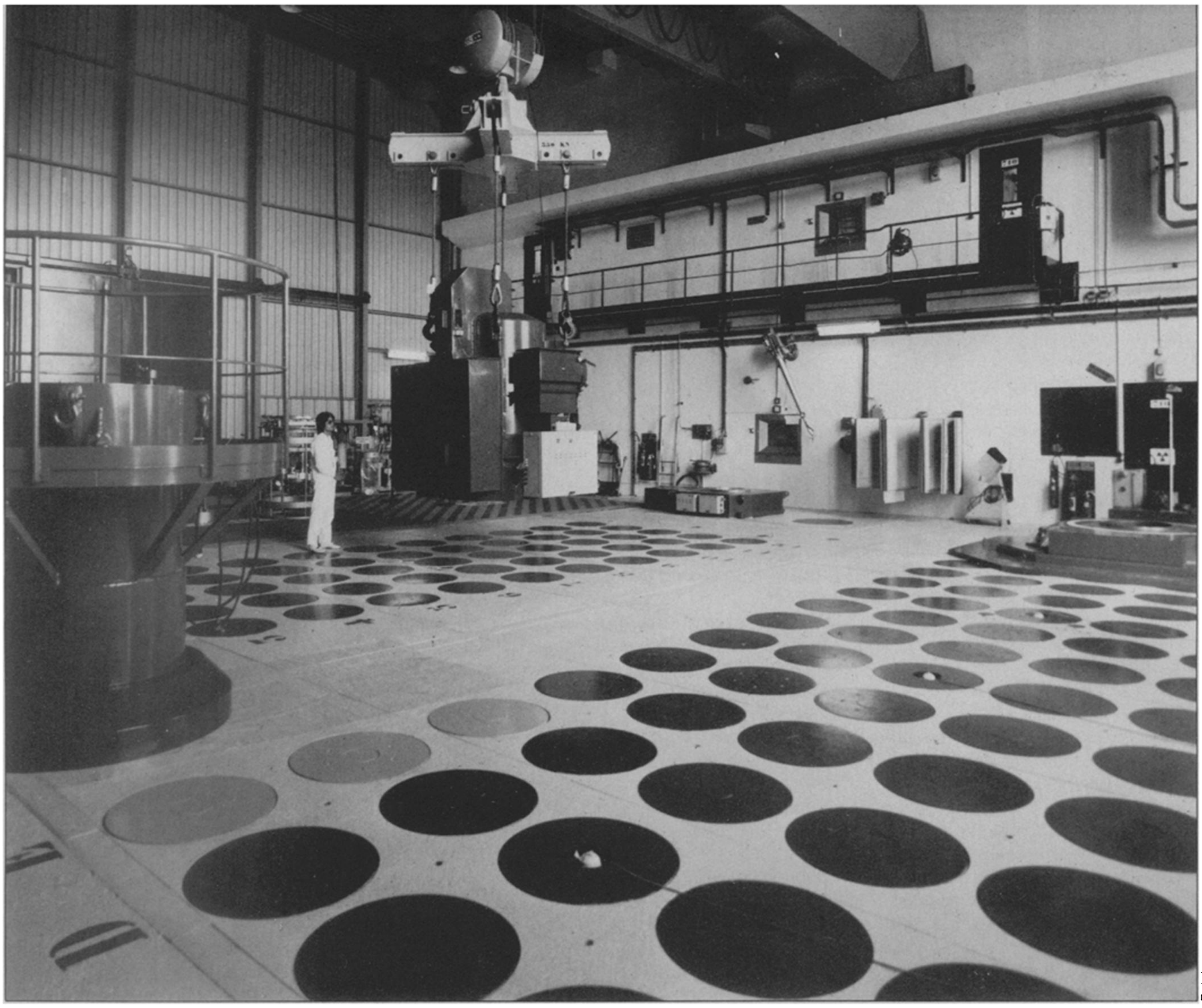

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If it's AVM, this must be France

International efforts to solve the radwaste disposal problem include France's showpiece AVM vitrification plant and other projects in Sweden, the United Kingdom, Germany and Canada

BY LINDA GARMON AND IVARS PETERSON

Third of a three-part series on high-level nuclear waste management.

"...*company in a journey makes the way to seem the shorter.*" — Izaak Walton

Every nation using nuclear energy has to face the problem of dealing with its radioactive waste. As spent fuel and residues from the reprocessing of spent fuel accumulate and public concern about radioactive waste disposal grows, most nations are developing nuclear waste-handling programs. Along with their own national programs, many countries are cooperating in their journeys toward solutions to the problems of handling nuclear waste.

Recently, a National Waste Terminal Storage (NWTS) program information meeting sponsored by the U.S. Department of Energy devoted for the first time a session to the international scope of nuclear waste management. Ralph E. Best of the NWTS Integration office noted, "Although there are differences in approach, each country acknowledges that many of the issues to be addressed transcend national boundaries and require a significant measure of international consensus."

The benefits of international cooperation include reducing duplication of efforts and costs, recognition of gaps or alternative approaches in research and development programs and the identification and resolution of specific technical issues. Perhaps, a feeling also exists that the public is more likely to accept concepts that are based on a wide consensus well outside the issues of national politics.

R. A. Simon, representing the Commission of European Communities at the recent International Symposium on the Scientific Basis for Nuclear Waste Management held in Boston, said that in the European Community, the consensus is that fuel reprocessing should continue, with activities in radioactive waste management based on a closed nuclear fuel cycle including the recycling of uranium and plutonium. Research and development programs are aimed at placing high-level wastes into deep geological formations, concentrating on four options: dome salt, clay, crystalline rock and subseabed burial.

As in the United States, the European repository designs rely on a system of bar-

The high-level waste glass containers formed in France's AVM plant are stored in an adjacent hall, left. The containers are stocked in concrete shafts, whose covers appear as dark circles.

riers — "a defense in depth." Borosilicate glass is the first choice for immobilizing the waste. Researchers are now testing a variety of materials for the second barrier, a corrosion-resistant container that must last from 250 to 1,000 years. Backfill materials to prevent water flow around the waste containers have yet to be assessed.

The U.S. nuclear waste management program benefits from international research through a network of agreements with international agencies and individual nations, along with numerous informal exchanges. An agreement with the Federal Republic of Germany, for example, involves brine migration experiments in the Asse salt mine. An agreement is under development with Canada to participate in an underground research laboratory in granite.

At the NWTS meeting, Carl Cooley and Glen Boyer of the U.S. Department of Energy pointed out the need for specific technical exchanges in the future and standardization of geotechnical methods as specific geologic sites were investigated. They said, "Building an international consensus can provide one of the links to revitalizing the nuclear industry at a time when its contributions will be extremely valuable to the energy supply of each country."

There are lessons to be learned from the experience of every country with radioactive waste management. The examples of the United Kingdom, Sweden, the Federal Republic of Germany, Canada and France are particularly interesting.

United Kingdom

Jutting out from the northwest face of Scotland is the Isle of Skye. There, geologist A. P. Dickin of the University of Oxford, U.K., recently concluded that "high-silica glass is more suitable for long-term disposal of radioactive wastes than borosilicate glass." Dickin developed a microprobe analysis technique to examine the leaching behavior of natural deposits of high-silica glass — that is, rhyolite — that have been exposed to heated groundwater. The results, published in the Nov. 26 NATURE, indicate that even after 200,000 years of "a high fluid flux at 400°C and 300 bar," only milligrams per square centimeter of rhyolite were leached. Although a corresponding high-silica glass recipe for radwaste would require a greater furnace temperature for melting, says Dickin, "the extra cost involved may be outweighed by its stability advantages over borosilicate glass."

Despite research such as Dickin's, the United Kingdom — like so many other countries — has decided to stick with borosilicate glass. Two other aspects of their radwaste management program are worth mentioning.

First, all United Kingdom high-level radioactive waste should end up in the form of borosilicate glass. "UK policy involves the eventual reprocessing of all spent fuel," London Department of Environment's F. S. Feates explained at the recent NWTS meeting in Columbus, Ohio. (For years, whether to reprocess *commercial* spent fuel has been somewhat of a controversy in the United States [SN: 12/19 & 26/81, p. 396]).

Second, the United Kingdom's "Radioactive Waste Management Advisory Committee" recently recommended that solidified high-level radioactive waste be stored for 50 years in an engineered storage facility prior to permanent disposal. Says Feates, "This could lead to a number of practical advantages: Radiation exposure to workers will be reduced, the problems associated with heat generation in a repository will be reduced and more time will be available to develop the disposal facilities which are required."

Sweden

A defunct iron-ore mine at Stripa is the radwaste community's showpiece for international exchange of information. Sweden, Finland, Japan, Canada, France, Switzerland and the United States all are involved to some degree in conducting research in granite at 350 to 400 meters below surface at that site. While the Stripa mine, which is 150 miles west of Stockholm, itself is not a suitable site for a repository, it does present a convenient set-up for the in situ gathering of data related to choosing and preparing a waste disposal site.

Over the past four years, researchers at Lawrence Berkeley Laboratory (LBL) in California have been involved in gathering such data at Stripa. "Perhaps the single most important conclusion we drew from our Stripa investigations is that site characterization cannot be concluded until one has access to underground openings that reach the depth of the proposed repository," LBL's Paul A. Witherspoon and colleagues reported at the recent NWTS meeting. For example, data on a rock mass's system of fractures—which can deform under stress—could not be collected from the surface in the detail LBL researchers were able to obtain underground, research colleague Phillip H. Nelson explains. In addition, "Experience at Stripa has shown the superiority of collecting groundwater samples from boreholes drilled from underground rooms as compared with samples collected in surface boreholes," Witherspoon says. The samples are collected in an attempt to characterize groundwater movement through a rock mass. When collected from the surface, the drilling procedure usually contaminates the water samples, because the high pressure necessary to circulate the drilling lubricants can force those fluids into the rock along the borehole. Drilling boreholes in underground rooms to collect water samples alleviates this problem.

Other studies Witherspoon and associates have conducted involve placing electric heaters in underground testing rooms to simulate the energy output from high-level waste canisters. Witherspoon and co-workers found that significant thermal stress occurs when electric heaters warm the rock to temperatures exceeding 300°C. (Sweden's radwaste managers intend to maintain a maximum repository temperature of 100°C simply by first holding waste in temporary storage for about 40 years and by spacing the canisters in the repository.)

Much of the remaining data collected by the LBL researchers will lie unanalyzed. While DOE will continue U.S. involvement at Stripa on a smaller scale, it canceled LBL's involvement in the program last September. "I've seen no official explanation of the demise of the project," Nelson told SCIENCE NEWS. "One rationale is that this site is in granite and the United States' candidate media [for waste repositories] are salt, basalt and tuff [SN: 1/12/82, p. 9]," he says. "Still, I think it is a big loss ... I certainly view the cancellation as a mistake."

Federal Republic of Germany

The focus of both scientific study and political controversy in the Federal Republic of Germany is the Gorleben salt domes, which stretch from Lower Saxony under the Elbe River into East Germany. In 1977, the Gorleben site was chosen as the best place for a comprehensive nuclear waste management center. Two years later, the Lower Saxony state government refused permission for the facility.

In September 1979, the federal and state governments presented a new concept for waste disposal: interim storage plants, a demonstration reprocessing plant, plutonium refabrication and the disposal of wastes, all to be located at different sites. The 1979 resolution also called for the investigation of other disposal techniques, including direct disposal of spent fuel.

Not all the pieces of the program are falling into place easily. Construction of the vitrification plant began in 1981, and formal application for a reprocessing plant site is just beginning amid more controversy. Although the federal government seems convinced that any problems with the Gorleben site can be overcome by tailoring the waste to suit the geological formation, technical objections continue to be raised. The salt domes are not covered by a layer of clay, they are in contact with groundwater in some places, and East Germany extracts natural gas from its section.

An amendment to the Atomic Law in 1976 closed the Asse salt mine, used from 1967 to 1978 as a test repository for low-level and intermediate-level radioactive

WHO IS DOING WHAT WITH HIGH-LEVEL WASTE AND WHERE?

Country	Current Practice	Future Plans
Belgium	Liquid wastes from Eurochemic reprocessing plant are stored in stainless steel tanks. Also, fuel reprocessing in France.	Vitrification processes are being considered for waste solidification, including the incorporation of a granular product into a metallic matrix. Solidified waste will be placed in engineered surface storage. Investigating clay formations for waste repository.
Canada	Engineered storage of irradiated fuel assemblies, both surface and underground.	Storage of fuel without reprocessing is considered satisfactory for at least 75 years. Methods for disposal of irradiated fuel and/or separated wastes in deep underground rock formations are being developed.
CSSR	Fuel reprocessing in another country.	Two-step solidification process on a pilot scale basis should be completed in 1982. An experimental storage facility for vitrified wastes is designed and will be constructed in the late 1980s.
Finland	Fuel reprocessing in another country.	Investigating crystalline rocks for repository of any returned solidified waste.
France	Liquid wastes are stored as acidic solutions at the Marcoule and La Hague reprocessing plants in stainless steel tanks. The PIVER pilot plant to solidify wastes into borosilicate glass was in operation from 1969 to 1973. It has been superseded by the AVM plant which commenced operation at Marcoule in 1978, capable of vitrifying wastes from an 800 ton/y fuel reprocessing facility.	Solidified waste will be stored in air-cooled vaults. A similar vitrification plant (AVH) will be installed at La Hague after confirmation of routine operation of the AVM plant. Investigating salt and crystalline rocks for waste repository.
Germany, Federal Republic of	Liquid wastes from WAK reprocessing pilot plant are stored in stainless steel tanks. Also, fuel reprocessing in France. Studies of solidifying wastes into borosilicate and phosphate glass are in progress.	Vitrification processes are being developed for conversion of the high-level wastes to glass after a three to five year cooling period. Salt formations are being studied for disposal of vitrified product and other solid radioactive wastes.
India	Liquid wastes stored as acidic solutions in stainless steel tanks.	A waste immobilization plant using a batch glass-making vitrification process is expected to be operating in 1981. Vitrified wastes will be stored in air-cooled vaults. Investigating igneous rock and sedimentary formations for waste repository.
Italy	EUREX pilot reprocessing plant began operation in 1970. Small quantities of liquid wastes are stored in stainless steel tanks.	Batch solidification to form borosilicate or phosphate glasses under consideration. Disposal of solid wastes in clay formations of low permeability is being investigated.
Japan	Reprocessing plant commenced operation in 1977 and liquid wastes are stored in stainless steel tanks. Also, fuel reprocessing in France.	Solidification processes being developed and a pilot plant will be constructed in early 1980s. Investigating granite and zeolite rock formations for waste repository.
Netherlands	Fuel reprocessing in France.	Investigating rock salt formations for repository of any returned solidified waste.
Sweden	Fuel reprocessing in France.	Any returned solidified high-level waste will be stored in underground air-cooled vaults and eventually disposed of in a repository deep in Swedish bedrock.
Switzerland	Fuel reprocessing in France.	Investigating evaporite formations for repository of any returned solidified waste.
UK	Liquid wastes are stored as acidic solutions at Sellafield and Dounreay reprocessing plants in stainless steel tanks.	Highly active waste is currently stored as a liquid. It is planned from the late 1980s to vitrify the waste using the French AVM system. Because of the temperature, the vitrified blocks will be placed in a specially designed store, cooled by air or water, on or near the surface for at least 50 years. The possibilities for disposal being considered are placing the blocks on or under the bed of the ocean or in deep geological formations on land. Research into the feasibility of ocean disposal and drilling program to investigate the properties of certain rock formations and the feasibility of geological disposal.
USA	Liquid wastes from government operations at Hanford and Savannah River plants are alkaline and stored as concentrated salt solutions or salt cakes in mild steel tanks; heat-generating cesium-137 and strontium-90 are chemically separated from Hanford wastes, encapsulated and stored in water-cooled basins. At the National Reactor Testing Station in Idaho, acidic wastes are stored in stainless steel tanks prior to calcination; calcined wastes are stored in stainless steel bins. No commercial reprocessing plants are operating. The Nuclear Fuel Services Plant in New York State operated 1966-1972 but is now shut down. Most high-activity wastes from this plant were made alkaline and are stored in a mild steel tank but small quantities of special wastes are stored in a stainless steel tank.	All high-activity wastes are to be solidified as soon as practicable. Long-term options being evaluated including storage in existing tanks or vaults, storage on-site in underground caverns, or shipment to off-site federal repository. Commercial fuel reprocessing was banned by Presidents Gerald Ford and Jimmy Carter and may cease indefinitely with the spent fuel being stored or disposed of. Any high-activity waste from fuel reprocessing is to be converted into an immobile form within five years after generation and transferred to a national repository within ten years. Both surface storage and deep geological disposal concepts for solidified waste and/or spent fuels are being considered within a National Waste Terminal Storage Program.
USSR	Liquid wastes stored in stainless steel tanks. Solidification processes to produce phosphate and borosilicate glasses have been investigated on a laboratory scale with radioactive wastes and on a pilot plant scale with inactive simulated wastes.	Industrial scale plant to vitrify wastes is expected to begin operation in the 1980s. Storage of solidified waste in near-surface facilities and deep geological disposal concepts are being studied.

After "The Management of Radioactive Wastes," IAEA waste, because of a new, time-consuming licensing procedure. "This change in the law brought about a situation in which, from the beginning of 1979 probably through the mid-80s, the Federal Republic has no possibility of disposing of the radioactive waste arising during operation of nuclear installations. Therefore these wastes have to be stored intermediately," reported A. Ziegler and H. Röthemeyer at the NWTS information meeting.

Because German utilities have to satisfy the government that they can safely dispose of nuclear wastes as a condition for construction and commissioning licenses for new reactors, the stalemate in Germany's nuclear program will continue until uncertainties in waste disposal are resolved.

Canada

The ancient crystalline rocks of the Canadian Shield, occupying almost half of Canada's area, provide numerous potential locations for disposal vaults. Field research and drilling is underway at five locations to provide scientists with information on rock properties and groundwater movement.

An important part of the program will be an underground research laboratory in Manitoba that will be the first test facility built below the water table in previously undisturbed granitic terrain, with construction to begin in mid-1983. The laboratory will consist of several small rooms at a depth of 300 to 500 meters. No nuclear waste will be used or disposed of in this laboratory.

Canada's waste immobilization program includes investigation of alternatives to glass, such as ceramics and glass-ceramic combinations, which are tailored specifically to Canadian disposal conditions. For immobilization of irradiated fuel, development work is currently directed toward relatively thin-walled metallic containers.

The governments of Canada and the province of Ontario agree there is no urgent need for early establishment of an operating disposal facility. During the research, evaluation and approval process, spent fuel, they expect, will continue to be stored safely at reactor sites.

France

This country has stood in the radwaste community's spotlight for some time now. As early as the late 1950s, France began extensive research on high-level waste solidification processes. By 1969, a pilot plant—the PIVER—was solidifying wastes into borosilicate glass. Then, in 1978, the PIVER was replaced by the AVM plant—a full-scale continuous vitrification plant at Marcoule. (The process that most probably will be used to convert U.S. high-level defense waste from the Savannah River Plant into borosilicate glass will be similar to the AVM process. For years, engineers at E.I. du Pont de Nemours & Co. have been working on the design of a borosilicate glass-making plant for those wastes.)

The vitrified wastes from the AVM plant now are stored in air-cooled wells. Eventually, they will be disposed of in deep geologic formations. At the NWTS meeting, J. M. Lavie and A. Barthoux of the National Radioactive Waste Management Agency (ANDRA) in France described the various disposal options that have been proposed in their country. One option is to "cool the packages completely on the surface for about 150 years and then bury them so as to consider them as merely cold packages, making it possible to have a compact storage unit." A second option is to cool them only partly on the surface—say, about 30 years—and then to bury packages "sufficiently distant from each other to prevent average heating from being prohibitive." A final option that has been proposed is to build a geological storage facility a few years after the fabrication of glasses, cool the packages in situ and eventually transform this storage facility into a permanent repository by sealing it. "All these solutions, and particularly the third one, are being investigated," Lavie and Barthoux reported. They do not expect disposal of any vitrified wastes before 1992.

Eyeing this international hodgepodge of nuclear waste activity from his home in Clinton, Tenn., is John G. Moore, formerly of Oak Ridge National Laboratory. Moore, who chaired the 1980 International Symposium on the Scientific Basis For Nuclear Waste Management in Boston, retired on New Year's Day from radwaste research to devote more time to a beloved hobby—cultivating flowers. But the international radwaste scene soon may bring him out of the greenhouse. "I've had several countries ask me if I'd be interested in consulting on the chemical process aspect of [radioactive waste management]," Moore explains. "I don't have to do it," he says, "I can get prestige staying at home and looking at these lovely flowers." But Moore is considering consulting because the radwaste community "has finally decided to get off its hump." Says Moore, international programs on the management of radioactive waste seem, in general, to be picking up speed.

"It appears to me that so far as high-level waste goes, the world has just about decided to go glass," Moore says. This puts the French — with the only full-scale glass-making plant in operation — "way ahead of us," he says. And this "jump" on the radwaste community has not gone unnoticed: Belgium, West Germany and the United Kingdom all have decided to buy the French vitrification process. "Even people in this country have asked, 'Why don't *we* buy it?'" says Moore.

If a major name of the international exchange game is to eliminate duplication of efforts and costs, then why doesn't the United States buy the process? Says Moore, "That's a good question." □

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CONCISE DICTIONARY OF SCIENTIFIC BIOGRAPHY — James F. Maurer, et al., Eds. A one-volume abridgement of the 16-volume *Dictionary of Scientific Biography,* which was designed to present the history of science by means of articles on the lives and achievements of scientists. This abridgement offers the essential facts from all the entries, set forth briefly and clearly and in significant proportion to the scope of the original articles. Scribner, 1981, 773 p., $100.

DICTIONARY OF THE HISTORY OF SCIENCE — W.F. Bynum et al., Eds. This dictionary is organized thematically around the key ideas of science in the hope of explaining core features of recent Western science within the context of its development. Princeton U Pr, 1981, 494 p., illus., $40.

THE DNA STORY: A Documentary History of Gene Cloning — James D. Watson and John Tooze. A history of the recombinant DNA regulation debate. Expresses the concerns of scientists researching in the field, the public's and the press's reaction to a science area that evokes both hope and fear and governments' reactions—federal, state and local. W H Freeman, 1981, 605 p., color/b&w illus., $19.95.

THE GRAND TOUR: A Traveler's Guide to the Solar System — Ron Miller and William K. Hartmann. Presents our planetary system as a new visitor might see it, not centered around earth, but with earth as only one planet out of many. Spectacular color paintings by space artist Miller plus photographs, text, diagrams and maps take the reader to 36 different objects in our solar system. Workman Pub, 1981, 192 p., color/b&w illus., $19.95, paper, $9.95.

KENNEDY, KHRUSHCHEV, AND THE TEST BAN — Glenn T. Seaborg with Benjamin S. Loeb, foreword by W. Averell Harriman. Harriman in the foreword says, "It is important that the story of the Limited Test Ban Treaty be told, not only for its value as history but also for the guidance this experience can provide for the conduct of future East-West relations." Atomic Energy Commission Chairman Seaborg's detailed daily journal was the basis for this dramatic account of the delicate diplomacy that made the treaty possible. U of Cal Pr, 1981, 320 p., illus., $16.95.

NEW DIRECTIONS IN OPHTHALMIC RESEARCH — Marvin L. Sears, Ed. Papers by leading experts in vision science presented at an international symposium in May 1980. Yale U Pr, 1981, 358 p., illus., $30.

OUTLOOK FOR SCIENCE AND TECHNOLOGY: The Next Five Years — National Research Council. Builds on the first outlook report (1979). Prepared for the National Science Foundation, this report considers topics ranging from ecology to nutrition, chemical synthesis to fuel science, mathematics to industrial research. W H Freeman, 1982, 788 p., illus., $24.95, paper, $15.95.

UNIVERSE — Don Dixon. A magnificent trip through the universe. Illustrations include both photographs, and drawings by the author, a leading space illustrator. The text, written for the general reader, describes the unique character of each planet, our own and other suns, galaxies, quasars and the search for extraterrestrial life in the universe. HM, 1981, 240 p., color/b&w illus., $35.