generator in the base of the cell shoots the cone-shaped rocket out through the flying shards of the cell cover and, a few feet clear of the ground, the rocket motor ignites. Almost simultaneously, the missile pitches over on its set course, aimed by a split second injection of Freon into its rocket exhaust, and becomes a distant streak in the sky almost before onlookers realize it has left its cell.

Sprint is controlled at each instant of its flight by Central Logic and Control, a computer designed by Bell Laboratories, the research arm of the Bell telephone system. The unique feature of the machine is that to handle its rather elaborate task in real time it contains not one but a tandem of 10 central processors, with a capacity of performing about 10 million operations a second.

Besides its 10 central processors, Central Logic and Control consists of 12 program stores, each with a capacity of 16,000 words, 15 variable stores constituting a "scratch-pad memory" for radar data that need only be held a short time, two input/output controls, and two timing and status units. The system can be divided into formally equal "green" and "amber" partitions, which check each other in real time for malfunction. The green partition components are the ones that fight the battle, the amber are for testing and maintenance. If the amber side detects any malfunction in the green, it instantly switches in one of its own corresponding components in place of the faulty green component. As with the radars, redundancy is cultivated to a high degree to ensure the equipment stays on line when needed.

The essence of the Safeguard system is the system design and its embodiment in the software, written by Bell Laboratories with IBM as a subcontractor. According to Shea, Bell has performed the software job in an "exemplary fashion," notably by designing in a significant performance margin.

Bell Laboratories, with its production arm, Western Electric, is the prime contractor for the whole Safeguard system, a job which it undertook at the request of the Army. Unlike other defense contractors, Bell's main business is not dependent on Defense Department contracts, which may make for greater objectivity in rendering advice. "Bell Labs has dealt very candidly with the government and has never overstated what they felt could be accomplished," says Shea. By all accounts the Bell design team has played its part in putting Safeguard together with remarkable efficiency—all performance specifications have been met or exceeded, and the North Dakota site is being completed on schedule. The cost, however, has been greatly exceeded—running some $1.3 billion above the 1969 estimate for Safeguard—but for reasons largely beyond Bell's control, such as inflation and schedule changes. The story of Bell's achievements in designing Safeguard cannot, however, be told, since the company declines to discuss this ultimate service to its subscribers.

When completed the Safeguard site in North Dakota will be operated for a year and a half to gain operational experience and may then be reduced to working a 40-hour week. The critics may be right in doubting its strategic effectiveness—"Technically it's a fine thing, but it's like a train that doesn't go anywhere," says one opponent—yet anyone visiting the pyramid in the North Dakota wheatfields crammed with its powerful and elegant machinery cannot help absorbing a sense that it will work, and that the Soviet Union was well advised to bargain for its limitation. It is, if nothing else, a notable monument to Western technology and preoccupations, one which, like the funerary pyramids of ancient Egypt, will move future generations to marvel equally at the civilization's extraordinary technical skills and at its unswerving devotion to the mortuary arts.

—NICHOLAS WADE

Plutonium (II): Watching and Waiting for Adverse Effects

If any of you have a pet beagle, guinea pig, or hamster that is involved in a plutonium spill, we can make a fairly accurate prognosis and outline an adequate course of treatment. [But] at best, the practice of extrapolating animal data to man is of questionable validity, and the extent to which this may be done with confidence should be established by human data as soon as possible.—JOHN A. NORCROSS, former director of the United States Transuranium Registry, 1972

Almost from the time of its discovery in 1940, and certainly by the late 1940's, radiological health researchers were well aware that plutonium's great potential value was fully matched by its enormous biological hazard. Studies with laboratory animals 25 years ago, for example, quickly established that internal doses of plutonium measured in micrograms were an even more potent carcinogen than radium.

A great deal more has been learned since then about the behavior of plutonium in animals, as the above quotation suggests. But even though plutonium has become an increasingly important and abundant industrial substance, the effects of small internal doses on workers exposed to this strange metal remain uncomfortably uncertain. "The record so far is pretty good," says Walter S. Snyder, an authority on the subject and for many years a leading health physicist at Oak Ridge National Laboratory. But, Snyder adds, "we are still on edge about this."

Faced with this uncertainty—and with the rising prospect that plutonium would begin to spawn a commercial nuclear fuel industry in the mid- or late 1970's—the Atomic Energy Commission (AEC) began in the summer of 1968 to set up a medical data bank to monitor the health of thousands of men occupationally exposed to plutonium. It was hoped that the data bank, which the AEC now calls the United States Transuranium Registry, would serve as a medical trip wire—an early warning system—that would either confirm by its silence that exposure limits adopted in the late 1940's were adequate for workers, or sound an alarm soon enough to head off the kind of occupational health disaster that befell radium workers in the early part of the century, some of whom are still developing malignancies traceable to their jobs.

Today, the Transuranium Registry has passed beyond many of its initial organizational difficulties and has settled into what promises to be a long, quiet watch for signs of adverse health effects. Centered at the AEC's Hanford Reservation in eastern Washington state, the registry has become the repository for medical data on some 6000 nuclear workers, almost all in plutonium operations. And it has begun to report the results of autopsies on plutonium workers as the information becomes available. About 40 autopsies have been performed thus far.

Peaceful as its existence is, the registry is not without its problems and its critics. For one thing, selling industry on the concept of a medical data bank has not been easy, and the job is not yet finished. It also happens that medical data collected so far comes almost entirely from those men most recently exposed to plutonium and other radionuclides, and who are therefore least likely to show any adverse effects in the near future—if such effects are ever to be found at exposure levels currently encountered by nuclear workers.

Whatever its shortcomings, though, the registry represents an innovation in preventive medicine and, in a sense, a novel experiment in technology assessment. As such, it serves to illustrate the difficulties—both social and scientific—of guarding against future catastrophes of occupational health.

Officially, the Transuranium Registry is part of the Hanford Environmental Health Foundation, a private organization that the AEC has contracted to provide medical services for the nearly 7100 employees at the 570-square mile Hanford Reservation. With an annual budget that fluctuates between $80,000 and $105,000, the registry employs one full-time administrative assistant, a part-time consultant, and a part-time director, William D. Norwood. A physician and researcher at Hanford for many years, Norwood, at the age of 72, says that he's looking for a younger man to take over but hasn't yet found a replacement.

The registry's basic approach has been one of classic epidemiology. It seeks to collect medical records of as many plutonium workers as possible and then to find correlations, if any, between "body burdens" of plutonium or other radioactive elements and any changes in longevity or patterns of disease that develop. The registry is especially—but not exclusively—interested in men known to have absorbed relatively large amounts of plutonium, either through inhalation or through contaminated skin wounds, the two main routes of intake. Most careful watch is kept for workers who may develop malignancies of the bone, lung, liver, or tracheobronchial lymph nodes, where plutonium tends to concentrate.

Those workers who sign authorization forms for autopsies are given a special identity card to carry, and if they leave the nuclear industry before they die, the registry pays for them to have periodic physical exams and "body burden" measurements. When the worker dies, the registry pays the family $350 toward funeral expenses. Other deceased enrollees can be traced, and their death certificates located, through their social security numbers.

Problems of Privacy

All of this brushes up against sticky questions about an individual's right to privacy. To avoid problems in this area, the AEC has made cooperation with the registry—both by companies and by their individual employees—entirely voluntary. In addition, all medical data, which is stored on computer tapes, is numerically coded by the registry to protect each worker's identity. Even so, Norwood said in a recent telephone conversation, "We've really had to sell the idea to industry." Besides questions of privacy, he said, "Some companies are afraid that we'll scare their employees by talking about the hazards of plutonium. So we have gotten varying degrees of cooperation."

After some initial resistance, the national laboratories and the big nuclear weapons plants handling large amounts of plutonium have all begun cooperating fully, with the exception of the Savannah River production plants run by DuPont at Aiken, South Carolina.*

In contrast with AEC's own facilities and those run by its contractors, the registry has encountered a stonewall of resistance from some of the smaller private companies in the vanguard of a new and potentially major new segment of the nuclear industry—the manufacture of "mixed" uranium and plutonium oxide fuel for conventional nuclear power plants. The AEC is expected to move toward encouraging production of this new fuel within the next year (*Science*, 20 September).

Two companies that intend to make plutonium fuel on a large scale—Westinghouse and Exxon Nuclear—have agreed to cooperate fully with the registry, once production begins in about 3 years.

But two other companies in the plutonium fuel business have balked. These are Nuclear Fuel Services, Inc. (NFS), whose spent fuel reprocessing plant near Buffalo, New York, is closed pending AEC approval of a major enlargement; and the Nuclear Materials and Equipment Corporation (NUMEC), whose plutonium plant at Leechburg, Pennsylvania, near Pittsburgh, is producing fuel for the AEC's breeder reactor program. Together, and when fully operating, the two companies employ only about 200 persons "at risk" of exposure. But both plants have suffered a number of leaks and spills of plutonium that have led to contamination of workers, seemingly in disproportionately high numbers.

Norwood said that NUMEC "hasn't said yes and they haven't said no," but that NFS seemed to have stopped answering his letters. "They haven't responded to my last two or three."

A spokesman for NFS told *Science* that he wasn't familiar with the letters, but that the company's management at present regards participation in the Transuranium Registry as "inappropriate," although no final decision has been made. The spokesman, vice president Claude E. Fountain, said that the company's position was that even inviting employees to participate in the registry voluntarily might be construed as "coercion."

Did the company invite employees to contribute to United Fund and local blood banks? "Of course," said Fountain, "But we view that differently."

A spokesman for a third private plutonium plant, located near Cimarron, Oklahoma, and owned by Kerr-McGee, said the company does not yet know enough about the registry to give it a "blanket endorsement" but that Kerr-McGee "welcomes added information."

In Norwood's view, the noncooperating companies are more likely to hurt themselves than the registry and its goals, although their resistance does deny the registry access to a number of persons exposed to plutonium oxide, a form of the element considered by some authorities to be particularly hazardous. He notes that, "If some former employee comes along and sues these companies for compensation, it might look to the people trying the case that

* DuPont gives the registry data only on workers known to have taken in more than 5 percent of the maximum permissible body burden of 40 nanocuries, a determination that is often difficult to make. The company replaces workers' names with coded numbers.

the company did not do everything it possibly could to protect employee health."

Norwood said that he had been informed that the Nuclear Energy Liability-Property Insurance Association, the national insurance pool that underwrites private nuclear facilities, had strongly urged the noncooperating companies to change their position.

How successful has the registry's recruitment been? No accurate figures are available, but upwards of 7000 to 8000 persons may now be employed in plutonium operations. The registry has signed up about 6000 of these workers, and some 850 of them have agreed to autopsies.

According to rough estimates supplied to *Science* by the AEC, however, about 17,000 persons are thought to have worked in plutonium operations from the beginning of the Manhattan project to the present. If so, that means the registry is monitoring only the most recent one-third of the population considered to have been occupationally "at risk" to exposure to plutonium. But finding and enlisting the cooperation of the first two-thirds has so far not been practical, Norwood said, explaining that, for one thing, early employment records are far from complete.

Even so, the apparent loss of the first 11,000 plutonium workers would seem

Briefing

NAS Okays Auto Emission Standards

The health-related auto emission standards embodied in the 1970 Clean Air Act are basically on target and there is "no substantial basis for changing the standards," according to a recently completed report by the National Academy of Sciences–National Academy of Engineering. Presumably the report will help buttress the act against weakening amendments when it comes up for review and overhaul next year. The act was supposed to be up for renewal this year, but it has been carried over with an interim appropriation.

The half-million dollar study was ordered by the Senate Public Works Committee last year following extensive hearings at which auto makers took issue with the standards, saying they were too strict and the required emission control devices were not cost-effective.

The academy committee disagrees with both contentions. While data are still inadequate, it says, the evidence that has accumulated since the standards were promulgated tends to confirm their desirability, and the safety margins are indeed "relatively modest." What's more, the report says the standards are justifiable in cost-benefit terms. It estimates the annual cost of reaching statutory emission standards at $5 to $8 billion, and assesses the benefits of clean air at between $2.5 and $10 billion a year.

The study was structured in three parts to analyze the effects on human health of specified pollutants, the relation of auto emissions to ambient air quality, and the costs and benefits associated with auto emission control.

The report estimates that air pollution can be said to be implicated in about 1 percent of all U.S. deaths each year and that automobiles contribute up to one-fourth of this pollution. So automobile exhaust fumes may send as many as 4000 people over the edge each year.—C.H.

Weather Mod Research Under a Cloud

The U.S. government has been trying to mount successful weather modification research programs since the late 1940's, but "an effective national weather modification research program has not been established," according to a recent report of the General Accounting Office (GAO).

If successful, such research could help "alleviate drought, reduce the destructive forces of hurricanes, suppress lightning . . . and dissipate fog," the study says. But the country lacks the capability to do these things operationally in part because the research has been conducted in a fragmented way by seven federal agencies and departments, the report says.

In fiscal 1974 the government spent $17.4 million on this research, but GAO concludes that the money could have been better used if all weather modification research programs were consolidated into a single agency.

The GAO employed unusually crisp language to describe the failure of the Interdepartmental Committee for Atmospheric Sciences (ICAS) in coordinating these programs. ICAS was set up in 1959 as a solution to the problem of fragmentation among agencies which was apparent even then. But now, "ICAS apparently has had little or no impact on increasing coordination and accelerating progress in weather modification research."

As an example of the inability of agencies to sacrifice their priorities to joint endeavors, GAO looked at the 5-year National Hail Research Experiment, begun in 1972, for which the National Science Foundation is chiefly responsible. After several agencies agreed on a plan, the following defections occurred: the Agriculture Department decided not to study the economic benefits of hail suppression (so NSF did) and did not make a study of lightning which was considered "imperative" to the project. The National Oceanic and Atmospheric Administratinon supplied one airplane for 1 year only, instead of the three pledged for the life of the project. The Atomic Energy Commission did not measure hailstones and make planned tracer studies. And the Department of Defense, instead of supplying two helicopters, told NSF it could have one, provided that NSF paid the bill—which NSF couldn't. GAO did not say whether the truncated project has been a scientific success: ". . . we found, comparing the planned efforts with the actual efforts that, for the most part, agencies could not and did not meet all their obligations."

Most of the federal agencies asked to comment on the study criticized it. The Agriculture Department's comment said GAO had not substantiated its premise that existing research programs were defective. Like most of the comments, it fought the proposed unified program: "I would not wish to defend a budget request on the basis that it enabled us to participate in a national weather modification program," the author said.—D.S.

to represent a considerable handicap. In addition, some scientists who are especially worried about the health effects of plutonium question the registry's heavy emphasis on long-term epidemiology. Among them is Donald P. Geesaman, a biophysicist at the University of Minnesota's School of Public Affairs.

"If all they're looking at is body burdens and the cause of death, this may be next to useless," Geesaman says. "God only knows what else plutonium workers are exposed to—tritium, other radionuclides, hydrocarbons you never dreamed of. For meaningful results you have to look on a fine scale for pathology near local depositions in tissues."

Norwood replies that a few close examinations of autopsied bone have been done, but that techniques need refinement and uncommonly large depositions are necessary now.

In large measure the Transuranium Registry's sensitivity as an early warning system depends upon the nature of the effects, if any, to be discovered. The appearance of a rare malignancy—a bone sarcoma, for example—among the first few dozen autopsies would be a clear signal that something was amiss. But hundreds of deaths among the registry's enrollees might be required to detect a statistical increase in garden variety lung cancer.

In the meantime, there is a growing urgency to the central question: Are current occupational standards for plutonium, set in 1949, still adequate? As the nation moves toward the commercialization of plutonium, the standards have become an issue between environmentalists on one side and the proponents of nuclear power and the radiation standards community on the other. Earlier this year, for instance, the Natural Resources Defense Council, a respected environmental law group, contended in a lengthy technical paper that current exposure limits for airborne plutonium were too high by a factor of at least 100,000. Others, like Karl Z. Morgan, an eminent health physicist at the Georgia Institute of Technology, believe that a solid biological case exists for reducing the present maximum permissible body burden of plutonium by a factor of 40 or 50. This limit is now set at 40 nanocuries, an amount of material about equal to a pencil-point dot on a piece of paper.

Many health physicists, however, believe that no change in the standards, or only a small one, is warranted. Frequently cited as a reason for reassurance is the lack of apparent effects in a group of 25 GI's who were heavily contaminated by plutonium during the Manhattan Project and who have been monitored carefully ever since by researchers at Los Alamos. Chester Richmond, for many years a leader in plutonium effects work at Los Alamos, notes that the only signs of pathology in these men so far are "metaplastic changes found in the sputum" of some of the men. Such changes, though a possible precursor of malignancy, are not uncommon in middle-aged men who smoke.

Even though their number is small, Richmond continues, "I feel very reassured that our standards are not way out of line as some have suggested. If they were—by orders of magnitude—you would have seen something in this group, perhaps a bone sarcoma. They would have raised a red flag."

Walter S. Snyder, a member of the internal exposure committee of the International Commission on Radiological Protection, the leading standards organization, is similarly sanguine but cautious. No adverse effects have been seen thus far, he notes, but if there was one lesson learned from the radium workers a half century ago it is that radiation-caused malignancies may take decades to manifest themselves.

"We are still on edge about this," Snyder says of plutonium. "We're playing a game with very little human data."

—ROBERT GILLETTE

Erratum: In the first of this two-part series on 20 September the Nuclear Materials and Equipment Corporation was incorrectly identified as the Nuclear Materials and Engineering Corp.

UN Conferences: Topping Any Agenda Is the Question of Development

The World Population Conference ended on 30 August in Bucharest without producing explicit agreement that there was a world population problem, and the United Nations Law of the Sea Conference in Caracas wound up a day earlier without doing any legislating. What both the UN-sponsored meetings did contribute was sharper definition of the division between the developing countries and the Western industrialized countries, particularly the United States. Does this mean that the conferences were failures—perhaps that the world conference is likelier to produce confrontation than cooperation? Or does it simply mean that the problems addressed at Bucharest and Caracas are of such magnitude and complexity that it is naive to expect instant results?

The question is a fair one since the world conference form is very much in vogue. A cycle that began with the Conference on the Human Environment in Stockholm in 1972 accelerated with this summer's meetings, and will continue with a World Food Conference from 5–16 November in Rome, an International Women's Year Conference in Bogotá next summer, and a World Conference on Human Settlements in Vancouver in 1976.

The UN Conference on the Law of the Sea, which is the third of its kind, was, in effect, recessed, and is scheduled to resume in Geneva from 17 March to 3 April next year and, with good luck, to conclude with a treaty-signing session back in Venezuela next summer. Not all world conferences are the same, of course. The Law of the Sea Conference differs significantly in aim and in dynamics from the population and food conferences, for example. Its object is a major revision of maritime law, with the stormiest issues involving territorial limits, fishing rights, and the exploitation of minerals beneath the seas. The conferences on environment, population, and food do not focus on specific questions of international law but, to make progress, require the accommodation of social and cultural differences as well as the reconciliation of conflicting economic and political interests. The issues under discussion can all be viewed as different aspects of the problems of underdevelopment.

A familiar phenomenon at the conferences has been the bitter, often ritualistic criticism of the United States by the developing countries and socialist