The canyons are heavily reinforced to withstand bombing and have massive shields in the walls to keep the radiation in. Currently maintenance and surveillance at each of the five reprocessing plants costs $35 million to $45 million a year. The DOE and Westinghouse Hanford, however, are attempting to decontaminate B-plant and another canyon, called Purex; they hope to put them into a state requiring relatively little maintenance. (The catchphrase at Hanford is "controlled, clean and stable.") The three-year projects aim to reduce annual expenses to $1 or $2 million a year.

At B-plant, though, about $10 million a year will still be needed to sustain the attached Waste Encapsulation Storage Facility. It houses water-filled pools that cool and shield some 1,900 capsules, each containing either cesium 137 or strontium 90. The isotopes were removed from the high-level waste tanks years ago to make the waste less thermally and radiologically hot.

The isotopes have half-lives of about three decades, but the radiation level at the surface of one of the capsules is enough to deliver a fatal dose in four seconds. The radiation is so intense that its interaction with the water around the canisters causes a bright blue glow, like a gaudy effect in a science-fiction movie. Some analysts have questioned how long the capsules can be kept as they are. Blush and Heitman, for example, wrote last year that "Hanford has no technical basis for assuring that WESF [the encapsulation storage facility] may be relied upon for long-term safe storage of these capsules."

The cesium and strontium capsules are the proverbial tip of the iceberg, in terms of Hanford's inventory of solid radioactive waste. In 40-year-old, water-filled basins near the Columbia River, the DOE and its contractors have been storing 2,100 tons of spent nuclear fuel, much of it corroded and releasing radioactive elements into the basin water. A strong earthquake, it was realized, could release up to 9,000 cubic meters of contaminated water from the basins into the soil and river, allowing radiation in the area above the basins to soar to lethal levels and dispersing fine radioactive particles into the air. In fact, in the 1970s a large quantity of contaminated water did leak from the basins, as did a lesser amount in 1993. (No radiation was dispersed into the air, because the leaks were slow, enabling additional water to be pumped in to keep the fuel bundles submerged.)

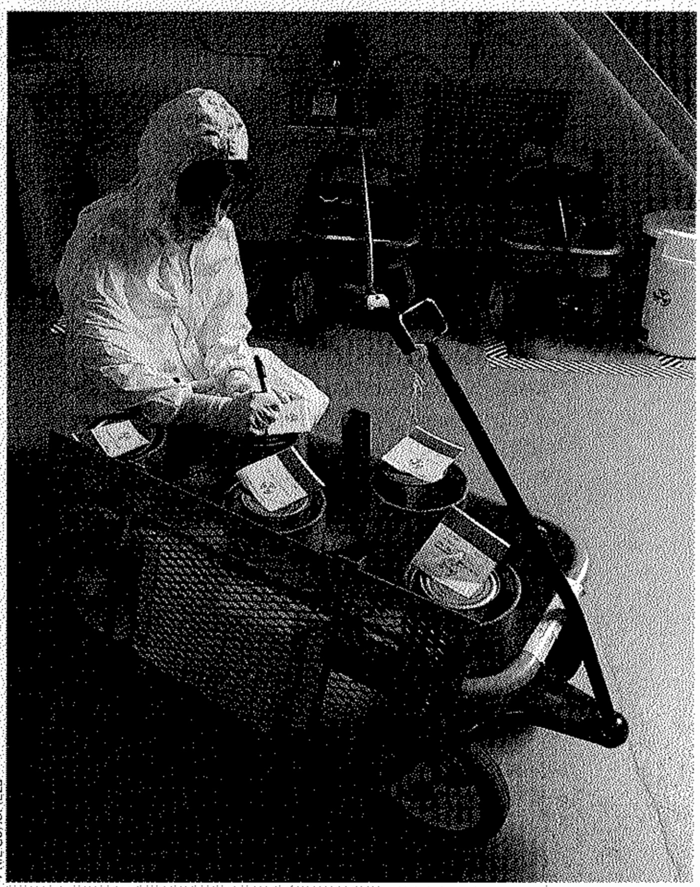
The DOE spends about $30 million a year maintaining the basins in this unsettling state. But a $700-million crash program to convert the fuel for stable, dry storage in an interim repository on high ground is about to begin. When completed, around the year 2000, the maintenance costs are expected to drop to about $1 million a year. As with Hanford's plutonium and cesium and strontium capsules, the ultimate disposition of the spent fuel is uncertain.

A New "Cleanup"

All told, about $600 million of Hanford's annual budget goes toward paying what cleanup officials call the cold war "mortgage"—safely maintaining buildings and plants, many old and decaying, and keeping them from leaking more radiation into the air, water and soil. In addition to the need to spend vast sums paying the mortgage, there are more complex reasons why so little actual cleanup has been achieved.

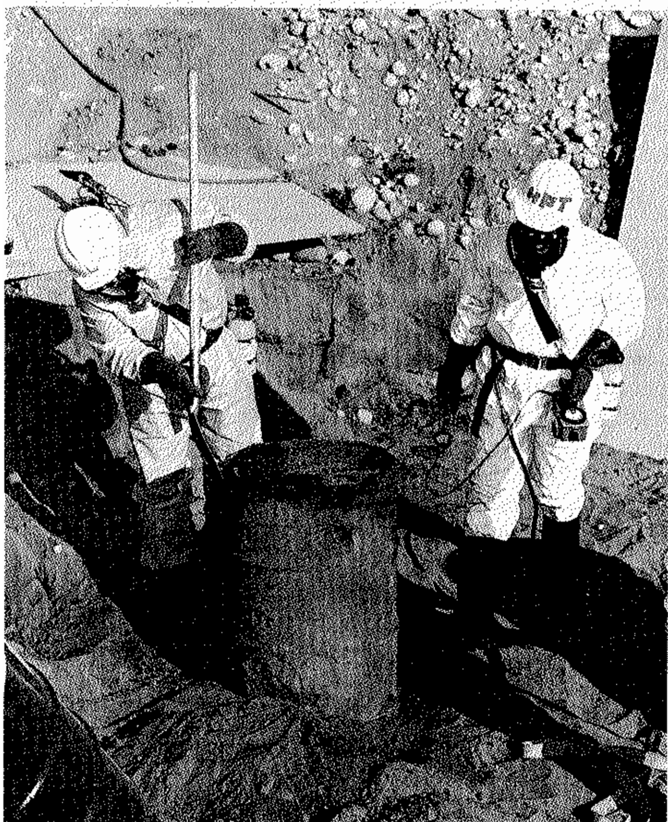
When the DOE's contractors at Hanford are not trying to keep urgent risks from becoming disasters, they are generally rounding up contaminants that were improperly disposed of or that are near groundwater or the river—for the sole purpose of redisposing of them more carefully and systematically in what is known as the 200 Area. This area, which includes the reprocessing plants and the high-level waste tanks, is on a plateau about 75 meters above the water table. Roughly 70 percent of Hanford's waste sites are already on the plateau, so the plan basically involves getting waste from the other 30 percent up there. In some cases, though, "what they are doing is moving a problem and giving it to someone else a generation later," one Hanford scientist says.

Besides being the destination for thousands of tons of waste and contaminants from the soil, the 200 Area will be the site of a storage building, a kind of interim repository, for the 2,100 tons of stabilized spent fuel, as well as another such facility for the immobilized, high-level waste from the 177 giant tanks. Currently an agreement



PHIL SCHOFIELD

TRANSPORTING PLUTONIUM is not child's play, appearances to the contrary. The handle allows workers to be more than a meter from the wagon's contents while pulling it, minimizing exposure to radiation. In addition, the wagon's cylindrical pedestals securely separate cans containing the material, so that an upset cannot trigger a spontaneous nuclear chain reaction.



DRUMS OF CONTAMINATED SOLVENT were simply buried in the soil 35 years ago; most of them decayed and leaked their contents. Unlike many of Hanford's 1,400 waste sites, though, the contamination in the case shown here was relatively confined.

with the state legally requires the DOE to bury in the 200 Area eight of the nine reactor blocks (the cores of the production reactors where the uranium rods were inserted) and their concrete pedestals, sometime around 2070.

Each reactor block and its pedestal comprise an enormous, highly radioactive pair of slabs weighing 15,000 tons. The leading plan for hauling them to the 200 Area involves the use of a $40-million crawling transporter; according to the Blush and Heitman report, one DOE official called the idea "lunatic." The additional costs of moving the reactors—rather than entombing them in place, as many technical analysts favor—have been put at $500 million.

When the hundreds of thousands of tons of waste have been consolidated, stabilized, packaged and redisposed in the 200 Area, basically all the plateau's 130 square kilometers will become a de facto repository, in all likelihood for thousands of years to come. (The short-lived DOE euphemism for such regions was "national sacrifice areas.")

And once this consolidation has been accomplished, how clean will Hanford be? So far specific levels of decontamination, consistent with an intended ultimate use, have not been set at most sites. In fact, the U.S. government still has no standards that can be used to determine when a radiological cleanup is complete. The goal of returning all of Hanford to pristine condition—an utter impossibility made plain by the most rudimentary analysis—has only recently fallen by the wayside. As spokesman Michael V. Berriochoa of Westinghouse Hanford puts it, "There isn't enough money in the world."

Improved Contracting?

Although the peculiar nature of Hanford often defies conventional metrics of cleanup, there is also ample evidence that much of the work done so far has been grossly inefficient. By the DOE's own estimates, cleanup projects started between 1989 and 1994 were 30 to 50 percent more expensive than their equivalents in the private sector.

Because virtually all work at the weapons sites is done by private contracting companies hired by the DOE, the ways contracts are written and structured can strongly influence the cost of work. Unfortunately, the DOE's traditional contracting method, known as a cost-plus or cost-reimbursal system, penalizes efficiency and thrift. Under this scheme, the DOE reimburses a contractor for all its expenses in making a product or performing a service.

Additionally, the DOE gives the contractor a percentage as profit; the more spent, the greater the profit. The system is a holdover from the early weapons days, when the risks and costs were largely unknown and constantly changing. Cleanup personnel may also fear that the harder they work, the sooner they will be unemployed. At Hanford, DOE spokesman Terry L. Brown notes, "you hear a lot of talk: 'I'm working myself out of a job.'"

In 1994, to try to deal with these problems, the DOE and Westinghouse Hanford switched to performance-based contracts. The approach separates huge tasks into a series of more manageable milestones leading to a specific outcome. The contractor's compensation depends partly or wholly on when and how well it meets the milestones. Similar versions are also being implemented at other DOE complexes besides Hanford and also in the contract the DOE has with Bechtel Hanford, another large contractor at the site.

Thomas P. Grumbly, who was assistant secretary in charge of the Environmental Management program until his recent promotion to undersecretary of energy, has high hopes for the techniques. The idea, he adds, is to "work on the economics first and realize that the economics, over time, will really change the system. How much time? I don't know. Four or five years."

Although most observers say performance-based contracting is too new to judge, a former DOE official intimately familiar with the Environmental Management program is pessimistic. To decontaminate a building, the former official explains, a contract would have to specify that "the building contains the following contaminants in the following concentrations. If you don't know what they are, you would have to issue a separate contract just to do the assessment, so you can write a specific enough contract to do the job right. I have no confidence that the DOE can get all the detailed knowledge to make it work. They would have to rely on the contractors themselves to do those assessments, in all probability."

John D. Wagoner, the manager of the DOE's Richland Operations Office, says that the DOE has called in the consulting firm Arthur Andersen to help write the next round of performance-based contracts. (Ironically, the contract with Andersen is not performance-based.)

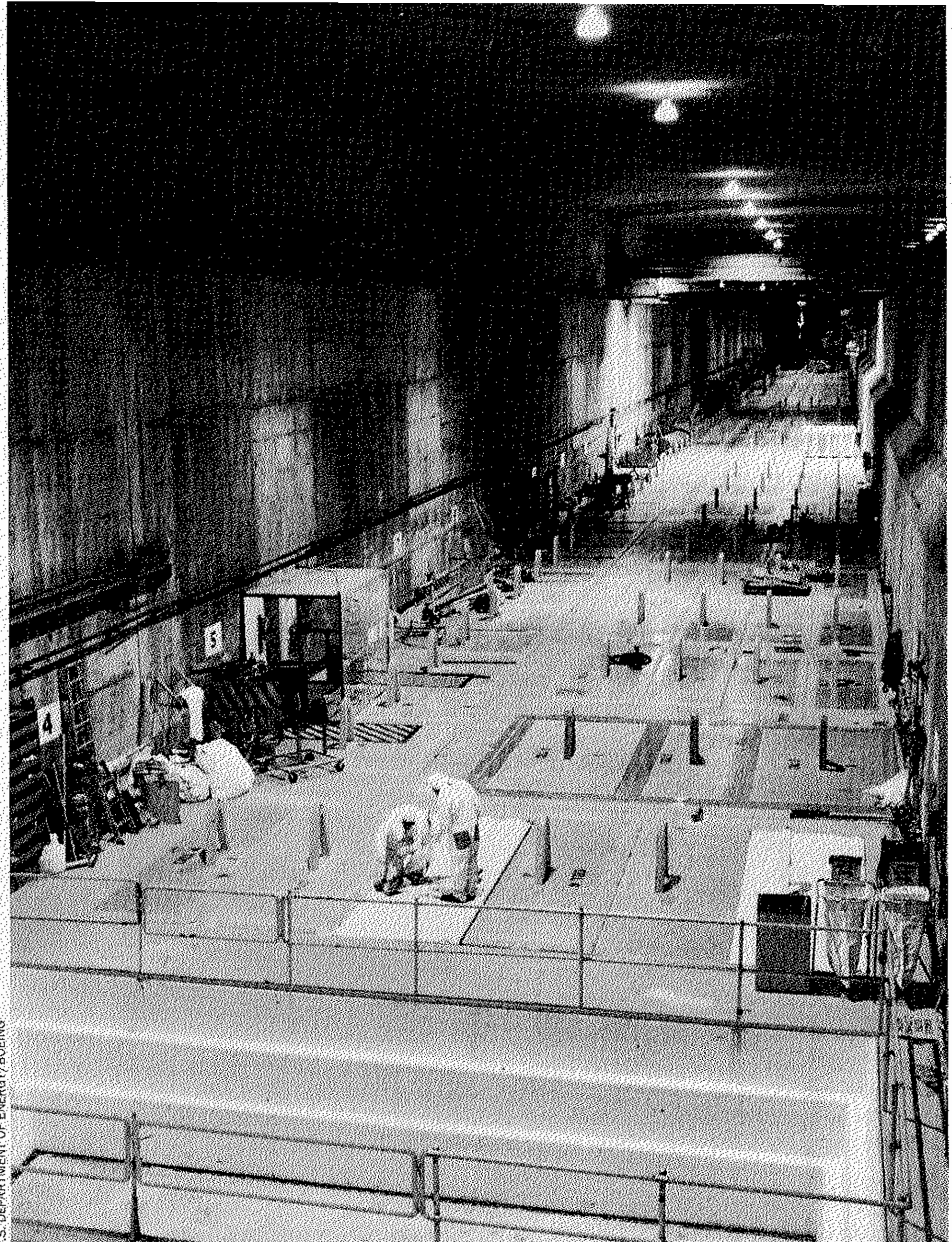
Whatever its current difficulties, performance-based contracting cannot be worse than the cost-plus system, many observers insist. "Contracting has been at the heart of the problems they've had," notes James Noël, assistant director for energy issues of the GAO.

Legal Hammer

Contracting, though, is not all that ails Hanford by any means. In 1989, around the time of the Rocky Flats crackdown, the DOE, the EPA and the state of Washington signed an exhaustive Tri-Party Agreement (TPA), which governs almost all aspects of environmental work at the site. The TPA, which lists specific activities and milestones and can fine the DOE for missing them, was the template for many other documents, called compliance agreements, governing environmental work on a number of DOE sites. Other than the federal deficit, the cost of the work that the DOE has committed itself to in the compliance agreements at all of its cleanup sites represents the single greatest liability of the U.S. government.

By all accounts, the TPA was a landmark that enabled the DOE and Washington State to begin working together despite deep mistrust. Because it is a legally enforceable document, the TPA also makes it less likely that the DOE—or Congress—will simply give up on the Hanford site in, say, 10 or 20 years. But possibly because of its accomplishments, the TPA's flaws are now apparently being overlooked. When it was drafted seven years ago, the TPA imposed on the DOE a hodgepodge of overlapping and sometimes conflicting state and federal environmental regulations. "The TPA was a punitive agreement," explains a Hanford veteran who witnessed its creation.

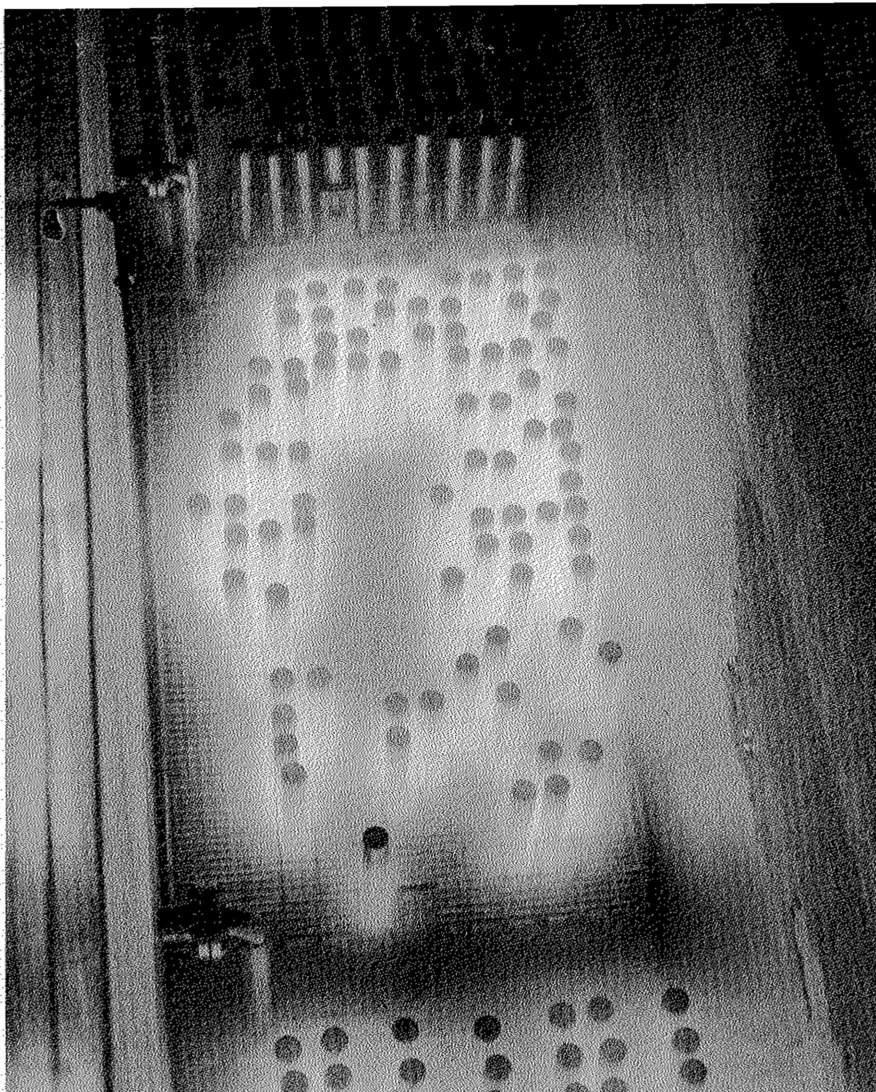
Besides the state and federal laws, the DOE's contractors have to continue complying with existing DOE "orders," which dictate how work must be performed. The 466 orders, says Caputo, the attorney at the Natural Resources Defense Council, are "byzantine and overlapping. They're from another era." In addition, the department and its contractors picked up further oversight in the late 1980s in the form of the Defense Nuclear Facilities Safety Board, an executive-branch agency that reports to Congress and also advises the secretary of energy. More recently, a Hanford advisory board has consolidated community oversight and input. "No one has ever tried to superimpose all these regulations simultaneously, let alone on the type of site we have," notes Gephart of the Battelle laboratory.


U.S. DEPARTMENT OF ENERGY/BOEING

REPROCESSING CANYON was where irradiated nuclear fuel was dissolved in nitric acid and chemically treated in successive "process cells" to extract its minute quantities of plutonium. The rectangular plates in the floor are the cover blocks for the cells. All the work was done by remotely operated cranes and other machinery to shield workers from lethal levels of radioactivity.

What the tangle of regulations and external oversight has apparently precluded is a coherent, rational and risk-based set of priorities for the complex as a whole. Many priorities were established by the compliance agreements, which set a legally binding timetable for projects and achievements at the sites. But the DOE, its contractors and the state eventually realized that the schedule set forth in Hanford's original TPA was "wildly unrealistic," as Caputo puts it. So far the state of Washington and the federal government have renegotiated the document four times to try to bring it more in line with reality. Each renegotiation is "an agonizing process, and lots of trade-offs are made," says Chris Abraham of the GAO's Richland bureau.

The absence of a consistent and complex-wide approach to setting priorities has been costly. Any problem becomes an urgent priority at Hanford—and the subject of hundreds of millions of dollars in funding—for largely political or regulatory reasons. "The history of Han-


PHIL SCHOFIELD

RADIATION from capsules of waste cesium and strontium is so intense that its interaction with water creates a glow bright enough to be seen with the naked eye. Radiation at the surface of the canisters is high enough to deliver a fatal dose in four seconds; the water in the pool shields the room above from the deadly emanations.

ford over the past 10 years has been: declare an idea, get started on it, and then someone stops you," says John Fulton, director of the spent-fuel project for Westinghouse Hanford.

Vestiges of various aborted projects are still visible at Hanford. They include the foundation of a huge facility to vitrify high-level waste ($286 million was spent on the project before it was terminated) and a plant to mix low-level liquid waste with cement, as well as associated storage facilities for the resulting blocks of grout ($197 million was spent). Constantly shifting priorities have also thwarted technology development efforts. "Unfortunately, the time cycles for program changes have been much shorter than the time cycles for technology development," says Billy D. Shipp, associate laboratory director in the environmental technology division of the Battelle laboratory.

There are also simpler examples of TPA flaws. In accordance with TPA provisions, the DOE spends about $23 million a year on experimental treatments of Hanford's groundwater. Yet several studies have found that current technologies—all variants of a method called pump and treat—are inadequate. At best, experts say, pump-and-treat techniques could only modestly improve or contain some of Hanford's existing plumes of contamination. "We could pump and treat Hanford's groundwater for the next century, and it would cost tens of billions of dollars, and we still would not have clean groundwater," Gephart explains.

One project seeks to curtail the seepage of strontium into a naturally occurring spring near the "N" reactor and the Columbia River. In conformance with the TPA and the demands of the state, DOE contractor Bechtel Hanford spent $4.8 million pumping and treating water from the spring to remove strontium. Over the next few years, Bechtel expects to build, for $1.5 million, an underground barrier of a material called clinoptilolite, to absorb and hold the strontium.

The sole purpose of all this work is to block from the river an utterly minuscule amount of strontium—its yearly radioactivity was last estimated to be a quarter of a curie. To put the radioactivity in perspective, the Columbia picks up an estimated 6,000 curies every year from natural sources in Canada and northern Washington.

A Jurisdictional Jumble

The TPA further complicates matters by placing Hanford under the jurisdiction of several environmental statutes, the two most important being the Resource Conservation and Recovery Act (RCRA) and the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA, also known as Superfund). Both laws specify how a contaminated site must be cleaned up. RCRA, however, which is usually administered by the state, pertains mainly to sites where hazardous waste was, or is being, treated, stored or deposited. Superfund, implemented by the EPA, covers contaminated sites that are no longer active. Superfund, unlike RCRA, can be applied to radioactive as well as chemical wastes. RCRA and Superfund also require different procedures and documentation.

Because of the way the TPA applies regulations to Hanford, any site that has both active and inactive hazardous-waste-producing components is technically covered by *both* RCRA and Superfund. Such dual coverage has seriously complicated hundreds of environmental projects at Hanford alone, the GAO and other investigators have found. For example, deactivation and decontamination of the nuclear reactors on the site are now covered by both RCRA and Superfund. In an attempt to avoid duplication, some reactors will be handled primarily under RCRA and the others mainly under Superfund, SCIENTIFIC AMERICAN has found. Thus, exactly the same task, being carried out by the same contractor, will be done and documented in two different ways, and the tons of debris will be disposed of in different waste facilities.

The TPA also applies both RCRA and

Superfund to the 177 tanks of high-level waste. The DOE's acquiescence to this dual coverage "foreclosed significant technological options in the cleanup of the Hanford tanks and created the possibility of a potential cost increase in the range of billions of dollars," according to a January 1996 report by the National Research Council. The DOE and its regulators have been attempting to solve the RCRA/Superfund problem since 1988, with little success.

Troubles Ahead

Serious as they are, the difficulties the DOE now faces seem to pale in comparison with the ones just ahead. For example, the TPA requires the DOE to vitrify the high-level waste in the 177 tanks. A big vitrification plant, the first ever in the U.S., was built at the Savannah River site in South Carolina; it is $2 billion over budget and six years behind schedule, according to the Institute for Energy and Environmental Research, a Takoma Park, Md., public-interest organization. (After innumerable delays, the plant was finally opened on March 12.)

Aware of the difficulty it would have in convincing Congress to underwrite another such venture, but obligated by the TPA to vitrify the waste, the DOE is now seeking one or more private companies to vitrify Hanford's waste. The companies would have to build and operate the vitrification plant, adhere to strict safety standards and assume all financial risk. The DOE would pay for the finished glass logs, enabling the firms—in theory—to profit. Most observers like the idea but are skeptical: "One of the big problems the DOE has had is inability to shift risk to a private company, so that if there is an unanticipated expense, or a catastrophic event, the private company suffers," notes Abraham of the GAO.

After the waste is vitrified, the DOE must take away all the glass logs, as well as part of Hanford's transuranic waste, and place them in permanent repositories in other states. That is what Washington State desires and the TPA stipulates. Standing in the way of this outcome, though, are tremendous obstacles. State opposition has blocked the opening of a repository for transuranic waste (containing plutonium or other elements with atomic numbers greater than 92) in New Mexico and the construction of a repository for high-level waste under Yucca Mountain in Nevada. The DOE now says a Yucca repository could not be ready before 2015; some experts suspect the opening will not take place for decades after that—if at all.

Even if the repositories can be put into use it is unlikely that they could contain more than a small fraction of Hanford's waste. Hanford's allocation of the hypothetical Yucca repository would hold about 6,000 vitrified logs. But the high-level waste in Hanford's tanks would occupy 20,000 to 60,000 such logs, according to the Battelle laboratory's latest estimates. Hanford's quantities of transuranic waste have been estimated to exceed the total capacity of the New Mexico transuranic repository—which, like Yucca, would have to take such waste from dozens of other sources besides Hanford.

Vitrification is one of several crucial issues whose resolution has been precluded by the precarious relationship between the state of Washington and the DOE. Analysts and, privately, site officials ponder such questions as: Should all the tank waste be vitrified? Should the reprocessing buildings be knocked down? Should the 15,000-ton reactor blocks and pedestals be hauled to the 200 Area and buried? Should hundreds of millions of dollars be spent pumping and treating groundwater that will never be clean?

The TPA requires that these questions be answered in the affirmative—even though rigorous technical analyses have argued against such moves. For example, some studies have suggested converting the gargantuan reprocessing buildings to low-level waste repositories. But the TPA currently rules out the possibility. Other problems also await solutions, including finding an ultimate destination for Hanford's many tons of spent nuclear fuel and plutonium.

What may finally force the issues is, as always, money. "A big vitrification plant will be real money," says Westinghouse Hanford president LaMar Trego. "So it will have to compete with plutonium disposition, Medicare, everything—I believe that, in their hearts, the regulators know there will be a big discussion on this in the end," he says.

That end, however, is fast approaching. DOE budgets, like those throughout the federal government, are being reduced. An unreleased study by Battelle considered cleanup strategies in light of an anticipated decrease in annual funding "from current levels [around $1.4 billion] to $1.05 billion in fiscal year 1998." After that year, funding would hold more or less constant for about 40 years. The Battelle report found that "a 50 percent reduction in the cost of cleanup must be immediately achieved and sustained to meet existing commitments and schedules with the projected $1.05-billion budget."

Given the unlikelihood of trimming the price of cleanup so much and, especially, the legally binding nature of the compliance agreements, the U.S. may have to reexamine its national priorities. For example, the $6 billion the DOE will spend this year to maintain, stabilize and clean up its weapons complexes is dwarfed by other budgets. The cold war has been over for years, but the U.S. will spend about $28 billion this year on intelligence alone—including $8 billion for reconnaissance and eavesdropping satellites and related programs. At $270 billion, this year's military budget roughly equals the anticipated cost of the entire DOE environmental management effort over the next half a century.

"While I understand the need to cut back on government programs and make them more efficient, shortchanging the DOE's cleanup budget will only increase the deficit in the long run," says Senator John Glenn of Ohio, whose state has numerous DOE weapons sites. "It may look good on paper, but it will only put off the day of reckoning. If we don't get a handle on this mess now, future generations will be left with a balloon payment constituting both an environmental and budgetary disaster." ■

Further Reading

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