will be "a tool of policy" rather than a genuine research organization.

If the suggested organization goes through, really fundamental work—like nuclear physics, radio astronomy, and molecular biology—would probably emerge in a reformed Science Research Council. More applied work would be done under the aegis of the appropriate ministry and would be more closely tied to the needs of the department—in line with the mission-oriented approach to research funding.

So far, these are no more than strong rumors, but they seem to fit in with the government's general philosophy. Until the situation becomes clearer, research workers are crossing their fingers and hoping for the best. But the indications are that the years of rapid growth have come to an end.—NIGEL HAWKES

Princeton-Pennsylvania Accelerator: End of an Era in Particle Physics

While high energy physicists eagerly await the birth of the $250 million National Accelerator Laboratory (NAL) near Batavia, Illinois, an older machine approaches the end of its federal funds. The lifeblood supplied to the Princeton-Pennsylvania Accelerator (PPA) by the Atomic Energy Commission (AEC) was cut off 1 July, perhaps only a few days before its giant successor comes to life with tests of its full energy beam. Thanks to a small transfusion of private funds, the PPA lingers on and hopes for an Indian summer of cancer-therapy research. But it has passed from the great world of high energy physics.

Its passing has stirred much less excitement than the arrival of NAL, but it, too, is a signpost that marks the turning point now reached by research into "the fundamental building blocks of matter." About a dozen smaller accelerators have been shut down in the past, but these closings were much less traumatic than the shutting off of the $40 million machine, which at its peak provided employment to 356 people and which cost $5 million annually to operate.

The PPA is located on highway 1 about 4 miles from the main campus of Princeton University. The University of Pennsylvania shared administration and use of the accelerator with Princeton, although AEC's contract was with the latter institution. The facility was also used by experimenters from other universities, whose share of the operating time rose to about 50 percent by 1970.

Paul W. McDaniel, director of research for the AEC, told a House appropriations subcommittee that the 1970 decision to close the PPA, only 7 years after it began operations, had caused "consternation" in the high energy physics and educational communities. The event brought home to particle physicists a reality that was already making them uncomfortable. The enthusiasm with which the 500 billion electron volt (Gev) NAL was awaited was tempered by chagrin at the growing realization that its cost would eat into the money available for smaller machines. In the days of rapidly expanding research budgets, the typical physicist had not dwelt on the sacrifices his local accelerator might have to make to the hungry god of higher energy.

The Princeton experience has already had a major impact on the way high energy physics is being planned, according to one Washington official. He calls it a "trigger" to compel long-range perspective and cost consciousness, adding: "It is used as the classical example of what you don't do."

The PPA was still pursuing an ambitious research program when it was caught in the vise between rising particle research costs and budget pressures on science. But there was general consensus among physicists that, if one of the high energy machines had to be sacrificed, PPA, whose 3-Gev energy level was the lowest among them, should be the first to go. Even Milton G. White, director of the Princeton accelerator, feels that the choice was not unreasonable, although he is unhappy with the timing.

Given more advance warning on the shutdown, White says, more research could have been accomplished at lower cost. Asked if the timing was the result of poor planning, White replied: "No one had any idea of the abruptness and depth of the cut-off of funds."

In July 1969 the AEC had asked White what the effect would be if PPA's budget were cut from $5 million to an annual outlay of $3.5 million or $2.5 million. The reply indicated that the smaller cut would make operations difficult, and the larger cut would make them almost impossible. In November 1969 PPA was told that, beginning in January 1970, they would be funded at the $3.5 million rate for the remainder of the fiscal year. The news came as a relief, but when January came, PPA was informed that its operations were to be altogether terminated.* "January was very much of a surprise after November," PPA's associate director Walter Wales told *Science*.

Between those dates, AEC's proposed funding for the machine had been rejected by the Bureau of the Budget, which allocated $2 million for fiscal 1971 to complete important experiments under way and close down the facility. The accelerator's fate was proclaimed in President Nixon's fiscal 1971 budget under "Reductions in Outmoded or Uneconomic Programs." Physicists at other accelerators may not have wept to see a competitor for scarce funds face cutbacks, but some of them, at least, were shaken by the death sentence. Their subsequent pleas to keep PPA alive, reportedly pressed even at the highest level, fell on deaf ears.

Phase-Out Policy

Wales regrets that there was not more time to "run the accelerator into the ground." The most economical way to phase out such a machine, he says, is to stop spending on improvements and treat it like an old car, to "live with the squeaks." Not only is the amount of experimentation per dollar spent greater when the cost of improve-

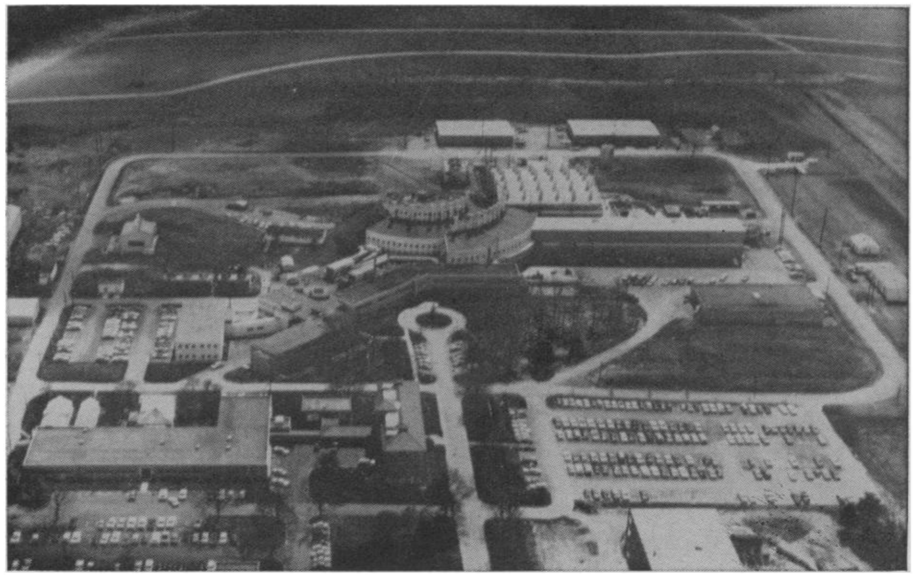
* At the same time, the 6-Gev Cambridge Electron Accelerator, shared by Harvard and the Massachusetts Institute of Technology, was cut from $3.5 million to $2.4 million. Research there is now limited to experimentation with the colliding beam.

ments is eliminated; waste of the investment in such improvements may be avoided if the shutdown of a facility is planned far enough in advance. For example, the $1.2 million spent in fiscal 1969 and 1970 to develop flat-topping projects (which produce a steadier flow of particles) that were then scarcely used might better have been spent to continue experiments with an unimproved machine or at another accelerator. Indeed, the sum was just the annual operating cost of a reduced program which PPA later proposed, without success, to both AEC and the National Science Foundation. Gerald F. Tape, president of Associated Universities Inc., which operates the Brookhaven National Laboratory, told *Science*: "If we knew today that some of these machines were going to be shut down in five years, there are some of these improvements we wouldn't be making now." He observed that a long lead time, including the budget process, is involved in such decisions, and added: "The psychological problem is really being able to admit that before the die has been cast. That's an issue that we haven't really learned to handle."

The execution of PPA was perhaps more of a surprise than it should have been. The question of shutting down high energy facilities had been raised in April 1969 during hearings before the Joint Atomic Energy Committee. In July of that year the AEC wrote to committee chairman Chet Hollifield (D–Calif.) that the previous manner of responding to budget cuts—distributing the loss among the accelerators—"may have reached its limit." The AEC still opposed a complete closing of any facility, but singled out PPA for a "significantly reduced mode of operation." A decision not to spread the pain more evenly made sense as it became clear that the scarcity of funds was not a temporary aberration. The return on the dollar invested in accelerator operation increases as it approaches its full capacity, and by 1969 most of the large accelerators were working below capacity.

Wales admits that it was not easy to read the writing on the wall. "You're admitting you don't have a long-term future. And that's something difficult to do. That's something we didn't do voluntarily. We were told we didn't have any future."

The high energy physics community as a whole has not found it much easier to face the change in its financial situation. In June 1969, just before the AEC asked PPA to consider deep cuts, the High Energy Physics Advisory Panel (HEPAP) reported that some of the older accelerators would have to be shut down "eventually." The panel combined a complaint over decreasing funds with a projection of federal high energy spending of $375 million for fiscal 1972. This 1969 projection now appears optimistic to the tune of about $160 million.



Princeton-Pennsylvania Accelerator

Since the preparation of this report, high energy physicists have been learning to live with a less rosy financial outlook. The sums being poured into the Batavia accelerator may still make other scientists burn with envy, but there is little left among the particle princes of the free-spending spirit that prevailed while the Princeton-Pennsylvania Accelerator was being built. Shortly after the decision to construct the machine was made, American scientists visiting Soviet high energy facilities were, in the words of one physicist, "shaken to their socks." Four months later a panel of physicists convened by the National Science Foundation recommended that annual spending for high energy physics be increased from a current level of $40 million to between $60 and $90 million by 1962. In fact, spending in fiscal 1962 reached about $100 million, and by 1966 had climbed to $176 million.

The PPA thrived in this period. Though originally estimated at $5 million, the original design cost $11.5 million, and major improvements such as the $8.4 million external beam facility brought total construction expenditures to $40 million. Today the massive complex of buildings and equipment is eking out a slender existence with a grant of $230,000 from the Fannie E. Rippel Foundation. This grant is being used to convert the accelerator to production of heavy nitrogen ions in hopes of attracting money for their use in cancer therapy. But the Rippel funds will run out 31 August, and White expects no response to his plea for cancer research money before January. He is desperately pursuing other sources of interim financing to keep the accelerator alive until then, so that there will at least be a machine to decide about. His message to the government is: "While you're making up your mind, we're dying."

The Scene at Princeton

The PPA facilities already have the eerie air of a ghost town. When a visitor enters the glass doors of the administration building there is no receptionist to greet him. Instead, a sign propped on a desk explains how to sign the register and where to find the staff telephone book. In the cafeteria, where employees were accustomed to stand in line and then search for a place to sit, a row of machines and one waitress offer Spartan fare to scattered diners. One of the remaining staff remarked, as he crossed the campus at midday toward the accelerator, that there used to be more people around at 3 a.m.

Those who are still around cling both to hopes for a rebirth and nostalgia for a golden age. They recall with pride the spirit of teamwork of their now departed colleagues. One administrator reports that many left with a plea to be rehired if the accelerator should resume operations, and another notes that almost every day someone returns just for a visit.

Since 1 July 1969, a total of 253 have departed, leaving a staff of only 42. Thirty of those who have left held administrative posts, 21 were maintenance staff, and the remaining 202 were operations personnel. Of the latter, 9 were physicists, 32 engineers, and the rest technicians. Except for two who recently underwent major surgery, none of the engineers are now unemployed, although a few experienced considerable delays in finding work. Six of the engineers have gone to other universities, 7 now have permanent positions at Princeton, and 17 have gone into private industry. Seven of the physicists have gone to other universities, and the other two are employed in industry. Three of the technicians, dismissed in March, are still unemployed.

R. J. Woodrow, associate treasurer at Princeton University, observed that it is difficult for a university to cut back on such service operations as grounds maintenance, purchasing, the cafeteria, and so forth, but he said that Princeton was able to absorb most of the administrative and clerical personnel. He stressed that the bigger the operation associated with a university, the more important that it stand apart on its own financial feet. He appeared unperturbed by the impact of the PPA closing on Princeton's finances, but others felt that the loss, at such a time, of a program with $5 million annual operating costs could only hurt the university.

Some of the equipment useful at other facilities has already been shipped away, but the accelerator itself and its building remain behind, now the property of Princeton University. The storage area will be used by the university's plasma physics research group, but it is difficult to imagine what use could be made of the big machine itself if the current fund-raising campaign proves fruitless.

The impact of the closing on the physics department has been much less tangible. White speaks of a "very sharp downturn in graduate student and young faculty morale." But Marvin L. Goldberger, the department chairman, feels that the principal loss to Princeton will be in its ability to recruit young faculty in high energy physics. Even here, he believes that the closing of PPA

DDT Stopped, Suit Dropped

The Environmental Defense Fund (EDF) has dropped the lawsuit alleging that Montrose Chemical Corporation of California, the world's largest manufacturer of DDT, had discharged massive quantities of DDT into the Los Angeles sewage system, which connects to Santa Monica Bay and the Pacific Ocean. The suit, filed against Montrose in October 1970, was dismissed after Montrose installed equipment to prevent the discharge and disconnected its DDT manufacturing operations from the sewer lines.

The EDF's lawsuit came after scientists had noticed, for several years, a disparity between the DDT concentration in marine wildlife off Southern California and that found in other marine environments. Livers of fish from Santa Monica Bay were found to contain DDT concentrations of more than 1000 parts per million (ppm), while typically DDT concentrates in the livers of similar fish at a level of a few parts per million or less. In December 1969, Star-Kist Foods, Inc., voluntarily removed 4000 cases of its canned mackerel from the market after it was discovered that the fish contained DDT concentrations above the federal tolerance limit of 5 ppm. In December 1970, the Food and Drug Administration seized 8000 pounds of kingfish with DDT concentrations of 19 ppm. Earlier that year, an attempt to impound 1260 pounds of both kingfish and queenfish with a DDT content of 14 ppm failed when the fish were sold before the federal authorities could act.

The Fate of the Brown Pelican

The EDF believes that Montrose is also responsible for the plight of the brown pelican. Although still a common sight in Southern California, the fish-eating brown pelican is facing extinction as a result of DDT contamination, EDF claims. Because of DDT-tainted tissues, the birds lay eggs with shells so thin that they break prematurely and therefore produce no young. Robert Risebrough, a pesticide specialist at the University of California, Berkeley, reports that in 1969 on Anacapa Island, the pelicans' nesting grounds, fewer than four pelicans were born out of 1000 nesting attempts. The nesting attempts were cut in half in 1970, producing only one young that survived. Risebrough hopes that the pelicans will resume reproduction when the discharge of DDT from Montrose has completely stopped.

Although it acknowledges that other businesses in the Los Angeles area could be the cause of DDT effluents in the waters, EDF says that these businesses—food packaging companies, food processors, and others—could not account for such an overwhelming amount of DDT. The County Sanitation District, also named as a defendant in the suit, recently removed 0.5 million pounds of sediment containing 5000 pounds of DDT from the sewage lines below the Montrose plant. Montrose asserts that it had begun to halt the discharge of DDT long before the EDF lawsuit, and that DDT effluents from the plant itself were down to less than 1 pound per day.

EDF Satisfied with Compliance

On June 1, Montrose allowed EDF attorney Norman Rudman to inspect its plant. Rudman was satisfied that Montrose had complied with EDF's demands, and EDF then recommended the suit's dismissal.

Meanwhile, Montrose has developed a method of "recycling streams," where DDT, salt, and water wastes from its manufacturing processes can be made useful again. In addition, an EDF lawyer told *Science* that Montrose may prompt "a whole new lawsuit" by loading tank trucks with DDT that cannot be recycled and dumping it directly into landfills that are said to be situated on impregnable rocks, thereby preventing leakage. The question EDF and others are asking is how many years might elapse before erosion begins and the DDT escapes.

—EDWARD P. JONES

makes less difference to Princeton than the opening of NAL, whose facilities will naturally draw talent to the Chicago area.

Graduate Education

Goldberger expressed grave concern over the impact of the closing of smaller high energy accelerators on the character of graduate education. The high cost of experiments at the big machines and the intense competition for time to use them, he warned, will reduce chances for graduate students to make real contributions to experiments rather than just serving as "an extra pair of hands."

One of Princeton's younger particle physicists, K. Goulianos, shared Goldberger's concern that pressures at places like NAL could dampen the initiative of the next generation of experimenters. He feels that those who have already been trained on smaller machines will still insist on doing things their own way at NAL, but wonders whether students trained at NAL will have acquired that same spirit of independence when their turn comes to run their own experiments. At places like Princeton, he observed, students have had some freedom to "play around," and to fail once in a while. He feared that with "everyone watching everyone" at the Batavia accelerator, pressure will grow to "run physics like a project."

Goulianos insisted that it is still too early to tell whether the atmosphere of NAL will dampen or stimulate the imagination of graduate students, and other physicists express optimism that young talent will find a way to innovate in new conditions. But even 2 years ago the HEPAP report warned against "creeping conservatism."

> With the increase in complexity, cost, and time scale of all experiments, and with limited funds, there can be a tendency toward overcaution. There is great competition for the time available at the accelerators, and a group, particularly with graduate students desirous of thesis material, may be tempted to design an experiment that is sure to yield publishable results rather than risk the effort for a bold and exciting but possibly unproductive one. This problem demands vigilance on the part of all workers in the field.

Milton G. White

While the character of the next generation of high energy physicists remains conjectural, that of today's elder statesmen is dramatically symbolized in the great machines they have built. White, who designed Princeton's first cyclotron in 1935, takes understandable pride in the huge accelerator he is struggling to keep alive. Asked about the "natural life" of these machines built at the moving frontier of knowledge, he said "that depends on the aggressiveness and imagination of the people who run them."

White has certainly harnessed his own energy to the search for new uses of his accelerator. He proposed to NASA that the high energy heavy ions a converted PPA could produce be used to investigate the effect of cosmic-ray bombardment of astronauts and sensitive computers in future prolonged space flights. Funds are not now available for such research, and White pins his hopes on use of such ions for radiation therapy. These heavy ions are expected to prove more effective than x-rays in treating cancer because they can be aimed more precisely at a tumor and because their densely ionizing power is believed to diminish the so-called oxygen effect, which makes it difficult for x-rays to kill tumor cells without heavy damage to healthy cells.

But White is not alone in his efforts to gain a new lease on life for his machine. At Berkeley, where the 6-Gev Bevatron may be approaching extinction, a plan has been developed to link it with the Heavy Ion Linear Accelerator so that like PPA it can accelerate heavy ions to high energies. Berkeley has an advantage in the presence there of biomedical researchers with experience in radiation therapy and interest in high energy heavy ions.

The conversion to heavy nitrogen ions for cancer therapy at Princeton is on the verge of completion, at a cost of about $75,000.

This conversion represents a basic departure from the primary purpose for which the machine was built. When the accelerator began operation in 1963, White wrote enthusiastically of the pursuit of "that 'primordial stuff' out of which all matter, including human beings, is composed." But in the same essay he already noted that the accelerator or its particles "may one day have applications to medicine, space studies, and other areas of science."

Now that he is trying to make that prophecy come true, White finds obstacles he had not anticipated. To be sure, the trend of public opinion and the Nixon Administration now emphasize the application of science to human problems. But White believes his quest for funds to shift the machine from basic science to cancer research is in a no man's land, between the high energy physicists and the biomedical scientists. The former, according to White, are obsessed with their chase after elementary particles (a passion he shares) and fearful of the diversion of any of their funds to applied research. Biomedical scientists, on the other hand, usually have projects already in mind for which they are trying to secure appropriations. As a result, White believes, the latter are not eager to promote unfamiliar programs at the expense of those to which they are already committed. And yet White has assembled an impressive dossier of testimonials from scientists anxious to see high energy heavy ions from his accelerator used for biomedical research.

The Nature of Matter, of Man

If he can find funds to keep his machine alive a little longer, White may then have a chance to secure a share of the growing sums being appropriated for the politically popular fight against cancer. But whatever the fate of his accelerator, he fears for the faith it has symbolized. He may adapt his machine to survive for a while in the changing climate of American culture, but he is troubled and puzzled by growing hostility toward science among the younger generation. White says that he can repeat the phrases used by critics of science and list the causes which have provoked their new attitudes, but that he cannot really understand them. And yet it is only 7 years since White, celebrating the accelerator's readiness for investigating ultimate mysteries, compared it to a cathedral because it "epitomizes the prevailing social-intellectual forces of the day. . . ." He then concluded that although there may be no end to the pursuit of knowledge of the nature of matter, it was "in the nature of Man to keep trying."

———D. PARK TETER

Erratum: In "The southern corn leaf blight epidemic" by L. A. Tatum (19 Mar., p. 1113), the first sentence of the third paragraph under the sidehead "History of southern corn leaf blight" on page 1114 should read "The loss in 1969 . . ." rather than "1968."

Erratum: In "Behavioral sensitivity to microwave irradiation" by N. W. King *et al.* (23 Apr., p. 398), lines 1 to 8, column 2, page 399, should read "basis of the level of focusing current used to control and monitor the output power of the magnetron (*25*). A shift from zero to a present level of available power in the exposure cavity was accomplished by applying 5 kv of 60-hz a-c voltage to the anode of the magnetron."