from the standpoint of ice conditions, there would be no chance to drill a relief well even then. Within a year's time, a blowout could result in the escape of some 87,000 cubic meters of oil unless the well is sealed spontaneously by debris.

Biodegradation of the oil would be slow under the arctic conditions, and in many places the oil would be too weathered to permit burning it off the surface. And, to make the situation still worse, storm surges could carry some of the oil inshore to pollute embayments, lagoons, beaches, and even some lakes. Such inshore pollution would occur principally in Canada, but pollution offshore could reach as far to the west as Point Barrow, Alaska.

The Canadian Arctic Resources Committee (CARC), a group made up of 28 Canadians prominent in business, law, science, and other fields, is criticizing the exploratory drilling project as outrageously precipitous and premature. Kit Vincent, executive secretary of this Ottawa-based group, says that CARC's objections to the way Prime Minister Pierre Trudeau's Liberal government has been handling this matter have to do with both substance and procedure.

Substantively, CARC is convinced that the 18-month study has not been adequate for the gathering of either the necessary ecological baseline data or the necessary information pertaining to such vital questions as weather patterns and ice movements. In the absence of such information, any regulatory program or blowout contingency plans that might be adopted will be poorly founded, CARC believes.

The group feels that, procedurally, the government has behaved very badly indeed. According to Vincent, "the whole offshore play [in the Beaufort Sea] was set in motion without public hearings and with extreme secrecy." The government gave its conditional approval of the Dome Petroleum permits 3 years ago without even informing or consulting its own party caucus in Parliament, Vincent says. In CARC's view, no final action should be taken with respect to the exploratory drilling without public hearings and parliamentary debate. CARC has just made its own contribution to serious public consideration of this issue by publishing a book, *Oil Under the Ice*, written by Douglas Pimlott of the University of Toronto.

How the question of oil exploration and development in the Beaufort Sea is handled by the Canadians is important not only in itself but also in terms of setting precedents that could influence U.S. decisions about oil drilling in this OCS province. The U.S. Department of the Interior has tentatively scheduled a Beaufort Sea lease sale for October 1977. At the moment, this proposed sale may look like just so much pie in the sky, but it does signify an intent ultimately to develop these oil and gas resources.

One big question that seems to underlie the whole matter of oil exploration and development in the Beaufort Sea has not yet been squarely addressed. It is simply whether either Canada or the United States should run the risks inherent in exploratory drilling in this OCS region of extreme hazards without first deciding whether the still greater risks that will have to be faced in recovering the oil are acceptable.

If the past is any guide, this question will go begging and the decision-makers in Ottawa and Washington will leave it to good luck and technology to get the oil out without polluting the Beaufort Sea.

—LUTHER J. CARTER

Basic Research Funding: ERDA De-energizes Nuclear Science

One of the questions that has worried many scientists about the creation of the Energy Research and Development Administration (ERDA) was what effect the urgency of its energy mission would have on basic research. Last year's budget was completed before the agency came into existence, so that the new staff made only mid-year course corrections to the funding patterns that had been established by their predecessors in the Atomic Energy Commission.

Now ERDA has submitted its own budget for fiscal 1977, and many scientists—particularly those doing nuclear research—are unhappy with the result. The message in the figures is that some fields of nuclear physics, particularly those centered in the universities, face a declining future with the agency. In 1977, the energy agency has eliminated funding for the Maryland cyclotron laboratory, canceled the contract for the Iowa State reactor program, and reduced support for virtually all of its low energy nuclear physics laboratories. In the previous 2 years, similar programs had been closed out at Rice, Texas, Michigan, and Kansas State, so there is evidence of a growing trend. All the surviving programs are being given a very careful review. Many scientists fear that these actions mean that sometime in the future all remaining nuclear science facilities at the universities, now numbering about a dozen, will be phased out. ERDA officials do not rule out the possibility.

"Nuclear science has been singled out for budget cuts," says Gerhart Friedlander, a nuclear chemist at the Brookhaven National Laboratory, "whereas the other physical sciences are doing rather well." At ERDA, most basic research categories were increased at least enough to compensate for inflation, but the nuclear science budget was reduced. The situation appears bleak enough that the somewhat somnolent community of nuclear scientists is beginning to mobilize its members, and knock on important doors in Washington. A National Academy of Sciences committee on the future of nuclear sciences, chaired by Friedlander, is turning its attention immediately to the effects of the 1977 budget, to recommend new government guidelines. Some nuclear scientists favor the formation of another broadly based committee, including a number of eminent physicists, to call attention to their plight.

Ironically, the area of research that the energy administration has chosen to cut back is the one upon which the Atomic Energy Commission was built. The facilities that are now being closed, small reactors and low energy accelerators, provided the data that led to atomic weapons and nuclear power. Many scientists argue that they are still important for the same purposes.

ERDA inherited a number of programs that had been competently managed for three decades by the Atomic Energy Commission, but bore little, if any, relation to the development of new energy resources. Foremost among these was the bulk of the country's high energy physics research, a $165 million program which appeared out of place in an energy agency, especially to some members of Congress. The legislative mandate for the Atomic Energy Commission included the study of the atom, but ERDA's mandate is to develop new and

Hail Suppression up in the Air

Nearing the end of a 5-year hail research program, investigators at Colorado's National Center for Atmospheric Research (NCAR) find they know an awful lot more about hailstorms than they did, but how to suppress hail still remains a mystery.

The National Hail Research Experiment (NHRE), funded at $2.5 million a year by the National Science Foundation (NSF), has therefore been undergoing a lengthy reexamination spurred by its director, David Atlas, who convened a conference of world-renowned atmospheric scientists last fall. In December, during the course of this reexamination, Atlas resigned because of "differences" with the management "on the optimum direction toward hail suppression research." Atlas was apparently among the first to conclude that the hypotheses on which suppression experiments were based didn't hold water. Now it seems just about everyone agrees that resumption of the cloud-seeding experiments that were conducted over three summers would be fruitless until existing data are further analyzed and more basic research is done on the nature of hailstorms.

Summer hailstorms are quite a problem in western states, causing an estimated $600 million in crop damage and another $150 million in property damage a year. The idea for the hail research program evolved in the early 1960's when the Russians reported spectacular successes in hail suppression using rockets and heavy artillery to bombard storm clouds with lead iodide crystals. Thinking the Russians were onto something (it is now not at all clear that they were) the Interdepartmental Committee on Atmospheric Sciences, composed of 12 federal agencies, asked the NSF to plan a national experiment to find out how hailstorms work and determine the efficacy of cloud seeding.

The NCAR in 1972 set about to conduct the first statistically controlled randomized seeding experiments, using silver iodide. Between 1972 and 1974 the NCAR monitored about 30 storms a year (seeding half of them and leaving the rest as the control population) in "hail alley," a 625-square-mile area in the lee of the Rockies along the Colorado-Nebraska border.

Hail Theory Cast in Doubt

No statistically significant reduction of hail was produced, and the results have contributed to the belief that hypotheses about hail formation, borrowed from the Russians, were wrong. The central concept was that hail is formed in a zone in the middle of a storm cloud where there is a heavy accumulation of supercooled liquid droplets. When particles are introduced, either naturally or artificially, they supply nuclei for the water to crystallize around. The purpose of seeding is to augment the number of particles so the hail will come down in many little pieces—hopefully to melt before landing—rather than in big chunks. The NHRE researchers have found, though, that the supposed liquid accumulation zones do not necessarily exist, and they believe that hail formation is not a one-step but a two-step process occurring in different parts of a cloud, all of which makes the results of seeding unpredictable. The research has also confirmed that in the Rockies there are at least two types of hailstorms—supercell and multicell (referring to single or multiple shafts of upwardly moving air)—which may respond very differently to seeding.

So, hypotheses that 5 years ago seemed "crystal clear," says NCAR executive director John Firor, have now "evaporated." There now even exists the possibility, not particularly encouraging for commercial cloud seeders, that seeding has actually increased the hail from some storms. Although there are differences of opinion on the interpretation of data, Atlas believes there is a case to be made that seeding increases hail in the case of supercell storms because the silver iodide supplies nuclei for the crystallization of water that otherwise might have blown harmlessly out of the top of the cloud.

Instilled with fresh awe for the complexities of atmospheric phenomena, the NHRE people, now under the direction of Donald L. Veal from the University of Wyoming, plan to stay away from random seeding for a while and concentrate on finding just what does go on inside those storms. This they do with the aid of ground-based radar, an armored plane for penetration into the heart of storm clouds, and sailplanes. Meanwhile the floor is wide open for new hypotheses.—C.H.

expanded energy sources as quickly as possible. Only fanciful relations—speculations about the possibility of "muon fusion" and "quark reactors"—have ever been suggested between high energy physics and practical power, although some of its peripheral technology can be helpful in energy research. A year ago many scientists worried about the health of high energy physics under ERDA (*Science*, 6 June 1975), but the fears have proved unfounded.

In fact the purity of high energy physics seems to have brought it special status. According to James Kane, director of physical research at ERDA, "We are essentially the custodians for high energy physics. We don't justify it in the same terms" as other types of basic research. The result is that in fiscal 1977, the science of the largest accelerators and the smallest particles will receive an 11 percent budget increase from ERDA, to $163 million. The National Science Foundation support will be $20 million. High energy physics did considerably better than the rest of the physical research activities at ERDA which were not put in any special category, and were only boosted by 8 percent.

The increment for basic research at ERDA was less than at other agencies, and it pales beside the 40 percent rise in the overall ERDA budget. But what has aggravated nuclear scientists most is that they did not even get a share of the modest increase. In the operating budget alone, the nuclear science funding fell from $79 to $77 million. Combining categories, support for molecular, materials, and geoscience research rose from $103 to $133 million in fiscal 1977, while nuclear sciences fell from $107 to $93 million (figures are budget authorizations, including capital equipment). Spokesmen from many areas of physics have been quick to condemn this shift in basic research as "severe," a "crisis," and a decision with dire consequences in the future.

"I think it is a disaster," says Victor Weisskopf of MIT, whose career includes ample contributions to both nuclear and high energy physics. "If they wanted to cut all basic science, that would at least be consistent," he says, "but they haven't. Of course, I would disapprove such a cut." The same sentiment is reflected by John Schiffer, nuclear physicist at Argonne National Laboratory and of the head of the nuclear division of the American Physical Society (APS). "I very much hope the things reflected in the 1977 budget can be reversed," he says, noting that overall funding for nuclear physics has been going down steadily since 1969. By now, according to Schiffer, the United States is spending less on nuclear sciences than West Germany, and if the expenditure is measured as a fraction of gross national product, many countries outspend the United States. "Even Great Britain spends 50 percent more than we do," Schiffer says.

While the National Science Foundation (NSF) supports some nuclear research, ERDA provides about three-quarters of the funding for the field. A reasonable-sized low energy nuclear physics laboratory, utilizing a cyclotron, a small reactor, or a Van de Graaff accelerator, will cost between $500,000 and $1 million to operate. Universities with a strong nuclear science program usually have such a facility, and a rough count indicates that ERDA now supports 10, plus 3 in the national laboratories, while the NSF supports 12. In many cases these laboratories will account for 25 percent or more of the university's physics research budget.

Such laboratories, where nuclear science was discovered in the 1940's and 1950's, are now the proletariat of nuclear research. They are being quickly outclassed by a newer generation of medium energy accelerators, which are both more powerful and more expensive to operate. Examples are the $53 million Los Alamos Meson Physics Facility, the $7.6 million Bates Linear Electron Accelerator at MIT, a large new cyclotron at the University of Indiana, the BEVALAC at Berkeley—a hybrid machine for heavy ions based on an out-of-date high energy accelerator—and a planned national heavy ion accelerator at the Oak Ridge National Laboratory. These intermediate energy facilities are designed to investigate new phenomena in nuclear physics, but they approach in size and cost the operations of high energy accelerators. Support for the medium energy accelerators received a token 1 percent increase, but laboratory directors expect that utilization of these accelerators will be reduced to two-thirds or one-half of full-time operation because of the tight budget.

In hard financial times, many sciences have had to give up some of their smaller research facilities. What distinguishes nuclear science, according to its spokesmen, is that many low energy machines are as much at the frontier of research as the medium energy facilities. The energies of these laboratories are also well-suited for assistance in nuclear power applications, such as breeder design and "nuclear burning" of wastes, and for study of some of the loss mechanisms in fusion experiments.

There was no warning of the cuts in the 1977 nuclear budget. Neither the APS nor the Academy was consulted, and the reductions are not being presented as part of a measured program with an end in sight. Even with the discontinuation of some sizable contracts—the largest being the University of Maryland cyclotron funded at $1.25 million—the surviving laboratories are facing substantial budget reductions. Argonne National Laboratory took a 10 percent cut for all nuclear physics programs, according to the laboratory director's office, and will have to drastically reduce operations at the CP-5 research reactor. Brookhaven National Laboratory's nuclear program was reduced 3 percent, and the Yale nuclear laboratory, one of the larger ERDA university contracts, was cut back 6 percent. With inflation at 9 percent, the reductions in research capability are obviously larger.

Speaking for ERDA, Jim Kane was not at all hesitant to discuss the budget with *Science*, although he said that the situation is too fluid to predict what the funding will be in the future. Noting that he has only been director of the physical research division for 2 months, he said, "I didn't make this decision, but I would have." Although ERDA administrators will not discuss the role of the Office of Management and Budget in setting basic research criteria, knowledgeable Washington officials say that the OMB gave the energy agency very tight constraints on its basic research budget for 1977, and furthermore fixed the funding levels for the different research fields. The decision to mark down nuclear research could probably have been reversed by the top management of ERDA, say these officials, but the decision stood. Within the constricted basic research budget, there was reportedly near unanimity in ERDA that the materials research was so crucial to energy development that it could not be reduced.

As Kane explains the problem of apportioning funds, "In an 8 percent growth budget, how do you start new programs?" He says that ERDA had important responsibilities to start new basic research programs related to fossil fuels, geothermal energy, and combustion, which could not be done without reductions in programs carried over from previous years. But to a question about nuclear science funding in the future, Kane replies, "I don't know. I'm not reluctant to answer, I just don't know."

Separate from the consideration of budget trends, Kane foresees the possibility that more university facilities may be closed in the future. "Nuclear physicists are pricing themselves up to the high energy physics bracket," he says, noting that the physicists themselves are driving the research effort toward more expensive machines. Just as their high energy colleagues have found that on a constant budget fewer new laboratories can be maintained, Kane expects that nuclear scientists will be forced to reduce their total number of facilities too. "If you want to do medium energy physics, I see the day when it can't be done and also sustain all the low energy physics in the universities."

Some scientists find the reduction of nuclear physics research, at just the time when nuclear power has been given renewed priority, especially shortsighted. "There seems to be an idea that nuclear science is not important to nuclear power any more," says Victor Weisskopf. "But that is mistaken. Nuclear power faces several critical problems—safety, reprocessing, and waste disposal—and nuclear science can contribute to all of them." Weisskopf also emphasizes that nuclear science still has intrinsic value, with important discoveries still occurring in the field, and that the university-based laboratories have an important pedagogical function. While it is very difficult to assess exactly what portion of nuclear science is applicable to nuclear power, Jim Kane says his personal estimate is that about one-third of the science is applicable, and two-thirds is basic or pure research.

Other factors besides budget stringency may have contributed to the squeeze on nuclear science. Some observers think the research field is tainted simply because it carries the word nuclear, which conjures an image that ERDA is clearly trying to rid itself of. Others think that the scientists themselves are partly to blame, for lack of organization and visible representation in Washington. While the high energy physicists have an advisory panel that meets four times a year to make recommendations for NSF and ERDA policy, the nuclear physicists have no such representation. "There is no doubt," said one observer, "that the high energy physicists have done a much better job of coordinating their priorities." Although such standing committees at times seem to produce more reports than the bureaucracy could possibly use, they are one way for scientists to bring their arguments to the attention of the OMB, if only indirectly.

Finally, it is simply difficult to decide if high energy physics is twice as valuable as nuclear physics (with over $200 million going to high energy physics this year). Is molecular and materials research a little more important (at about $150 million) than nuclear sciences (at $100 million)? Many scientists would agree that the potential for practical applications is somewhat greater for basic materials research, though both areas have much more potential than high energy physics.

Perhaps the more important question is whether the entire basic research program is supported generously enough. On that subject, the former assistant administrator of ERDA who oversaw basic research, John Teem, says, "My own judgment is that we are getting perilously close to the critical edge where the answer is no."

—WILLIAM D. METZ