

begun in the past two years are the quantum wave project, exploring the quantum behavior of electrons in nanometer-scale semiconductor devices; the microphotoconversion project, investigating the use of lasers to control chemical reactions in extremely small regions; the electron wavefront project, studying the ways to exploit the information in the phase of an electron to explore the structure of biopolymers as well as semiconductors (see the article by Akira Tonomura in *PHYSICS TODAY*, April 1990, page 22); and the atomcraft project, aimed at creating and analyzing material structures at the atomic level.

Perhaps the most speculative ERATO project has been one labeled the quantum magneto flux logic project.

The project director, Eiichi Goto of the University of Tokyo, had developed a computer element known as the flux parametron in 1953. The advent of small superconducting Josephson junctions opened the possibility of applying Goto's concept to the design of computer devices sensitive to a single quantum of magnetic flux. The ERATO group is exploring how to realize the promise these devices offer of high switching rates with low power consumption—a promise that, in Rowell's view, may make these devices one of the more practical options for the oxide superconductors, which must operate at high temperatures. (See the figure on page 59.) Alan Engel, overseas representative for ERATO, told us that the group has reached 4.5-GHz operation and may

end up with a 20-gigaflop scalar processor by the end of the project. (Other computers with that speed are parallel processors.)

Every year ERATO begins three new five-year projects, with \$2–3 million annual funding for each. Chiba likened an ERATO project to a form of performing arts, with JRDC serving as producer, a dynamic and well-known scientist as the director and a team of young scientists as the performers. The project director plays a critical role as mentor to the younger scientists. Chiba typically selects a director who can excite the team and builds the project around him. Because the average age of the performers is about 31 years, Chiba termed ERATO a “playground for youngsters.” —BARBARA GOSS LEVI

CHERNOBYL AFTERMATH TO BE ASSESSED BY INTERNATIONAL EXPERT TEAM

In 1964, in one of the first major studies of reactor safety in the United States, a team of scientists at Brookhaven concluded that a worst-case meltdown accident in a 1000-MW light water reactor could affect an area that “might be equal to that of the state of Pennsylvania.”

The Brookhaven study assumed no containment or confinement structure, so that there was no barrier to the dispersal of radioactive materials, whereas in the accident that took place at Chernobyl on 26 April 1986, the reactor did have a containment—admittedly a weak one. On the other hand, the accident at Chernobyl was even more severe than the one postulated in the Brookhaven study, in that slow-neutron reactions in an overmoderated graphite-water reactor went out of control, causing the plant to explode. The initial explosion was more nearly comparable to a chemical explosion than to that of an atomic bomb in terms of its energy, which was roughly equivalent to the cohesive energy of the containment. That initial explosion, together with at least one follow-on explosion, thrust a large proportion of the plant's radioactive inventory into the atmosphere.

The scientific and medical communities have yet to determine just how large an area was severely affected by the Chernobyl accident, and in just what way the area was affected. But a spate of troubling recent reports in the world press suggest that the lingering impact of the accident has been very severe indeed.

Partly as a result of such reports, a

major international study has been organized, the Ukrainian and Byelorussian governments have issued urgent appeals for international assistance, and all Soviet-built power reactors—including plants that are not of the same type as the Chernobyl units—are under continuing review.

Renewed concern

The fourth anniversary of the Chernobyl nuclear power plant explosion was an occasion this year for renewed concern about the consequences of the accident. The anniversary was declared a day of mourning in the Ukraine, and tens of thousands turned out for a service in Kiev, the capital of the Ukraine, which is located about 80 miles south of Chernobyl. In Byelorussia, another area severely affected by fallout from the explosion, the 35 000 workers at the Gomselmash engineering works in Gomel walked off the job for the day, demanding that the region be declared a disaster zone.

For *Le Monde*, the prestigious daily paper published in Paris, the anniversary was an occasion to raise questions in a front-page commentary piece about whether Soviet authorities were keeping the commitments they made immediately after the accident to take adequate remedial measures and to report to the world fully and openly on what they were doing.

Almost as if in response to such questions, it was announced on 7 May that a major expert study has been launched under international aus-

pices to evaluate what the USSR has done to date and what it plans to do in the years ahead. The study is being done in response to a request the Soviet government made last October to the International Atomic Energy Agency in Vienna, seeking organization of a group of international experts to assess “the concept which the USSR has evolved to enable the population to live safely in areas affected by radioactive contamination following the Chernobyl accident, and... the effectiveness of the steps taken in these areas to safeguard the health of the population.”

Scope of study

The study has been organized by the IAEA in cooperation with the Commission of the European Communities, the Food and Agricultural Organization, the UN Scientific Committee on the Effects of Atomic Radiation, and the World Health Organization. About 100 experts from all over the world will be involved in the study, which is to be done over a period of about six months starting immediately. At the end of that time, a report will be made to the world community. Itsuzo Shigematsu, director of the Radiation Effects Research Foundation in Hiroshima, Japan, heads the study team.

Specialist teams will address the following tasks:

- ▷ Historical portrayal of the events leading to the current situation and description of the current status
- ▷ Corroboration of assessments of the environmental contamination

- ▷ Corroboration of individual and collective dose assessments
- ▷ Clinical health effects from radiation exposure and evaluation of the general health situation
- ▷ Evaluation of protective measures, including intervention criteria, action levels and countermeasures taken.

Separately from the international study, on 30 April the Ukrainian Council of Ministers issued an appeal to "governments, the publics of foreign countries, and international organizations" to "cooperate in the elimination of the consequences of the Chernobyl power plant accident." The appeal said that the Ukrainian program to eliminate consequences of the accident could cost "billions"—monetary units unspecified—in investments. The program will include, according to the appeal, continued resettlement of people from the danger zone, protection of water sources, radioecological monitoring of polluted territories and monitoring of the health of affected populations.

Separately, the Byelorussian government has asked for international help to relocate and medically treat people living in areas affected by the accident. A Byelorussian diplomat is reported to have said in Brussels that two million Byelorussians live in such areas.

Ukrainian report

In a progress report on the Chernobyl aftermath issued with the appeal, the Ukrainian government reported that more than 1600 villages and towns, with more than 1.5 million inhabitants, were located in the contaminated area; more than 90 000 individuals have been resettled to 101 newly built villages in clean areas; farmhouses are being built to accommodate the resettlement of 14 entire villages; and in 1990 new apartments are to be provided for the resettlement of an additional 15 000 people. The progress report said that 6.5 million hectares of farmland and forests were affected by radioactive contamination from the accident—nearly 25 000 square miles.

The report said that special attention has been paid to those who participated in cleanup operations (more than 130 000 individuals in the Ukraine) and to children and adults with severely affected thyroid glands (about 150 000 individuals). By the end of 1989, the report said, 450 000 people in the Ukraine, including 111 000 children, will have undergone medical checkups and received medical assistance. More than 12 million square meters of territory have been cleaned up, and 500 000 cubic meters

of radioactive waste has been deposited in special sites.

According to the report, 9.2 billion rubles—roughly \$1 billion at the current black market rate—have been spent on remedial measures to date. It said that 17 billion rubles more will be needed for the remedial program now planned, of which 8 billion will be spent in the next five years. The Ukrainian republic has established special accounts for the deposit of foreign donations to the remedial program, and it also is asking for direct help with pharmaceutical and medical products that are in short supply.

The report says that the All-Union Scientific Center of Radiological Medicine that has been established in the Ukraine "could be turned into an international center specializing in the elimination of the aftermath of nuclear plant accidents."

Substantial additional expenditures will be required, the report says, to manage the complete phasing out of the Chernobyl plant by 1995, a course of action recommended in February by the Supreme Soviet of the Ukrainian Soviet Socialist Republic. According to sources at the IAEA, the Soviet government has set up a committee to evaluate the possibility of phasing out the Chernobyl reactors, and the expectation is that they indeed will be shut down at the earliest opportunity.

Reactor safety

The Chernobyl accident appears to be roughly of the type described by Niels Bohr during World War II when he identified the essential difference between the extremely violent fast-neutron explosion in an atomic bomb and the worst kind of slow-neutron explosion that could take place in an atomic power plant. As paraphrased by Rudolf Peierls in a review article last year, Bohr pointed out that a "reactor depends on slow neutrons, which have to travel considerable distances before they cause further fission, so that the development of the chain reaction is slow. When the released energy has heated the reactor to a temperature that will melt or vaporize its materials, the expansion and dispersal will stop the chain reaction. The energy released is therefore only of the order of the cohesive energy of the structure, so that the explosion is no more violent than that from chemical explosives."

Many Western reactor experts have come to the conclusion that the Chernobyl-type reactor, the so-called RBMK, is of a defective design partly because it is overmoderated—mean-

ing that the reactivity of the reactor increases, by a positive feedback mechanism, when water is lost—and partly because it is not equipped to cope with the consequences of a reactivity excursion. Reactor specialists in the West have been much less well acquainted with reactors of the other major Soviet type, the VVER, which more closely resembles US light water reactors and is not overmoderated. The impending unification of the two Germanies has opened VVER reactors in East Germany to Western inspection, however, and experts are arriving at the unsettling conclusion that these reactors also are seriously unsatisfactory because of design defects, obsolete features, aging materials, poor construction and poor operating cultures.

At this writing, West Germany's Ministry of Environment and Nuclear Reactor Safety is about to issue a report on the five nuclear reactors in East Germany, four of which—the VVER units at Greifswald—already have been studied by outside specialists. Sources at the ministry and at the IAEA say it is a foregone conclusion that at least two of the Greifswald units will have to be permanently closed. Six months ago East German authorities disclosed that one of the Greifswald units came very close to melting down in 1975.

Economic implications

East Germany benefits from the special advantage of having a rich uncle in the form of West Germany, which is willing (if not exactly eager) to help it cope with the very prodigious costs of phasing out nuclear power plants and replacing them with electricity from other sources. But there also are reported to be at least a dozen VVER reactors in Czechoslovakia, Bulgaria and the Soviet Union itself, and they too may have to be shut down or substantially modified for safe operation.

Altogether, the problems posed by the overmoderated RBMK reactors and the aging VVERs amount to a special test of *perestroika* ("restructuring"). In addition to the enormous costs of medical and environmental remedial measures, as outlined in the report from the Ukrainian republic, it seems clear that huge expenses associated with closing some reactors also are part of the aftermath of Chernobyl.

These costs are being incurred, of course, at a time of great economic difficulty for the USSR, and the implications for the international community are self-evident.

—WILLIAM SWEET