**Balanced Program Plan
Volume XI: Fission**

**Analysis for Biomedical
and Environmental Research**

June 1976

Prepared for the Division of Biomedical
and Environmental Research,
Energy Research and Development
Administration, under Contract
No. E(45-1):1830

Battelle

Pacific Northwest Laboratories

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BALANCED PROGRAM PLAN
VOLUME XI: FISSION

ANALYSIS FOR BIOMEDICAL
AND ENVIRONMENTAL RESEARCH

by
R. F. Foster
Fission BPP Coordinator

Prepared for the Division of Biomedical
and Environmental Research,
Energy Research and Development
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No. E(45-1):1830

June 1976

BATTELLE
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FOREWORD

Development of the Balanced Program Plan was initiated in the spring of 1975 by the Assistant Administrator for Environment and Safety, Dr. James L. Liverman and organized by Dr. Raymond Cooper, Division of Biomedical and Environmental Research. The goal was a redefinition of research efforts and priorities to meet ERDA's requirements for a program of health and environmental research to support the development and commercialization of energy technologies.

As part of the Balanced Program planning effort the major ERDA-supported multidisciplinary laboratories were assigned responsibility for analyzing the research needs of each of nine energy technologies and describing a research program to meet these needs. The staff of the Division of Biomedical and Environmental Research was assigned the task of defining a research program addressed to each of five biomedical and environmental research categories (characterization, measurement and monitoring; physical and chemical processes and effects; health effects; ecological effects; and integrated assessment and socioeconomic processes and effects) applicable to all energy technologies. The first drafts of these documents were available for a workshop in June 1975 at which the DBER staff and scientists from the laboratories developed a comprehensive set of program recommendations.

Pacific Northwest Laboratory was assigned responsibility for defining research needs and a recommended research program for fusion and fission technologies. This report, Volume XI, for fission was prepared by Dr. Richard F. Foster with input from the staff of the Pacific Northwest Laboratory, other multidisciplinary laboratories, and DBER. This report also reflects the discussions at the Workshop in June 1975.

W. J. Bair
Manager
Environmental and Safety Research Program

ERDA - DBER
BALANCED PROGRAM PLAN
FOR
FISSION FUEL CYCLE

Prepared By: Pacific Northwest Laboratory*

INTRODUCTION

To provide a strong basis for allotting resources for health and environmental research in support of all of the energy technologies being developed by ERDA, the Division of Biomedical and Environmental Research (BER) initiated a Balanced Program Planning effort. This effort involved both the BER staff, which developed its plan on the basis of the King-Muir interagency study categories, and the national laboratories, which developed their plans on the basis of various energy technologies. The Pacific Northwest Laboratory (PNL) prepared plans for fission and fusion fuel cycle technology. This report is confined to the fission fuel cycle.

PNL solicited descriptions of ongoing work and future plans that involve nuclear fission power from the other national laboratories. A working draft of this report was sent to the BER staff and to the other participating laboratories for review and comment prior to a workshop held by ERDA during the week of June 23-27, 1975. Comments received on the working draft and from the BER staff at the workshop have been taken into account in this version.

* The PNL staff most heavily involved in the preparation of the plan were: R. F. Foster (Team Leader); M. H. Karr (Technology Description); R. W. Perkins (CM&M); C. E. Elderkin (Transport); M. F. Gillis (Health Effects); B. E. Vaughan (Ecological Effects); and W. H. Swift and J. C. King (Integrated Assessment).

Because of the AEC heritage, many ongoing BER programs are concerned with ionizing radiation and radioactive materials. The Fission Technology category thus inherits several major programs that have flourished at the laboratories for many years. This Balanced Program Plan for Fission does not attempt to provide an "energy technology rationale" (or program unit) for all of these ongoing programs. Rather, this plan for Fission Technology is based on the priority biomedical and environmental research needs associated with the supply of power from the nuclear fuel cycle. Consequently, the scope of the plan and the associated budget projections do not include some important programs currently supported by BER.

MAJOR ISSUES ASSOCIATED WITH THE USE OF NUCLEAR POWER

If nuclear (fission) power is to expand at a rate that is needed to help avert a serious energy shortage, several major issues must be resolved. Some of these issues are common to all thermal power stations. Others, however, are especially associated with radioactive materials; the dominant one is public fear of the effects of exposure to radiation. These effects usually are considered to be cancer, birth defects, genetic defects, somatic damage, premature aging, and adverse ecological changes. Possible sources of radiation exposure are normal releases (and leakage) from reactors, fuel processing plants and waste disposal and storage facilities; accidents (minor to catastrophic) at reactors, fuel reprocessing plants, waste storage facilities, and during the transport of irradiated fuel elements and radioactive wastes; sabotage of nuclear facilities; diversion of fissile material and its use for extortion; and the presence of plutonium (and other actinides) in the environment that will not decay for thousands of years.

A wealth of information has already been developed on many of these issues. Nevertheless a serious problem faces the nuclear industry in public opposition to siting of nuclear power plants and other nuclear facilities, including waste disposal areas. This opposition results, in part, from the public's lack of understanding of the true nature and extent of risks and the consequences of both minor and major accidents. Also the full social and economic importance of the industry to the nation, as compared with its alternatives, is not generally recognized or understood.

In order to correct misconceptions, there is a need to communicate clearly and accurately to the public the documented facts. These would include such things as:

- the real risks to the health of present and future generations associated with each phase of the nuclear fuel cycle, including the ultimate disposal of radioactive waste, as contrasted to perceived risks based on misinformation or a lack of precise information;
- the nature of possible major accidents and their consequences;
- safety precautions to minimize deleterious effects of routine operations and to prevent major accidents;
- technology being developed to provide further protection of the public and the environment; and
- the social and economic importance of nuclear power to the nation.

BER programs that bear directly on these issues, and especially those concerned with the effects of plutonium, warrant the highest priority. Such programs include those that provide quantitative data on the late effects of radiation delivered at very low doses and dose rates, on the risks of inhaling plutonium particles, and on the long term behavior and fate of plutonium, other actinides, and ^{129}I in the environment. As it becomes available, factual information about radiation risks and the need for power must be communicated to the public in ways that allow balanced judgments.

Several major issues concerned with the siting of nuclear facilities, transport of radioactive materials and safeguards could be mitigated by the creation of large nuclear complexes. However, such installations, if developed, would propagate new problems that would require solution; among them would be heat dissipation, power transmission, system reliability and institutional jurisdictions.

FISSION FUEL CYCLE TECHNOLOGY

Three possible fission fuel cycles are currently envisioned: uranium, mixed (plutonium and uranium) oxide, and thorium-uranium. At the present time, the uranium and mixed oxide fuel cycles for light water reactors and the thorium-uranium fuel cycle for high temperature gas reactors are the principal candidates for electric power production. The potential health and environmental effects of mixed oxide cycle breeder reactor technology will be different in magnitude and specifics but not in their basic nature. The following discussion deals principally with the uranium and mixed oxide cycles jointly as a model fission fuel cycle. This cycle involves nine primary components:

1. mining of uranium ore
2. milling of the ore to produce purified uranium oxide (U_3O_8)
3. conversion of U_3O_8 to uranium hexafluoride (UF_6)
4. isotopic enrichment of ^{235}U
5. conversion of the isotopically enriched UF_6 to UO_2 , recycling of plutonium, and fabrication of fuel elements
6. power production
7. spent fuel reprocessing
8. waste management
9. fuel and waste transportation.

Each of these components is described below, with emphasis on possible health, environmental, or social effects.

MINING

Uranium ore averages about 0.2%, or 4 lb of U_3O_8 per ton of ore. Both open pit and underground mining are currently

employed. Open pit mining is characterized by a large open excavation, large piles of overburden placed nearby, a network of roads and yards, and an influx of ground water that is pumped into surface drainage. Overburden is used to fill mined areas after they become sufficiently large to justify reclamation. During the later stages of mining and cleanup, filling of the final pit is uneconomical and these areas are sometimes converted to small man-made lakes.

Underground mining is characterized by service buildings, a head frame with truck loading facilities, a mine waste pile, a flow of water pumped to surface drainage from underground sumps and discharges of ventilation air. While the surface structures and facilities may occupy only a few acres, underground mine reaches may extend a mile or more.

Most uranium ore reserves are found at depths requiring underground mining (deeper than 400 ft). It is anticipated, therefore, that the amount of ore produced from underground mines will increase in the future. Most of the known reserves are in New Mexico, Wyoming, Texas, Colorado, and Utah. Presently about 70% of the uranium ore is mined in New Mexico and Wyoming and 17% in Colorado and Utah.

Although conventional surface and underground mining techniques are the current practice, plans have been made to test in situ solution mining techniques. These methods involve the injection of acidic or alkaline solutions into ore bodies followed by removal of uranium salt solutions from wells adjacent to the chemical injection wells.

Airborne radioactive emissions such as uranium-bearing dusts and radon gas and its daughters are released to the atmosphere during mining operations. More ventilating air is discharged from underground mines than from other types of mines, due to the need to dilute the radon gas emanating from uranium ore.

Dissolved and suspended uranium and its daughter products occur in mine drainage water. Those originally contained in the earth overburden are returned to the ground as backfill material. Some become airborne or waterborne from the overburden piles through wind or water erosion and leaching.

The BEIR report and other studies have concluded that while uranium mining increases the amount of surface uranium and its decay products, it does not cause measurable increases in environmental radioactivity outside the immediate vicinity of the mines. Health effects appear, therefore, to be of concern primarily from the standpoint of occupational exposure.

Although common practice is to backfill most of the mined-out open pit areas, reliable methods for restoring the ecological balance and returning a site to stable conditions and useful biological productivity have not been developed. The water resources of a region can be substantially impacted by mining, especially those in arid areas where mines and mills are likely to be clustered together.

Little is known about the social costs and benefits related to esthetics, historical values, recreational values, and the economically less important divisions of ecosystems in the mining areas, or about the relationship of mining to alternative uses of the land. The average population density in the four states where most mining operations occur is 11.5 people per square mile. Since uranium mines are usually located in particularly remote areas, the average population density within a 50 mile radius of a mine is approximately 5 to 10 people per square mile.

MILLING

In the milling operation uranium ore is crushed, ground, and then leached with either sulphuric acid or sodium carbonate solution to extract the uranium values. The leach liquors are

purified and concentrated by ion exchange or solvent extraction and the uranium is recovered as ammonium diuranate. The latter is calcined to U_3O_8 , commonly called "yellowcake." Process water transports the solid waste tailings and spent chemicals to retention ponds where most of the water evaporates but some percolates into the ground.

Crushing and grinding operations create large amounts of dust that is removed in collectors. Airborne radioactive gases and particulates include radium, thorium, uranium oxide, radon and radon daughters. Exhaust air from mills also contains sulfur dioxide, sulphuric acid fumes, and organics.

Liquid and solid chemical and radiological wastes are discharged to a tailings retention pond. The pond area is devoted to permanent disposal of mill tailings. It is anticipated that after mills are decommissioned (after about 20 years of operation) pond areas will be graded and covered with earth. However, the restored area will have only limited use because of the radium, thorium, and unrecovered uranium contained in the tailing residues.

A significant concern in water-short areas (typical of uranium mining districts) is the amount of process water consumed through evaporation from tailing ponds. Effects on water quality caused by seepage from the ponds into groundwater aquifers or surface drainage are not well defined.

The isotopes of interest from milling activities are primarily ^{226}Ra and ^{222}Rn . Studies made at active and inactive mill sites with covered and uncovered tailings showed no significant radiation exposure to the public from these sources.

Population dose attributable to the uranium milling industry is expected to be relatively low. While uranium milling activities contribute to the content of radioactivity in the

environment, it appears from available measurements that population doses from this source cannot be distinguished from background. Thus, as is the case with uranium mining, the principal health effect concern is with occupational exposure.

URANIUM HEXAFLUORIDE (UF_6) PRODUCTION

Yellowcake (U_3O_8) from the milling operation is converted into gaseous UF_6 presently at two plants, one in Illinois, the other in Oklahoma. One production plant uses a dry process of successive reduction, hydrofluorination (with hydrofluoric acid) and fluorination (with fluorine) of the uranium, followed by fractional distillation. The other uses wet chemical solvent extraction followed by calcination to prepare a high-purity uranium feed to the dry process steps.

About 15% of the wet process water is ultimately discharged as raffinate and the remainder is used for process coolant. About 90% of the coolant water eventually is returned to the source and 10% evaporates from holding ponds. The dry process water is used predominantly as a coolant in heat exchangers and most of it is discharged to surface water.

In the dry process, the bulk of the impurities entering with the yellowcake is rejected as solids from the fluorination tower; in the wet process most of the impurities are contained in dissolved solids in the solvent extraction raffinate.

Off gases produced during UF_6 production include hydrogen, hydrogen fluoride, hydrogen sulfide, volatile metallic fluorides of uranium, silicon, vanadium, and molybdenum, and oxides of nitrogen. Of greatest concern are the fluorides released and their potential for accumulation in vegetation.

Water released from UF_6 processes contains trace quantities of uranium. Impounded raffinate liquid from the wet process

contains soluble radionuclides, of which radium is present in the greatest amount. Increased evaporation of water and disposal of sludge by burial are potential impacts that require attention. Burial of radioactive solid wastes from the dry process constitutes a similar problem.

URANIUM ENRICHMENT

Isotopic enrichment of uranium is necessary to increase the 0.7% concentration of ^{235}U in natural uranium to the 2 to 4% ^{235}U fuel content needed for existing light-water nuclear reactors. At present, three gaseous diffusion plants, which are among the largest industrial facilities in the world, are in operation; one is in Tennessee, one in Kentucky, and one in Ohio.

The process presently used involves diffusion of UF_6 gas through porous membranes. About 1700 separation stages are needed to produce 4% enriched UF_6 . Large facilities and large quantities of electric power are needed to drive the compressors that create the gas flow through each porous barrier stage. Process cooling requirements involve evaporation of large quantities of water through cooling towers and discharge of some water to natural water bodies.

Gases released from the enrichment plants contain small quantities of uranium, fluorides, sulfur dioxide, and nitrogen oxides. Liquid effluents consist of blowdown from the process cooling system which contains sulfates, sodium, calcium, and chromium; liquid waste from cleanup operations and auxiliary production facilities containing uranium, fluorides, nitrates, chlorides, iron, and ammonia; condensate and blowdown from onsite steam plants containing sodium and phosphorus; and sanitary water and sewage treatment plant effluent containing chlorine.

Accidental releases of UF_6 can lead to exposure to both radioactive materials and hydrogen fluoride. Isotopes of interest are ^{234}U , ^{235}U , ^{236}U , ^{238}U , and naturally-occurring daughters.

Fuel fabrication involves the conversion of enriched UF_6 to UO_2 powder which is formed into pellets and sintered to the desired density. Finished pellets are clad in zirconium alloy or stainless steel tubes which are assembled in bundles of fixed arrays to be handled as fuel elements. Conversion of UF_6 to UO_2 typically involves an ammonium diuranate (ADU) process as an intermediate step. Off-specification material is recycled into the fabrication line or processed through a scrap recovery cycle.

Currently there are ten plants in operation located in Virginia, Connecticut, North Carolina, Missouri, Washington, Oklahoma, Tennessee, Pennsylvania, and South Carolina.

Most of the process water is used for cooling and does not come in contact with uranium or process chemicals. Liquid process wastes that are released offsite are first diluted with the cooling water.

Chemical process off-gas contains small amounts of fluorides and uranium which are released to the atmosphere from the plant ventilation system.

The liquid effluent from various parts of the process contains combinations of fluoride, nitrates, and ammonia. In some plants this liquid stream is treated with lime to form a calcium fluoride precipitate and released to a holding pond. It is then diluted with process cooling water prior to release offsite. Effluent from the holding pond, which contains fluoride and nitrogen in the form of ammonia and nitrates, represents a potential environmental impact.

Radioactive releases of uranium and its daughters occur from scrap recovery raffinate holding ponds. Also, the calcium

fluoride solids retained onsite contain small concentrations of uranium. All releases represent small percentages of the allowances stipulated in 10 CFR 20.

PLUTONIUM FUEL FABRICATION

In the process of power production from uranium fuels, the fissionable isotopes ^{239}Pu and ^{241}Pu are produced and are recovered in the fuel reprocessing component of the fuel cycle along with other plutonium isotopes.

Recycle of plutonium in light water-cooled or breeder reactors requires production of a mixed oxide (MOX) fuel that contains both uranium and plutonium dioxides.

The process most likely to be used in the 1980s and beyond is one that blends ceramic grade PuO_2 from the reprocessing plant with natural UO_2 . The blended powders are cold pressed, sintered into pellets, and loaded into zirconium alloy tubes. The sealed rods are shipped to uranium fuel fabrication plants for assembly into fuel elements. Plutonium-contaminated wastes leaving the plutonium handling facility are mostly solids. Frequently these solids have been incorporated into concrete or other material to decrease the mobility of the contamination.

Water use, power consumption, and thermal effluents are all less than those required to manufacture an equivalent amount of UO_2 fuel.

Fabrication of MOX releases plutonium, americium and curium to the biosphere. Calculations indicate that the radiation doses that may result will be only a small fraction of natural background. Nevertheless, plutonium is very toxic if deposited in the body and great precautions are taken to avoid any accidental release. Additional safeguards are used to protect against theft or misuse of plutonium.

POWER PRODUCTION (REACTORS)

A nuclear power plant is basically a steam electric plant that uses a nuclear reactor as the heat source for steam generation. The three types of nuclear steam supply systems in commercial operation in the U.S. are the light water boiling water reactor (BWR), in which steam is generated in the primary coolant and routed directly to the turbines; the light water pressurized water reactor (PWR), which transfers heat from the nonboiling primary coolant to a secondary steam generation system; and the high temperature gas-cooled reactor (HTGR), which uses helium gas as the primary coolant with separate steam generation. All three use enriched uranium fuel (potentially mixed oxide or ^{233}U fuel in the future). The fissioning of ^{235}U , ^{239}Pu , and ^{233}U atoms produces heat and also creates radioactive waste products. The ^{233}U is bred from thorium in HTGRs.

Keeping radioactive contamination of the primary coolant within bounds requires waste treatment. This is referred to as the "rad waste" system, which typically includes filtration, ion exchange, and evaporator unit operations. Gaseous waste systems use charcoal absorbers to retain radioiodine so that short-lived isotopes will decay. Cold traps are sometimes used to retain noble gases.

Nonradioactive pollutants associated with nuclear power plants include heat removed in the steam turbine condensers and biocides (e.g., chlorine), which are used to minimize fouling of the condenser tubes and cooling towers. Because of the large capacity of a nuclear unit, condenser cooling requires large volumes of water and results in a sizable (typically 10°C) temperature rise in the water between intake and discharge.

At marine sites, condenser cooling can be accomplished by once-through wet cooling towers (either mechanical or natural

draft), cooling ponds, or spray ponds. In the two latter instances, treatment or disposal of cooling water blowdown is needed. In the future, dry cooling towers, which transfer waste heat directly to the atmosphere, may find increased use, particularly in arid regions of the west. Regardless of cooling mode, the waste heat typically is equivalent to about twice that converted to electrical energy.

In addition to the primary reactor plant and cooling water systems, typical nuclear generating stations are provided with underwater spent fuel storage systems to allow decay of the shorter-lived fission product radionuclides and to dissipate the heat released by this decay.

Small releases of low-level radioactive wastes occur routinely. Of greater concern are the potential health effects of exposure to accidental releases of volatile radionuclides such as ^{131}I , the noble gases krypton and xenon, and to a lesser extent the longer-lived but less mobile fission products such as ^{90}Sr , $^{103-106}\text{Ru}$, and ^{137}Cs . Occupational exposure to ionizing radiation, particularly for maintenance personnel, is a significant issue at this time.

Environmental effects may result from release of biocides and anticorrosion agents, generation of radioactive solid wastes from spent resins, filters, sludges, evaporator residues, etc., discharge of large quantities of heat to the atmosphere and to receiving waters, and effects on biological communities caused by cooling water intake structures and condenser systems.

Of social significance is the use of large amounts of cooling water, the land use commitments and the esthetic impact of plant sites and electrical transmission lines. Public perception of the risks to human health and the environment engendered by nuclear reactors and the relationship to the actual risk is currently the subject of widespread debate and is one of great social significance.

In addition to the potential effects of reactor power plants on the environment, very significant constraints are placed on the siting of such facilities by the environment itself. The availability of certain resources such as water, airshed ventilation capacity, and seismology, must be assessed in terms of trade-offs with other uses.

In the future, fast breeder reactors may assume a significant role in power production as well as in the generation of additional fissile material. Such reactors will use larger quantities of plutonium, necessitating greater attention to the health and social issues associated with this element.

FUEL REPROCESSING

Through fuel reprocessing, uranium and plutonium are recovered from the fission products and transplutonium elements present in the spent fuel are discharged from the reactor plants.

Typically, one fuel reprocessing plant will serve the needs of a few tens of reactor plants. At the present time no commercial reprocessing plants are in operation but by the year 2000 ten or more plants located throughout the U.S. may be required.

Fuel reprocessing begins when spent reactor fuels are put into underwater storage basins where further decay of short-lived radionuclides occurs and sufficient fuels of similar makeup are accumulated for chemical processing. Following storage, the spent fuels are mechanically processed to remove auxiliary hardware and the tubes are cut into short segments. The pieces are then leached with nitric acid solution to dissolve the nuclear fuel. The undissolved residual cladding (tubing) material of zirconium alloy or stainless steel and other fuel element hardware becomes a solid waste which is packaged and temporarily stored.

Typical processing of the nitric acid-based dissolver solution consists of passing it through two or more stages of solvent

extraction (the Purex process) plus (optional) supplemental ion exchange for plutonium or adsorption of uranium. Three separate aqueous streams result. One contains the uranium, another the plutonium, and the third is a waste carrying essentially all the fission products and actinide elements. Typically, the reprocessing plant achieves separation of product plutonium and uranium from the fission products by a factor of about 10^7 .

Following solvent extraction processing, the uranium nitrate solution can be converted to UO_2 or U_3O_8 by calcination. The plutonium nitrate stream can be further processed by precipitation of plutonium oxalate and/or calcination to PuO_2 for recycle.

The acidic waste stream containing the fission products and transplutonium elements is presently concentrated by evaporation and stored to await further waste management activities.

It should be pointed out that prior to the reprocessing step, and except for accidental fuel element failures, the radioactive fission products and actinides are well contained within the fuel element cladding. Once the fuels enter the reprocessing step the mobility of the various radionuclides is markedly increased, with concomitant potential for contamination of the plant and environs.

Existing fuel reprocessing technology releases virtually all of the noble gases (predominantly ^{85}Kr) and tritium, and also small amounts of iodine (including the long-lived isotope ^{129}I), to the environment with subsequent worldwide accumulation. Very small amounts of other fission products (such as ^{90}Sr , ^{103}Ru , ^{106}Ru , and ^{137}Cs) and actinides are released to the atmosphere via off-gas treatment and ventilation systems.

Reprocessing requires the handling of numerous highly radioactive process streams with potential exposure of workers to radiation and radioactive contamination. Low-level radioactive liquids released from the early plants included tritium,

ruthenium, strontium, and cesium isotopes. The designs for future plants do not contemplate the routine release of liquid wastes to the environment.

Because of the large inventories of radioactive contaminants and their physical and chemical forms, the possibility of substantial environmental contamination from reprocessing plants is greater than from power reactors.

WASTE MANAGEMENT

Radioactive wastes result from operations in several components of the fission fuel cycle, as discussed earlier, and from certain commercial operations (e.g., radiopharmaceuticals) not in the fuel cycle. These wastes include the fission product radionuclides, the transplutonium actinide elements and unrecovered uranium and plutonium contamination. Common practice is to categorize wastes as either "high-level" or "other than high-level," depending primarily on the amount of radiation involved and the need to dissipate the heat resulting from radioactive decay.

High-level wastes result from the first aqueous separation step in fuel reprocessing and contain essentially all the fission products and transplutonium actinide radionuclides present in the irradiated fuel. Other than high-level wastes result from the production of UF_6 , fuel fabrication, reactor operations, and fuel reprocessing.

High-level wastes that originate as the nitric acid-based solvent extraction raffinate in the fuel reprocessing step currently are concentrated by evaporation and stored as liquid in underground tanks equipped for heat removal. An optional interim storage step (<5 years) can be used to allow decay of the shorter-lived and hence higher heat-generating fission products. Following this decay period the principal radionuclides present

are ^{90}Sr , ^{106}Ru , ^{137}Cs , and the residual transuranic alpha-emitting radionuclides $^{239-242}\text{Pu}$, $^{241,243}\text{Am}$, and ^{244}Cm .

A waste material with substantial transuranium contamination will be the fuel cladding hulls (the solids remaining after the leaching of fuel material from the chopped fuel elements). Thousands of cubic feet of solid waste containing several hundred megacuries of activity are expected from this source. Shielding against penetrating radiation is required for cladding hulls.

Current regulations call for conversion of the high-level waste to an encapsulated stable solid and transfer to a Federal repository no later than 10 years after its generation. Solidification processes currently being developed include calcination to the oxide and possibly conversion to a glassy or microcrystalline solid. The final solid will be encased in a sealed canister prior to shipment to a Federal repository. Hundreds of thousands of megacuries of radioactivity will eventually be involved.

All high-level waste management operations will be conducted remotely in heavily shielded facilities. Following conversion to a stable solid form, two options exist for disposition of the high-level waste. These options are referred to as "storage" and "disposal." "Storage" implies the ability to retrieve the material at some future time with the expectation that a program of perpetual surveillance and ability to repair or replace will be necessary. "Disposal" refers to techniques in which there is no intent to retrieve the waste.

The disposal concept most thoroughly studied to date is placement of the waste within a deep geological formation. If a formation has been stable over geologically long periods of time; if the hydrology of this formation is such that water is not flowing through it; if a storage chamber is excavated in the

formation and the radioactive wastes are placed in it in chemical and physical forms that will not react with the formation; and if the operators carefully withdraw, leaving the storage chamber sealed and undisturbed, there is good reason to believe that the radioactive materials will remain isolated in the formation for geological periods of time in the future. Although the waste would not be physically irretrievable, retrievability would be unnecessary. Other possible options for disposal are being studied, such as use of the seabed, outer space, and transmutation.

Regardless of the storage or disposal concept adopted, provisions must be made for shielding and dissipation of heat generated by radioactive decay.

Other than high-level wastes are relatively low in the emission of radiation and heat but they are generally bulky (currently approximately 1,000,000 ft³ of solid wastes are produced per year in the U.S.) and frequently contain significant quantities of plutonium and other actinide elements. Because of the presence of some long half-lived nuclides (~25,000 years for ²³⁹Pu), management in perpetuity is a major issue.

Currently regulations are pending which will require that wastes containing significant quantities of transuranic elements be disposed of at federally-owned and controlled reservations. Retrievable storage systems are currently employed. Concepts for permanent disposal in deep stable geologic formations much like those discussed above for high-level wastes are being considered for transuranium wastes. Research is also underway to develop techniques such as compaction and incineration for volume reduction.

Presently, other than high-level radioactive wastes are buried in shallow trenches in their shipping containers. At this time there are no plans to recover the wastes at a later date. Commercially operated burial sites on state-owned land

are licensed and regulated by the states through agreements with NRC. Existing commercial burial facilities are located in Washington, Nevada, Illinois, Kentucky, South Carolina, and New York.

Radioactive waste burial grounds represent a dedicated use of land and some constraint on the use of nearby land and ground water for some other purposes. They also offer the potential for migration of radioactivity to the atmosphere, water and vegetation. Surveillance and maintenance of the sites may be a perpetual social obligation of the states.

High-level waste storage entails similar concerns. It is in this component of the fuel cycle that the highest inventory of radionuclides exists at any one location. Although the quantities of radioactive materials are large, the volumes are relatively small and with many precautions taken to avoid contamination of the biosphere, the risk of radiation exposure to the general public can be less than for other than high-level wastes. Unresolved questions concerning the best methods and sites for waste storage constitute major social issues at this time.

High-level and transuranic waste disposal, when it is fully developed will, by definition, not entail adverse effects on public health or the environment. However, the disposal environment must be thoroughly understood and the integrity of the disposal concept must be assured for periods of time comparable to those encountered in geological processes. The ultimate disposal of radioactive wastes is currently a major issue in achieving public acceptance of the fission fuel cycle as a whole.

FUEL AND WASTE TRANSPORTATION

Many steps in the fuel cycle involve transportation. These include the shipment of:

- ore from mine to mill
- uranium concentrate from mill to UF_6 production plant
- UF_6 to enrichment plant
- enriched UF_6 to UO_2 plant
- UO_2 to fabrication plant
- UO_2 fuel elements to reactors
- radioactive spent fuels from power stations to reprocessing plants
- wastes from reactors, fuel fabrication plants and fuel reprocessing plants to burial grounds
- high-level waste from reprocessing plants to Federal repositories
- plutonium oxide from reprocessing plants to mixed oxide and fuel fabrication plants
- ^{233}U from reprocessing plants to HTGR fuel fabrication plants.

Shipments are made by both rail and truck. Most truck shipments, except shipment of ore from mines to mills, are over public highways.

Systems for shipment of enriched uranium or plutonium are designed to avoid criticality under a variety of accident conditions. Irradiated fuel elements and high-level wastes are shipped in heavily shielded transport casks with provision for cooling en route.

The major concern in the transport of waste and fuel is the potential for accidental radiation exposure to the public along the shipping route. Under normal conditions, transportation of materials in the fission fuel cycle does not contribute

significantly to the radiation dose to the public. There is, however, a potential for transportation accidents, followed by exposure of the public to radionuclides released to the environment.

PROBLEM DEFINITION

Areas of fission fuel cycle technology that need research effort were identified by considering each step of the cycle in relation to each of the King-Muir Categories. As a result of this process the following dominant problems were identified. The matrix on Page 27 visually relates these problem areas to the King-Muir Categories.

CHARACTERIZATION, MEASUREMENT AND MONITORING

- Characterization of physical and chemical states of radio-nuclides released to and present in the environment as this affects their availability to man.
- Development of better instruments and analytical methods for quantifying specific contaminants present at very low concentrations in effluents and environmental media.
(Such quantification is needed to demonstrate compliance with as-low-as-practicable regulations.)
- Development of better instruments for real-time measurement of dose to workers and environmental contamination by plutonium and other transuranic elements.

TRANSPORT PROCESSES

- Dispersion of airborne contaminants in local areas and regions of complex air flow.
- Resuspension characteristics of plutonium and other radioactive particulates that could be inhaled by man.
- Dispersion characteristics in surface waters of heat and other contaminants present in power plant coolant.
- The fate of contaminants in water discharged to the ground.

- The role of plants and animals in translocating radioactive wastes.

HEALTH EFFECTS

- Identification of agents associated with nuclear fission technology that are potentially hazardous to workers and the public.
- Determination of pathways for radioactive and other hazardous materials to human beings and the nature of potential injury.
- Assessment of health effects in population groups exposed to radioactive and other hazardous agents.
- Determination of the basic processes of damage, repair, recovery, and amelioration in biological systems exposed to radioactive and other hazardous agents associated with nuclear fission technology.

[Although not a problem associated with the fission fuel cycle, we encourage the further development of methods by which nuclear fission technologies and their by-products may be used for the benefit of human health.]

ECOLOGICAL PROCESSES AND EFFECTS

- Characterization and assessment of effects on aquatic and terrestrial ecosystems caused by cooling water systems of nuclear (and other thermal) power plants.
- Prediction of the behavior and fate of radioactive contaminants that enter aquatic and terrestrial ecosystems from all phases of the fission fuel cycle.
- Assessment of effects on plants and animals from the levels of radioactive contaminants that may exist in the environment from planned and accidental releases.

- Rehabilitation of mined lands (a significant problem in coal extraction technology).

INTEGRATED ASSESSMENT

- Dissemination of factual information about the tradeoff between risks and benefits associated with fission power.
- Development of better methods for evaluating environmental, economic, and social impacts of the siting, construction and operation of fission fuel cycle facilities.
- Assessment of overall risk to the public associated with nonreactor components of the fuel cycle.
- Development of long-term regional strategies for the provision of power.

Program Units associated with these dominant problem areas as well as with some other issues of lesser importance are presented in the next section. Program Units are arranged by King-Muir Category and identified by a coding system, as follows:

Capital C means CMM Category

lower case: c = characterization
m = measuring and monitoring

Capital T means Transport Processes Category

lower case: a = via the atmosphere
w = via the water
g = through the ground

Capital H means Health Effects Category

lower case: i = identification of effects
c = characterization of risk
e = dose/effects relationships
b = basic mechanisms
t = therapy and prophylaxis

Capital E means Ecological Processes and Effects Category

lower case: t = terrestrial ecosystems

a = aquatic ecosystems

Capital I means Integrated Assessment Category

lower case: e = environmental research information

s = social and economic effects

t = total impact assessment

i = implementation alternatives

The units are numbered consecutively within each King-Muir Category. The order of presentation is not according to relative importance.

On the matrix chart, the relevance of each program unit to each cell of the chart is indicated either by the presence of the code number or by a solid or dotted line extending into adjacent cells. All health effects units apply to all steps of the fuel cycle, but there is obviously less involvement in steps where only purified uranium is handled.

BALANCED PROGRAM PLANNING UNITS
ASSOCIATED WITH THE FISSION FUEL CYCLE

	MINING	MILLING	UF ₆	ENRICHMENT	FUEL FABRICATION		REACTORS	FUEL PROCESSING	WASTE MANAGEMENT	TRANSPORTATION
					U	Pu				
CHARACTERIZATION MEASUREMENT AND MONITORING	Cc-1	Ccm-2	.....	Ccm-3	—	Cm-4	Cm-5	Cm-6		
					Cm-9		Cm-8		Ccm-7	
TRANSPORT PROCESSES							Ta-1			
							Ta-2		.....	
							Ta-3		.....	
							Ta-4			
	Tw-5						Tw-6			
	.....	Tg-7		.....			Tg-7			
							Ta-8	.....		
HEALTH EFFECTS	ALL PROGRAM UNITS OF THE HEALTH EFFECTS CATEGORY ARE ASSOCIATED WITH RADIATION AND RADIOACTIVE MATERIALS ORIGINATING FROM ALL OR SEVERAL STEPS OF THE FUEL CYCLE. HOWEVER, THE GREATEST EXPOSURES WILL USUALLY RESULT FROM REACTOR OPERATION AND FUEL REPROCESSING									
ECOLOGICAL PROCESSES AND EFFECTS	Et-1	Et-2								
	.....	.....						Et-3	.....	
								Ea-4	.....	
							Eat-5		.....	
							Ea-6			
							Ea-7			
							Ea-8			
									Eat-9	
INTEGRATED ASSESSMENT	Is-5						li-2	li-1		.....
	Is-6						li-3	li-4		
		It-7					Is-5			
							Is-6			
							It-7			
							It-8			
							Ie-9			
							Ia-10		.....	

— MAJOR INVOLVEMENT

..... MINOR INVOLVEMENT

BUDGET

Each Program Unit (identified in the next section) has been assigned an estimated cost. For the most part these estimated costs are shown as a range within which the actual costs are expected to fall. The actual costs will, of course, not be determined until specific proposals (189s) associated with the program units are submitted and approved. In some cases (notably Health Effects) the estimated cost range represents the lowest budget year (usually the first year) and the highest budget year (usually the fifth year).

The estimated costs selected are not based upon apportionment of funds in direct relationship to the severity or urgency of a problem. Rather, they represent our best estimate of the level of funding needed to develop the required information on the problem in a timely manner. Further, the great disparity in the costs of performing different kinds of research has been considered (e.g., large scale laboratory experiments with animals versus paper studies that do not require elaborate facilities).

As pointed out in the introduction, this plan and its estimated budget do not attempt to provide the justification or the source of funding for all of the research work currently supported by BER that embraces radiation and radioactive materials.

The estimated program unit costs are summarized below by King-Muir Category. (The titles have been shortened to conserve space in this tabulation.)

CATEGORY: Characterization, Measurement, and Monitoring

<u>Code</u>	<u>Subject</u>	<u>\$M Per Year</u>	
Cc-1	Mine Atmosphere	1.0 -	1.5
Ccm-2	Milling - Environmental Pollution	0.5 -	1.0
Ccm-3	Uranium Fuels - Occupational Exposure	0.5 -	1.0
Cm-4	Plutonium Fuels - Occupational Hazards	1.0 -	2.0
Cm-5	Reactors - Environmental Radioactivity	2.0 -	3.0
Cm-6	Reprocessing Plant Effluents and Worker Exposure	1.5 -	3.0
Ccm-7	Waste Transport - Realtime Measurements	0.5 -	1.0
Cm-8	Worldwide Monitoring	1.0 -	2.0
Cm-9	Radiation Dosimetry	0.5 -	1.0
Total Category		8.5 -	15.5

CATEGORY: Transport Processes

Ta-1	Dispersal in Complex Air Flow Conditions	1.3 -	3.0
Ta-2	Regional Distribution Patterns	3.5 -	5.0
Ta-3	Hemispheric and Global Distributions	0.2 -	0.5
Ta-4	Resuspension	1.0 -	3.0
Tw-5	Mine and Mill Water	0.1 -	0.3
Tw-6	Power Plant Effluents	1.0 -	2.0
Tg-7	Soils and Groundwater	0.5 -	1.0
Ta-8	Weather Modification	1.8 -	2.0
Total Category		9.4 -	16.8

CATEGORY: Health Effects

Hi-1	Identification of Hazardous Materials	0.5 -	0.7
Hi-2	Biological Screening of Hazardous Agents	2.5 -	3.5
Hc-3	Kinetics and Distribution of Hazardous Agents	3.5 -	5.0
Hc-4	Quantification of Dose and Dose Distribution	6.0 -	8.7

CATEGORY: Health Effects (Cont'd)

<u>Code</u>	<u>Subject</u>	<u>\$M Per Year</u>	
He-5	Detection and Quantification of Damage	4.0 -	5.8
He-6	Somatic Effects of Actinides	6.7 -	9.7
He-7	Genetic Effects of Actinides	5.0 -	7.2
He-8	Biologic Effect of ^3H and ^{85}Kr	4.8 -	7.0
He-9	Biologic Effects - Accidents	4.5 -	6.5
He-10	"Hot Particles" - Cancer and Genetic Damage	3.5 -	5.0
He-11	Linear Extrapolation - Very Low Dose Rates	2.5 -	3.6
He-12	Dose - Effects - Developing Mammals	2.7 -	3.9
He-13	Influence of Disease on Radionuclide Deposition	2.8 -	4.1
He-14	Extrapolation of Animal Data to Man	2.8 -	4.1
Hb-15	Primary Interaction of Radiation with Cells	5.0 -	7.2
Hb-16	Mechanisms of Repair and Recovery	3.2 -	4.7
Ht-17	Removal of Radionuclides	2.3 -	3.4
Ht-18	Amelioration of Effects of Radionuclides	2.4 -	3.5
He-19	Epidemiological and Clinical Studies	4.6 -	7.7
He-20	Uranium Mining Hazards	2.3 -	3.9
He-21	Effects of External Radiation	3.7 -	5.4
Total Category		75.3 -	110.6

CATEGORY: Ecological Processes and Effects

Et-1	Mine Rehabilitation	1.0 -	1.5
Et-2	Disposition of Tailings	0.2 -	0.7
Et-3	Behavior and Fate - Terrestrial	2.5 -	5.5
Ea-4	Behavior and Fate - Aquatic	2.5 -	5.5
Eat-5	Effects of Radiation	0.9 -	3.5
Ea-6	Heat and Chemicals - Aquatic Life	3.0 -	6.5
Ea-7	Intake and Outfall Effects	1.8 -	4.0

CATEGORY: Ecological Processes and Effects (Cont'd)

<u>Code</u>	<u>Subject</u>	<u>\$M Per Year</u>
Et-8	Drift from Cooling Towers	0.5 - 1.3
Eat-9	Translocation of Contamination by Biota	1.0 - 2.0
Total Category		13.4 - 30.5

CATEGORY: Integrated Assessment

It-1	Risk Assessments - Nonreactor	2.0 - 3.0
Ii-2	Determining Demand for Power	0.5 - 0.8
Ii-3	Regional Power Planning	2.0 - 3.0
Ii-4	Site Selection Methodologies	1.0 - 1.5
Is-5	Identification, Assess, and Management of Economic Impacts	0.3 - 1.0
Is-6	Identification, Assess, and Management of Social Impacts	0.3 - 1.0
It-7	Availability of Supporting Resources	1.0 - 2.0
It-8	Tradeoffs for Alternative Electric Energy Sources	1.0 - 2.0
Ie-9	Energy/Health/Environmental and Societal Information	2.5 - 3.5
Ia-10	Environmental and Institutional Criteria for D&D	0.2 - 0.4
Total Category		10.8 - 18.2

CONSOLIDATION:

<u>Category</u>	<u>\$M Per Year</u>
CMM	8.5 - 15.5
Transport Processes	9.4 - 16.8
Health Effects	75.3 - 110.6
Ecological Processes and Effects	13.4 - 30.5
Integrated Assessment	10.8 - 18.2
Total Fission Technology	117.4 - 191.6

CHARACTERIZATION, MEASUREMENT AND MONITORING

PROGRAM UNITS

PROGRAM UNIT TITLE: Quantitative and Qualitative Analysis of
Mine Aerosols Code Cc-1

Technology: Fission

King-Muir Category: Characterization, Measurement and
Monitoring

Scope

Mining of nuclear fuels results in exposure of mine workers to aerosols containing pulverized rock, radon and radon daughters, blasting residues and diesel exhausts. This exposure has been found to produce serious respiratory effects. While considerable work has been done on characterizing uranium mine atmospheres and associated pulmonary accumulation, further work is needed in 1) technology for monitoring the aerosol exposure of individual workers, 2) separation and chemical analysis of aerosol particles in the 0.05 to 1 μ m range, and 3) methods for measuring aerosol deposition in experimental animals and human beings from biopsy or autopsy samples.

Milestones

- 1 year: Characterize the atmosphere in representative uranium mines with modern equipment and establish the aerosol composition, including unattached radon daughter content, in areas of significant worker time exposure.
- 2 years Determine the relationship between the dosimetry estimates of workers based on personnel monitoring practices with that estimated from detailed mine aerosol characterization.

3 to 5 years: Improve instruments and technology for aerosol analysis, working level value determination, and personnel dosimetry.

Program Unit Priority: B

Severity of the Problem: B

Extent of the Problem: C

Need for Information: B

Urgency: A

Estimated Program Costs

\$1,000,000 to \$1,500,000 per year

CHARACTERIZATION MEASUREMENT AND MONITORING

PROGRAM UNITS

PROGRAM UNIT TITLE: Identification and Measurement of Pollutants
from Fission Fuel Milling Code CCm-2

Technology: Fission

King-Muir Category: Characterization, Measurement and
Monitoring

Scope

Milling operations normally require rock crushing, acid or alkaline leaching, solvent extraction or ion exchange purification and precipitation to produce the uranium or thorium oxide, and disposal of tailings and spent liquids. The aerosols generated during crushing operations are similar to those from mining and can generally be considered with the mining problem. The mill wastes contain easily extractable and erodible materials which are toxic to environmental biota and man. This program unit seeks to generate information on 1) the chemical and physical forms and mobilities of the longer-lived members of the uranium and thorium chains and the toxic trace elements in the plant wastes, 2) the levels of these pollutants in nearby soils, vegetation and biota, and 3) the concentrations of these pollutants in nearby ground water and in runoff from previously generated disposal mounds.

Milestones

- 1 year: Determine to a first approximation the chemical and physical forms and amounts of radionuclides in liquid and solid residues from operating mills.
- 2 years: Establish the levels of mill pollutants in environmental biota, soils, ground water and runoff in environs of mill waste disposal sites.

3 to 5 years: Establish detailed physical-chemical forms of pollutants from mill waste disposal sites; complete measurements of amounts and forms of pollutants in nearby soils, surface and ground waters and biota, and correlate chemical-physical forms in the disposal site with observed mobilities. Recommend monitoring techniques and instrumentation required to meet regulatory standards.

Program Unit Priority: B

Severity of the Problem: B

Extent of the Problem: C

Need for Information: B

Urgency: A

Estimated Program Costs

\$500,000 to \$1,000,000 per year

PROGRAM UNIT TITLE: Personnel Exposure and Pollutant Release to
the Environment from Uranium Enrichment and
Uranium Fuel Fabrication Code Ccm-3

Technology: Fission

King-Muir Category: Characterization, Measurement and
Monitoring

Scope

For use in nuclear power plants, natural uranium or recycled uranium must be enriched by the UF_6 diffusion process, and may in the near future be enriched by gas centrifugation or laser isotope separations. With recycled uranium traces of plutonium and other transuranium elements are present which accumulate at specific points in the enrichment process, whereas with natural uranium this problem does not occur. This program unit will 1) determine the probable sites within the enrichment process where transuranium elements concentrate and the potential radiation exposure to plant workers, 2) define the physical and chemical forms of U, the transuranium elements and nonradioactive pollutants such as fluorine to which workers are exposed and which are present in plant effluents, and 3) develop necessary measurement and monitoring technology for evaluation of worker exposure and effluent analysis.

Milestones

- 1 year: From transuranium element chemistry and site studies determine the location of accumulation of transuranium elements in operating enrichment plants.
- 2 years: Estimate the radiation exposure to enrichment plant workers from transuranium element accumulation and determine amounts and chemical and physical forms of radioactive and chemical pollutants in plant effluents.

3 to 5 years: Develop and improve measurement and monitoring technology to observe pollutants which accumulate in enrichment plants or are released in effluents from recycled uranium.

Program Unit Priority: B

Severity of the Problem: B

Extent of the Problem: C

Need for Information: B

Urgency: A

Estimated Program Costs

\$500,000 to \$1,000,000 per year

PROGRAM UNIT TITLE: Worker Exposure from Fabrication of Plu-
tonium Fuels Code Cm-4

Technology: Fission

King-Muir Category: Characterization, Measurement and
Monitoring

Scope

In the preparation of Pu fuels several processes exist which could result in the inhalation of Pu particles or exposure to low energy radiation. Since the decay of ^{241}Pu produces ^{241}Am , exposure to this isotope is also of prime concern. This program seeks to 1) develop improved personnel monitoring technology for measuring the low energy photons, alpha and beta particles, and neutrons from Pu fuel fabrication procedures; 2) characterize the relative importance of these types of radiation for presently used and possible future fuels; and 3) determine the physical and chemical properties of uranium, americium and other transuranium element aerosols to which workers may be exposed.

Milestones

- 1 year: Determine the spectrum of energies of the photons, alpha and beta particles, and neutrons to which workers are exposed.
- 2 years:
- 1) Develop simplified personnel monitoring technology for the full spectrum of radiation and radioactivity to which workers may be exposed.
 - 2) Determine physical and chemical properties of Pu aerosol particles to which workers may be exposed.

3 to 5 years: Develop and optimize measurement and monitoring technology for assessing total worker exposure.

Program Unit Priority: B

Severity of the Problem: B

Extent of the Problem: C

Need for Information: B

Urgency: A

Estimated Program Costs

\$1,000,000 to \$2,000,000 per year

Code Cm-5

Fission

Characterization, Measurement and Monitoring

Scope

Nuclear power reactors generate a wide range of fission products, activation products and transuranium elements. With the "total burnup" of nuclear fuel made possible by recycling, the transuranium elements become a far greater fraction of the nuclear fuel. In reactor operation there are planned releases and the potential for accidental releases. Research is required in measurement methodology to meet "as-low-as-practical" release criteria for the radionuclide spectra from high burnup fuel. This program unit will develop information on 1) amounts of potentially hazardous radionuclides in effluent streams from nuclear power reactors and the routes by which they enter these effluents, 2) the physical and chemical forms of the more abundant long-lived and potentially hazardous radionuclides, and 3) technology for the measurement of amounts and forms of radionuclides in plant effluents and in the reactor environs.

Milestones

- 1 year:
- 1) Develop technology for measuring low concentrations of radionuclides in liquid and gaseous nuclear power plant effluents.
 - 2) Determine the amounts of the various radionuclides in these effluents.
 - 3) Develop monitoring techniques for measuring low concentrations of the more toxic nuclides in the environment.

- 2 years: Determine the physical and chemical forms of the more potentially hazardous radionuclides in effluents.
- 3 to 5 years: Develop field monitoring techniques for in situ direct measurement of the biologically active radionuclides and the transuranium elements in effluents and environmental media.

Program Unit Priority: A

Severity of the Problem: B
Extent of the Problem: A
Need for Information: B
Urgency: A

Estimated Program Costs

\$2,000,000 to \$3,000,000

PROGRAM UNIT TITLE: Radioactive Effluents from Nuclear Fuel
Reprocessing Plants and Worker Exposure
Code Cm-6

Technology: Fission

King-Muir Category: Characterization, Measurement and
Monitoring

Scope

In a nuclear fuel reprocessing plant the uranium, thorium and plutonium are separated and purified for recycle while the fission and activation products and the spent transuranium isotopes are isolated for disposal. With highly irradiated power reactor fuels the potential worker exposure to neutron and low energy radiation from the transuranium elements is of major concern. This program unit will 1) develop sensitive monitoring and measurement technology which can continuously or periodically measure radionuclide concentrations or radiation levels at work stations within the plant or at sites within the environment at levels down to a fraction of the natural background, 2) develop survey instrumentation to permit the more abundant transuranium elements to be monitored or measured in situ, and 3) determine the chemical forms of the principal radioactive aerosols and liquid to which workers may be exposed or which may enter the environment.

Milestones

- 1 year: Determine the spectrum of radionuclides in liquid and gaseous effluents from chemical reprocessing plants with special emphasis on the long-lived ^{99}Tc , ^{129}I , and the transuranium elements.
- 2 years: Determine the energy spectrum and relative dose contribution to plant workers with particular emphasis on neutron and the low energy photons from the recycle fuel.

- 3 to 5 years: 1) Develop personnel, plant and field dosimetry technology for improved continuous or periodic measurements.
- 2) Determine physical and chemical forms of radionuclides to which workers are exposed or which enter the environment.

Program Unit Priority: A

Severity of the Problem: B

Extent of the Problem: A

Need for Information: B

Urgency: A

Estimated Program Costs

\$1,500,000 to \$3,000,000 per year

PROGRAM UNIT TITLE: Exposure from Nuclear Waste Storage and
Waste and Fuel Transport Code Ccm-7

Technology: Fission

King-Muir Category: Characterization, Measurement and
Monitoring

Scope

The research requirements in waste fixation and storage are similar to those for Nuclear Fuel Reprocessing. During transport of irradiation or plutonium-bearing fuels and of radioactive wastes, there is a potential for spills. This program unit will 1) develop more sensitive real-time detector systems for measuring the extent and amount of radioactivity in very minor, or in more significant accidental releases during transport of wastes and of irradiated or unirradiated fuels, and 2) determine the amounts and forms of radionuclides which may enter the environment from fixation, storage and transport processes.

Milestones

- 1 year: Conduct feasibility studies to determine the most sensitive possible technologies for rapid real-time measurement of radioactivity (particularly the transuranium elements) from possible accidental releases.
- 2 years: Determine the spectrum, amounts and forms of radionuclides which may enter the environment from waste fixation, storage of waste and fuel transportation.
- 3 to 5 years: Develop improved detection systems for continuous monitoring and for measuring environmental contamination and personnel exposure from accidental releases during transportation.

Program Unit Priority: B

Severity of the Problem: B

Extent of the Problem: A

Need for Information: B

Urgency: B

Estimated Program Costs

\$500,000 to \$1,000,000

PROGRAM UNIT TITLE: Measurement of Worldwide Radionuclide
Levels and Distributions Code Cm-8

Technology: Fission

King-Muir Category: Characterization, Measurement and
Monitoring

Scope

As nuclear power production develops throughout the world, increasing hemispheric and global levels of associated radionuclides must be measured. While nuclear power production is still small compared to other energy technologies, baseline levels of contaminants should be determined. These contaminants should be distinguished from and compared with fallout distributions from nuclear testing.

Milestones

The time frame for this technology is established, but milestones are not yet identified.

Program Unit Priority: B

Severity of the Problem: C

Extent of the Problem: A

Need for Information: B

Urgency: C

Estimated Program Costs

\$1,000,000 to \$2,000,000 per year

PROGRAM UNIT TITLE: Radiation Dosimetry Research and Development

Code Cm-9

Technology: Fission Fuel Cycle

King-Muir Category: Characteristic Measurement and Monitoring

Scope

Control of radiation exposures requires adequate radiation monitoring and protection procedures, both routine and emergency. Instruments and techniques must be developed for assessing the field quantities in various exposure situations. Because of the magnitude of this problem and because of the need for accuracy of measurements and overall quality assurance, equipment and procedures must be significantly improved. The use of micro-processors in spectrometry systems and of small general-purpose computers in the handling of large quantities of data is now commonplace. In order to assure that population exposures are kept "as low as practicable," additional developments will be required in the area of stable integrating detector systems for measuring environmental radioactivity. In addition, considerable effort must be expended on calculational techniques for instantaneous assessment of radiation hazard profiles in the vicinity of population centers following accidental releases of radioactivity.

Milestones

- 1 year: Review needs for instrumentation and procedures for controlling hazards in each phase of the fuel cycle; identify problem areas in instrumentation, data handling techniques, and record-keeping procedures.
- 2 to 5 years: Refine design of measuring and monitoring systems; perform tests in the field; certify the performance of environmental and personnel monitoring

systems; implement improved procedures; demonstrate dose evaluation techniques for large areas following accidental releases of radioactivity; develop techniques for automatic data processing for records storage and reporting.

Program Unit Priority: B

Severity of the Problem:	B
Extent of the Problem:	B
Need for Information:	B
Urgency:	A

Estimated Program Costs

\$500,000 to \$1,000,000 per year

TRANSPORT PROCESSES

PROGRAM UNITS

PROGRAM UNIT TITLE: Dispersal of Releases to the Atmosphere
from Reactors in Complex Air Flow
Conditions Code Ta-1

Technology: Fission

King-Muir Category: Environmental Transport Processes

Scope

Reactors are often located in areas where classic descriptions of transport and dispersion do not apply. Available models are not capable of accurately analyzing lake, seashore and off-shore locations, mountainous and forested areas, or other complex terrain situations. Exposure levels and affected areas can only be identified for the simplest situations. Experimental and modeling studies are needed to develop the necessary capability for estimating dose patterns in complex flow and dispersion conditions commonly experienced in reactor siting.

Technology Time Frame

Established and expanding

Program Unit Priority: B

Severity of the Problem: C

Extent of the Problem: B

Need for Information: B

Urgency: A

Estimated Program Unit Cost

\$1,300,000 to \$3,000,000 per year

PROGRAM UNIT TITLE: Regional Atmospheric Distribution and Deposition Patterns of Radioactive Materials from Reactor Networks and Other Fuel Cycle Facilities Code Ta-2

Technology: Fission

King-Muir Category: Environmental Transport Processes

Scope

To estimate total population exposure from regional nuclear power developments, several factors must be better understood: multi-state transport and dispersion of routine releases to the atmosphere, removal of radioactive material by precipitation and interaction of the plume with the surface, and resuspension of deposited material into the atmosphere. The low-level, long-term exposure of the affected population by inhalation of direct and resuspended plumes cannot be accurately estimated without this improved understanding of delivery and dilution processes. These processes are of particular concern with regard to the long-lived transuranics and ^{129}I , in addition to tritium, ^{85}Kr and other shorter-lived radionuclide effluents. Nonnuclear effluents, such as fluorides, from the nuclear fuel cycle also have characteristic behaviors in the atmosphere which must be evaluated.

Technology Time Frame

Established and expanding

Program Unit Priority: B

Severity of the Problem: C
Extent of the Problem: B
Need for Information: B
Urgency: A

Estimated Program Unit Cost

\$3,500,000 to \$5,000,000 per year

PROGRAM UNIT TITLE: Hemispheric and Global Distributions of
Radioactive Materials from Worldwide Pro-
liferation of Nuclear Power Production

Code Ta-3

Technology: Fission

King-Muir Category: Environmental Transport Processes

Scope

As continued development of nuclear power production proceeds throughout the world, increasing levels of all associated radionuclides must be anticipated. Modeling studies of hemispheric and global transport processes must proceed for adequate assessments.

Technology Time Frame

Established and expanding

Program Unit Priority: C

Severity of the Problem: C

Extent of the Problem: A

Need for Information: C

Urgency: B

Estimated Program Unit Cost

\$200,000 to \$500,000 per year

PROGRAM UNIT TITLE: Resuspension of Radionuclides Deposited in
the Environment Code Ta-4

Technology: Fission

King-Muir Category: Transport Processes

Scope

Radioactive materials being processed at nuclear fuel cycle facilities, in transit between facilities and at storage sites are subject to spills. Because of their availability at the earth's surface they are vulnerable to resuspension in the atmosphere and thus to inhalation by people and animals. Similarly, mine tailings and milling waste piles are subject to resuspension from the surface. Of special concern at this time are plutonium and other long-lived actinides associated with expected LMFBR operations. The quantities of resuspended radionuclides in various physical and chemical forms that might constitute significant hazards to people can now be estimated only within orders of magnitude. Studies are needed to determine the resuspendability of radioactive materials under a variety of surface characteristics and weather conditions.

Technology Time Frame

Established and expanding

Program Unit Priority: A

Severity of the Problem: B

Extent of the Problem: B

Need for Information: A

Urgency: A

Estimated Program Unit Cost

\$1,000,000 to \$3,000,000 per year

PROGRAM UNIT TITLE: Transport and Transformation of
Contaminants in Mine Water and Tailing
Leachates Code Tw-5

Technology: Fission

King-Muir Category: Transport Processes

Scope

Radioactive and nonradioactive trace metal contaminants are discharged to surface and ground waters in drainage from mines, effluents from mills, and leachates from tailings. Frequently this occurs in regions where scarce water resources must be husbanded for multiple uses. This program unit will evaluate the extent of water pollution resulting from effluents from mining (both conventional and in situ solution technology) and milling and the transport of these pollutants in surface and ground waters under the existing hydrologic and chemical conditions. The results will permit assessment of the effects of increased mining activity on aquatic resources.

Technology Time Frame

- 1) Ongoing surface and subsurface conventional mining
- 2) Test of in situ solution mining by 1980

Program Unit Priority: B

Severity of the Problem: C
Extent of the Problem: B (Western States)
Need for Information: B
Urgency: B

Estimated Program Unit Cost

\$100,000 to \$300,000 per year

PROGRAM UNIT TITLE: Transport of Heat, Radioactive Materials,
and Chemical Contaminants Associated with
Electric Power Production to Marine and
Fresh Water Systems Code Tw-6

Technology: Fission (also Fossil-Fueled Power
Production)

King-Muir Category: Transport Processes

Scope

In almost all instances, electric power production operations require large quantities of condenser cooling water. This water is usually withdrawn from and returned to fresh or marine surface waters. Research is needed on the transport processes affecting the fate of heat, radioactive materials, and chemical contaminants associated with cooling water and other process effluents. These results, coupled with biological studies, will contribute to improved design of cooling water and waste treatment systems.

Technology Time Frame

Applicable to essentially all the power production systems

Program Unit Priority: B

Severity of the Problem: B
Extent of the Problem: A
Need for Information: C
Urgency: A

Estimated Program Unit Cost

\$1,000,000 to \$2,000,000 per year

PROGRAM UNIT TITLE: Transport Processes in Soils and Ground-
water Systems Code Tg-7

Technology: Fission (also applicable to Coal
Extraction)

King-Muir Category: Transport Processes

Scope

Several operations in the nuclear fuel cycle involve discharge or burial of chemically or radiochemically contaminated materials into soils or groundwater systems. Research is necessary to advance and demonstrate methodologies to predict the chemical and physical behavior and transport of contaminants in soils and geologic formations. The results of the research will provide tools for designing waste management systems to assessing the environmental effects of accidental or operationsl discharges and evaluate impacts on alternative land uses and restoration operations.

Technology Time Frame

Currently in use

Program Unit Priority: B

Severity of the Problem: B

Extent of the Problem: B Generally occurs at specific
site locations

Need for Information: A

Urgency B Continuing problem

Estimated Program Unit Cost

\$500,000 to \$1,000,000 per year

PROGRAM UNIT TITLE: Weather Modification Effects from
Waste Heat Disposal at Nuclear Power
Parks Code Ta-8

Technology: Fission

King-Muir Category: Environmental Transport Processes

Scope

Natural atmospheric processes can be affected and modified by the introduction of man-produced heat and moisture into the atmosphere. Where significant energy and mass input is concentrated over a limited region, as in a Nuclear Energy Center, meteorological effects (whirlwinds, thunderstorms, increased cloud cover, higher ground fog frequencies and augmented rainfall) could be especially exaggerated. Theories and observations for almost all problems relating to the meteorological effects of large power centers are inadequate. Therefore, experiments must be performed, the processes involved must be modeled, and the potential modifications must be evaluated for heat and moisture inputs to the atmosphere from various configurations and numbers of nuclear power generating facilities.

Technology Time Frame

Parks are in the conceptual stage; their existence is several years in the future.

Program Unit Priority: B

Severity could conceivably be great
Only a very few large centers are likely
Need for information is high
Some lead time is available

Estimated Program Unit Costs

\$1,800,000 to \$2,000,000 per year

HEALTH EFFECTS

PROGRAM UNITS

PROGRAM UNIT TITLE: Potential Hazards of Radioactive and
Nonradioactive Materials Associated
with Existing and New Fission Fuel
Cycles Code Hi-1

Technology: Fission

King-Muir Category: Health Effects

Scope

Existing data from human epidemiological and laboratory model experiments and engineering and physical science studies will be critically reviewed to assess the probability of health effects from radioactive materials and other potentially hazardous agents occurring in existing and new fission fuel cycles, from mining operations to the transport and storage of nuclear wastes. The likelihood of exposure to radioactive materials in accident situations will also be determined.

Technology Time Frame

Milestones

Program Unit Priority: B

Severity of the Problem:	C
Extent of the Problem:	B
Need for Information:	A
Urgency:	A

Estimated Program Unit Cost

1st year -	\$500,000
3rd year -	\$600,000
5th year -	\$720,000

PROGRAM UNIT TITLE: Determination of the Toxic Potential of
Radioactive and Nonradioactive Materials
Associated with Existing and New Fission
Fuel Cycles through Development and
Application of Biologic Screening
Systems Code Hi-2

Technology: Fission

King-Muir Category: Health Effects

Scope

Radioactive materials and other fission fuel cycle agents suspected of being hazardous to humans, both during routine operations and in the event of accidents, will be tested by new, efficient and sensitive in vitro (cellular) and animal screening and testing systems to rapidly identify carcinogenic, mutagenic, teratogenic, and otherwise harmful agents from nuclear fission technology sources.

Technology Time Frame

Milestones

Program Unit Priority: B

Severity of the Problem:	C
Extent of the Problem:	B
Need for Information:	B
Urgency:	A

Estimated Program Unit Cost

1st year -	\$2,500,000
3rd year -	\$3,000,000
5th year -	\$3,500,000

PROGRAM UNIT TITLE: Kinetics and Disposition in Animals of
Radioactive Materials and Other
Hazardous Agents Code Hc-3

Technology: Fission

King-Muir Category: Health Effects

Scope

Laboratory animals, models and various routes of exposure will be used to determine uptake, deposition, distribution, translocation, modification, and excretion of radioactive materials and other hazardous agents and identify organs, tissues and cells at risk. Such information is basic to understanding the incorporation of hazardous agents and their metabolism. Of particular importance are the transplutonium isotopes, including all the isotopes of plutonium, and radionuclides of the thorium-uranium fuel cycle, as single and combined source terms.

Technology Time Frame

Milestones

Program Unit Priority: A

Severity of the Problem:	B
Extent of the Problem:	B
Need for Information	B
Urgency:	A

Estimated Program Unit Cost

1st year -	\$3,500,000
3rd year -	\$4,200,000
5th year -	\$5,050,000

PROGRAM UNIT TITLE: Development of Instrumentation and
Methods to Quantify Dose and Dose
Distribution Code Hc-4

Technology: Fission

King-Muir Category: Health Effects

Scope

This project is directed toward improved in vivo methodology for quantifying dose and dose distribution in experimental animals and man. It includes improved instrumentation; advanced dosimetric techniques including microdosimetry; advanced data processing; and other methods for accurately estimating dose, spatial and temporal resolution and dose rates to specific tissues and organs in the exposed subject.

Technology Time Frame

Milestones

Program Unit Priority: A

Severity of the Problem: B

Extent of the Problem: B

Need for Information: A

Urgency: A

Estimated Program Unit Cost

1st year - \$6,000,000

3rd year - \$7,200,000

5th year - \$8,700,000

PROGRAM UNIT TITLE: Development of Criteria and Methods for
Detecting and Quantifying Damage Due to
Key Radionuclides and Other Hazardous
Materials Associated with Fission Fuel
Cycles Code He-5

Technology: Fission

King-Muir Category: Health Effects

Scope

The development of improved dose-response data requires refinement of existing criteria for response. This refinement depends on improving methods for detecting tissue damage, particularly following exposure levels and periods which are now considered to produce no clinical effects. Quantification of damage not only will provide further refinement of dose-response experiments but is vital to proper clinical assessment and prognosis in cases of human exposure. Basic biological and chemical indices must be sought to aid in the detection of primary radiation insults and to serve as early diagnostic signs of degenerative, mutagenic and carcinogenic effects.

Technology Time Frame

Milestones

Program Unit Priority: A

Severity of the Problem:	A
Extent of the Problem:	B
Need for Information:	A
Urgency:	A

Estimated Program Unit Cost

1st year -	\$4,000,000
3rd year -	\$4,800,000
5th year -	\$5,800,000

PROGRAM UNIT TITLE: Somatic Pathologic Effects and Dose-Response Relationships of Important Actinides Associated with Current and Emerging Fission Fuel Cycles, Especially the Breeder Fuel Cycles

Code He-6

Technology: Fission

King-Muir Category: Health Effects

Scope

The introduction and expansion of breeder power reactors will be accompanied by a marked increase in the national inventory of heavy radionuclides associated with the thorium-uranium and plutonium fuel cycles. Long-term effects studies in animals must be conducted prior to the accumulation of these materials because of the increased occupational and public risk involved. The major effort will be directed toward establishing dose-response data on long-term, low-level exposure by the inhalation route.

Technology Time Frame

Milestones

Program Unit Priority: A

Severity of the Problem:	A
Extent of the Problem:	B
Need for Information:	A
Urgency:	A

Estimated Program Unit Cost

1st year -	\$6,700,000
3rd year -	\$8,050,000
5th year -	\$9,700,000

PROGRAM UNIT TITLE: Genetic Effects of Important Actinides
Associated with Existing and Emerging
Fission Fuel Cycles, Particularly Plu-
tonium, Americium and Curium Code He-7

Technology: Fission

King-Muir Category: Health Effects

Scope

The question of genetic effects associated with actinide dispersal in the environment is particularly important because of the insidious nature of nonlethal mutation and its potential threat to humanity. Animal experiments are needed to establish gonadal deposition, quantitative estimates of radionuclide amounts within effective range of sensitive germinal tissue, and the resulting incidence of genetic alteration that results in somatic effects. Depending on the source term and results, such studies could conceivably modify human exposure limits established in other studies.

Technology Time Frame

Milestones

Program Unit Priority: A

Severity of the Problem:	A
Extent of the Problem:	B
Need for Information:	A
Urgency:	B

Estimated Program Unit Cost

1st year -	\$5,000,000
3rd year -	\$6,000,000
5th year -	\$7,200,000

PROGRAM UNIT TITLE: Biologic Effects and Dose-Response
Relationships of Tritium, Tritium
Compounds and ⁸⁵Kr Code He-8

Technology: Fission

King-Muir Category: Health Effects

Scope

Proliferation of power reactors will result in increased amounts of ⁸⁵Kr, tritium and tritium compounds in the environment. It has been estimated that the average annual whole-body dose to the U.S. population from nuclear power may increase by up to a factor of 100 by the year 2000. Although the average whole-body dose at that time will still be low (less than .05 mrem/person), occupational groups and populations near nuclear parks will experience higher exposure than the average population and will face greater risk. The biologic effects of the nuclides that will contribute most of the dose should be studied prior to and parallel with expansion of fission power production.

Technology Time Frame

Milestones

Program Unit Priority: A

Severity of the Problem:	B
Extent of the Problem:	A
Need for Information:	A
Urgency:	B

Estimated Program Unit Cost

1st year -	\$4,800,000
3rd year -	\$5,800,000
5th year -	\$7,000,000

PROGRAM UNIT TITLE: Biologic Effects and Dose-Response
Relationships of Radionuclides and
Other Hazardous Materials to Which
Man May be Exposed in Credible
Accident Situations Code He-9

Technology: Fission

King-Muir Category: Health Effects

Scope

Although the probability of an accident at any point in the fission fuel cycle is low, the chances for direct and indirect human exposure must increase as proliferation of fission power facilities proceeds. Responsible technology development must admit the possibility of accidents and establish contingency plans for such situations. As materials (such as the recently recognized plutonium-sodium complexes) that will be released in such situations are identified, biologic effects studies will aid in the assessment of the actual health hazards they present and help guide the development of occupational and public health measures that will minimize impacts on human populations.

Technology Time Frame

Milestones

Program Unit Priority: A

Severity of the Problem: A
Extent of the Problem: A
Need for Information: A
Urgency: B

Estimated Program Unit Cost

1st year - \$4,500,000
3rd year - \$5,400,000
5th year - \$6,500,000

PROGRAM UNIT TITLE: The Role of Spatial Distribution of
Internal Radiation-emitters in the
Induction of Carcinogenic and Muta-
genic Change Code He-10

Technology: Fission

King-Muir Category: Health Effects

Scope

The "hot particle" controversy revolves around the question of whether radionuclides (primarily beta and alpha-emitters) evenly distributed throughout an organ (primarily the lung) produce a higher incidence of cancer or genetic damage than an identical organ burden distributed in discrete, localized aggregates. Since the answer may have a direct impact on the establishment of maximum permissible lung burdens, it is essential that studies designed specifically to resolve this controversy be conducted as soon as possible.

Technology Time Frame

Milestones

Program Unit Priority: A

Severity of the Problem:	A
Extent of the Problem:	B
Need for Information:	A
Urgency:	A

Estimated Program Unit Cost

1st year -	\$3,500,000
3rd year -	\$4,200,000
5th year -	\$5,050,000

PROGRAM UNIT TITLE: Determination of the Validity of Linear
Extrapolation of Dose-Response Curves
to the Case of Very Low Dose Rates and
Long-term Exposure, Especially for High
LET Radiation Code He-11

Technology: Fission

King-Muir Category: Health Physics

Scope

Because experimental data are not available for very low-level, long-term exposures to radiation, it is a common practice to extrapolate linearly from known data to zero dose on the dose-response curve. However, it is not known whether the curve in this region is linear, concave upward or downward, sigmoid, or if a response threshold exists. Since the major problem area in health effects of radiation deals with very low doses received over long periods of time, this portion of the dose-response curve is of great importance and the validity of the linear extrapolation hypothesis must be experimentally confirmed or refuted.

Technology Time Frame

Milestones

Program Unit Priority: A

Severity of the Problem:	A
Extent of the Problem:	A
Need for Information:	A
Urgency:	A

Estimated Program Unit Cost

1st year -	\$2,500,000
3rd year -	\$3,000,000
5th year -	\$3,600,000

PROGRAM UNIT TITLE: Determine the Biologic Effects and Dose-Response Relationships of Radiation and Radionuclides for the Developing (Fetal, Perinatal, Juvenile) Mammal Code He-12

Technology: Fission

King-Muir Category: Health Effects

Scope

Developing tissues characteristically show a higher susceptibility to radiation damage than mature tissues. In order to define hazards to and permissible exposure limits for the developing human, it is essential first to characterize experimentally effects and dose-response of radiation and incorporated radionuclides in fetal, perinatal and juvenile mammal models. Considerable information is lacking on those heavy nuclides associated with breeder reactor technology and on the delayed effects of perinatal and juvenile exposures via inhalation.

Technology Time Frame

Milestones

Program Unit Priority: A

Severity of the Problem:	B
Extent of the Problem:	A
Need for Information:	A
Urgency:	A

Estimated Program Unit Cost

1st year -	\$2,700,000
3rd year -	\$3,250,000
5th year -	\$3,900,000

PROGRAM UNIT TITLE: Influence of Pre-existing Disease
States and Altered Metabolism on
Radionuclide Incorporation and
Effects Code He-13

Technology: Fission

King-Muir Category: Health Effects

Scope

Little is known about the influence of existing disease and altered metabolic functions on the kinetics, disposition and effects of radionuclides. For example, iron deficiency--the major nutritional deficiency in the U.S.--is known to enhance gut absorption of certain heavy nuclides and may increase the transport of plutonium across the blood-testis and blood-ovary barriers. Much more information is needed on the influence of common diseases, nutritional deficiencies and intentionally altered physiologic function (drugs, alcohol) on the incorporation and ultimate health effects of radionuclides, particularly those which have high carcinogenic or mutagenic potential.

Technology Time Frame

Milestones

Program Unit Priority: B

Severity of the Problem:	A
Extent of the Problem:	B
Need for Information:	B
Urgency:	B

Estimated Program Unit Cost

1st year -	\$2,800,000
3rd year -	\$3,400,000
5th year -	\$4,100,000

PROGRAM UNIT TITLE: Extrapolation of Dose-Effect Relation-
 ships in Laboratory Model Systems to
 Man Code He-14

Technology: Fission

King-Muir Category: Health Effects

Scope

Experimental animals, organs, tissues, cells and culture techniques for toxicologic and pathologic studies will be used to develop predictive models for extrapolation of laboratory system data to man. It will be necessary to compare dose-effect relationships among different species as well as whole animal results and those obtained by cell and organ culture techniques. Eventually, predictive models applicable to long-term, low-level exposures to various combinations of agents and to delayed toxicologic effects will be developed.

Technology Time Frame

Milestones

Program Unit Priority: A

Severity of the Problem: A

Extent of the Problem: A

Need for Information: A

Urgency: B

Estimated Program Unit Cost

1st year - \$2,800,000

3rd year - \$3,400,000

5th year - \$4,100,000

PROGRAM UNIT TITLE: Primary Reactions by which Radiation
Transfers Energy to Biologic Media
and Subsequent Transport and Radio-
chemical Processes Leading to Observ-
able Lesions Code Hb-15

Technology: Fission

King-Muir Category: Health Effects

Scope

This program will study the initial processes by which radiation interacts with biological materials, the means by which the deposited energy is transported through cellular systems, and how physical radiation interaction is related to early biochemical changes in or on cells. It will further clarify the mechanisms by which biological amplification occurs between initiation of damage and expression of response and elucidate the basic processes that lead to irreversible cellular injury. Eventually descriptive and predictive models of radiation effects in biological systems will be developed based on fundamental physical and chemical understanding of radiation-induced changes. The scope of this program also includes studies of the synergisms between radiation and other hazardous agents in biological systems. Knowledge of the mechanisms and host factors which contribute to injury is particularly valuable in the development of methods to interrupt these processes.

Technology Time Frame

Milestones

Program Unit Priority: A

Severity of the Problem:	B
Extent of the Problem:	B
Need for Information:	A
Urgency:	A

Estimated Program Unit Cost

1st year - \$5,000,000

3rd year - \$6,000,000

5th year - \$7,200,000

PROGRAM UNIT TITLE: Processes by Which Radiation-Induced
Lesions are Repaired and Returned
Code Hb-16

Technology: Fission

King-Muir Category: Health Effects

Scope

Mechanisms of repair and recovery from cellular and sub-cellular damage caused by radiation and other toxic agents associated with nuclear fission technology will be investigated. This should suggest methods for augmenting or using these mechanisms to encourage host recovery and to prevent carcinogenic and mutagenic sequelae. In addition, these studies, which are designed to yield basic knowledge of cell biology, molecular biology and immunology, may aid in the preclinical detection and diagnosis of subtle toxicologic and pathologic effects resulting from low-level exposure.

Technology Time Frame

Milestones

Program Unit Priority: A

Severity of the Problem:	B
Extent of the Problem:	C
Need for Information:	A
Urgency:	A

Estimated Program Unit Cost

1st year -	\$3,200,000
3rd year -	\$3,900,000
5th year -	\$4,700,000

PROGRAM UNIT TITLE: Methods for Removing Incorporated
Radionuclides with Long Effective
Half-Lives from Tissues Code Ht-17

Technology: Fission

King-Muir Category: Health Effects

Scope

Identifying and limiting human exposure to all radionuclides associated with energy production may not be possible. It is therefore essential that we either develop chemical or physical methods to remove incorporated radionuclides with long effective half-lives or enhance normal body clearance mechanisms. Emphasis should be directed to removing lung-deposited oxide aerosols of actinides and of all long-lived bone-seeking nuclides associated with existing and evolving fission fuel cycles. Considerable animal research is required prior to human trials.

Technology Time Frame

Milestones

Program Unit Priority: A

Severity of the Problem:	A
Extent of the Problem:	C
Need for Information:	A
Urgency:	A

Estimated Program Unit Cost

1st year -	\$2,300,000
3rd year -	\$2,800,000
5th year -	\$3,400,000

PROGRAM UNIT TITLE: Protective and Ameliorative Techniques
to Minimize Long-term Adverse Effects
of Incorporated Long-lived Radio-
nuclides Code Ht-18

Technology: Fission

King-Muir Category: Health Effects

Scope

Devices, methods and pharmacologic agents will be developed and applied to assist in biological recovery and repair following exposure to radionuclides with long half-lives and to protect against the effects of incorporated radioactive materials and other hazardous agents associated with nuclear fission technology. The program will evaluate methods to minimize or eliminate the effects of radiation and other agents and develop protective and ameliorative techniques to minimize the long-term adverse effects of such agents if removal is shown to be impossible.

Technology Time Frame

Milestones

Program Unit Priority: A

Severity of the Problem:	A
Extent of the Problem:	C
Need for Information:	A
Urgency:	B

Estimated Program Unit Cost

1st year -	\$2,400,000
3rd year -	\$2,900,000
5th year -	\$3,500,000

PROGRAM UNIT TITLE: Epidemiological and Clinical Studies
in Selected Occupational and General
Population Groups Code He-19

Technology: Fission

King-Muir Category: Health Effects

Scope

Exposure risk and health effects in man produced by chronic, long-term low-level exposure to radiation and hazardous agents (primarily plutonium, transplutonium elements, and other radioactive materials associated with nuclear fuel cycles) will be quantitatively evaluated. Clinical examinations, including bioassay and whole-body counting, will be conducted periodically on both occupational personnel and on selected local population groups. Of major importance is epidemiological and clinical follow-ups on people known to have received doses of internal emitters of long effective half-life. In addition, body burdens accumulated through one-time and long-term low-level exposure will be assessed by establishing and conducting post-mortem programs similar to those now in place at Hanford, Oak Ridge and Mound Laboratory. Data from these studies will be compared with disease (e.g., cancer) incidence and life span among population groups remote from nuclear fission facilities. Changes in assessment techniques will also become necessary to accommodate the rapid accumulation of large amounts of transplutonic elements (e.g., Am, Np, Cm) associated with plutonium breeder fuel cycles.

Technology Time Frame

Milestones

Program Unit Priority: A

Severity of the Problem: A

Extent of the Problem: A

Need for Information: A

Urgency: B

Estimated Program Unit Cost

1st year - \$4,600,000

3rd year - \$5,900,000

5th year - \$7,700,000

PROGRAM UNIT TITLE: Occupational Hazards Associated with
Uranium Mining Code He-20

Technology: Fission

King-Muir Category: Health Effects

Scope

Proliferation of fission power production facilities will necessarily be accompanied by a marked increase in uranium mining activity in the U.S. and elsewhere. Current inhalation hazards are based upon estimates of working history and consider only one of several toxic air pollutants. The specific cause and effect relationships of these agents must be assessed both singly and in combination to realistically evaluate the risks of emphysema, lung cancer, and pulmonary fibrosis in uranium miners. The current incidence of lung cancer in these men is of epidemic proportions. The danger from rockfall and equipment failure must also be determined for various underground mining operations.

Technology Time Frame

Milestones

Program Unit Priority: A

Severity of the Problem:	A
Extent of the Problem:	B
Need for Information:	A
Urgency:	A

Estimated Program Unit Cost

1st year -	\$2,300,000
3rd year -	\$3,000,000
5th year -	\$3,900,000

PROGRAM UNIT TITLE: Biologic Effects of External
Radiation Code He-21

Technology: Fission

King-Muir Category: Health Physics

Scope

While the study of biologic effects and dose-response relationships of internal emitters comprises the major portion of radiobiological research related to fission-produced energy, we must continue to study the effects of whole- or partial-body exposure from an external source. Such exposure is by far the most common in both the general population and in occupational groups. Because current human exposure limits are generally quite low, delayed somatic, teratogenic, and genetic effects warrant the greatest attention. However, large doses may be received in accident situations, so studies of acute somatic effects cannot be neglected.

Technology Time Frame

Milestones

Program Unit Priority: A

Severity of the Problem:	B
Extent of the Problem:	A
Need for Information:	A
Urgency:	B

Estimated Program Unit Cost

1st year -	\$3,700,000
3rd year -	\$4,500,000
5th year -	\$5,400,000

ECOLOGICAL PROCESSES AND EFFECTS

PROGRAM UNITS

PROGRAM UNIT TITLE: Rehabilitation of Pit and Surfaced
Mined Lands After Uranium Ore
Extraction Code Et-1

Technology: Fission

King-Muir Category: Ecological Processes and Effects

Scope

Most of the uranium ore mined in the United States is in the Rocky Mountain States of Colorado, Wyoming, Utah, and New Mexico. Surface and pit mining are joining deep mining as important modes of ore extraction. As high grade ores in the Rocky Mountains are exhausted, surface mining may be employed on low grade but extensive ore deposits in Tennessee and adjacent states, causing correspondingly larger areas of land disturbance per ton of uranium extracted. The purpose of this program unit is to develop sound ecological principles amenable to the local climate, topography, soil, genetic stocks available, and land use management goals that can be applied to land rehabilitation after ore extraction.

Milestones

1 to 3 years: Review past and present land rehabilitation methods applicable to currently active uranium mines.

Establish experimental areas in selected operating mines where conventional rehabilitation procedures can be compared with innovative procedures.

3 to 6 years: Evaluate different rehabilitation treatments in terms of biological productivity, species diversity, esthetics, and economic performance (e.g., livestock grazing, crop production, or wildlife habitat).

6 to 10 years: Recommend types of land rehabilitation to be applied to individual mine sites.

Technology Time Frame

Ongoing and expanding

Program Unit Priority: B

Estimated Program Costs

\$1,000,000 to \$1,500,000 per year

PROGRAM UNIT TITLE: Disposition of Tailings from Uranium
Processing Mills Code Et-2

Technology: Fission

King-Muir Category: Ecological Processes and Effects
(Terrestrial)

Scope

Mill tailings are low in plant nutrients, easily erodible by wind and water, and may have chemical additives that are deleterious to the healthy growth of plants. This program unit will develop means to 1) stabilize mill tailings in place by establishing suitable vegetative cover, 2) substitute tailings for backfill at ecologically safe landfill sites, and 3) return tailings to ore-depleted mines.

Milestones

1 year: Inventory existing mill tailing repositories in the United States and estimate their present and potential impact on the environment in terms of biological productivity, species diversity, esthetics, and biotic and abiotic dispersal of radioactivity.

2 years: Select a site and conduct an experimental study to establish plant cover.

3 to 5 years: Modify experiments to improve plant cover.

Technology Time Frame

Ongoing and expanding

Program Unit Priority: B

Estimated Program Costs

\$200,000 to \$700,000 per year

PROGRAM UNIT TITLE: Behavior and Fate of Radionuclides in
Terrestrial Ecosystems Code Et-3

Technology: Fission

King-Muir Category: Ecological Processes and Effects

Scope

Radioactive materials enter terrestrial ecosystems in the gaseous and liquid effluents of all phases of the fission fuel cycle. Of particular importance are the normal operating effluents from nuclear power and fuel reprocessing plants; accidental releases can also be of major concern near the sites of incidents. Knowledge of the cycling, dispersion and ultimate fate of these nuclides as a consequence of both abiotic and biotic processes, including reconcentration in food chains, is necessary to estimate their contributions to the radiation dose to people and other organisms and to identify ways this dose can be mitigated, if necessary. The availability and fate of plutonium and other long-lived transuranic elements is of particular interest to the public and scientific community at this time. It must be determined whether the deposition sites of such radionuclides serve as sinks where these materials remain chemically inactive or as reservoirs that serve as a continued source of the nuclides to the food webs.

Technology Time Frame

Ongoing and expanding

Program Unit Priority: B

(A substantial fund of knowledge has already been developed, but it needs to be refined.)

Estimated Program Costs

\$2,500,000 to \$5,500,000 per year

PROGRAM UNIT TITLE: Behavior and Fate of Radionuclides in
Aquatic Systems Code Ea-4

Technology: Fission

King-Muir Category: Ecological Processes and Effects

Scope

Radioactive materials are introduced into fresh, marine and estuarine surface waters with the aqueous effluents from nuclear power plants and other nuclear facilities that supply or process the fuel. Some of these radioactive materials remain easily available to aquatic biota and man, others are soon depleted from the water by sedimentation and are deposited. In order to estimate their radiation dose contribution to man and to aquatic life, an accurate knowledge of their cycling and fate is essential. This includes their uptake by plants and transfer through food webs and also their fixation by sediments. Activation products of the transition elements and some of the fission products, such as Cs-137 and I-131, are of particular interest because of their large concentration factors. The long-lived transuranic elements (principally plutonium, americium, and curium) are also of special interest because of the inventories that may accumulate over extended periods of time. Similar to the case with soils, there is a need to determine the potential for the formation of soluble metals in the sediments, the bioavailability of the radionuclides to the lower trophic levels, and the role of microorganisms in changing the physical/chemical state of the metals.

Technology Time Frame

Ongoing and expanding

Program Unit Priority: B

(A substantial fund of knowledge has already been developed, but several facets need more work.)

Estimated Program Costs

\$2,500,000 to \$5,500,000 per year

PROGRAM UNIT TITLE: Effects of Radiation Exposure on Natural
Populations Code Eat-5

Technology: Fission

King-Muir Category: Ecological Processes and Effects

Scope

The effects of external radiation and, to a lesser extent, internally deposited radionuclides on a number of terrestrial and aquatic organisms have been investigated. Relatively few studies have been made on complete natural communities in order to establish the dose levels at which sensitive species begin to show a response. Such dose-effect relationships need to be better established because of the possibility that low chronic dose rates may produce an unanticipated response because of multiple stresses on the community. Additional work in this area would likely add needed credibility to the concept that radionuclide concentrations acceptable for man are without effect on ecosystems. A part of this program includes the development of better methods for the quantitative assessment of the effects of environmental contaminants on ecosystems.

Technology Time Frame

Ongoing and expanding

Program Unit Priority: B

(Although the information is urgently needed, the severity of the problem is low.)

Estimated Program Unit Costs

\$900,000 to \$3,500,000 per year

PROGRAM UNIT TITLE: Effects of Heat and Toxic Chemicals on
Aquatic Life Code Ea-6

Technology: Fission and Other Fuels for Thermal Power
Plants

King-Muir Category: Ecological Processes and Effects

Scope

All liquid effluents from fission fuel cycle facilities discharge at least small quantities of chemical wastes and some facilities, especially thermal power plants, discharge very large volumes of cooling water. The perceived effects of the heat, and to some extent the toxic chemicals, have resulted in substantial delays of some power stations and expensive modifications for others. The true effects of both heat and toxic chemicals (including synergism) need to be resolved as soon as possible in order to avoid needless off-stream cooling systems and waste of the energy required to drive them. The program should include both acute and chronic exposure; both near and far field ecosystems; and the peculiarities of cold shock as well as elevated temperatures. Emphasis should be placed on sublethal effects and their relationship to the functioning of the aquatic community at risk.

Technology Time Frame

Ongoing and expanding

Program Unit Priority: A

Estimated Program Unit Costs

\$3,000,000 to \$6,500,000 per year

PROGRAM UNIT TITLE: The Effects of Cooling Water Intakes and
Outfalls on Aquatic Life Code Ea-7

Technology: Fission and Other Fuels for Thermal Power
Plants

King-Muir Category: Ecological Processes and Effects

Scope

The large volumes of water withdrawn at power plant cooling water intakes create potential problems for aquatic biota. These problems include the entrapment and entrainment of fish and slower swimming organisms within the influence of the intake; the impingement of organisms upon screening devices; and the passage of smaller organisms which penetrate the screens and are carried through the condenser systems. Basic information is required on the physiological and behavioral capabilities of aquatic species to cope with the natural stresses they experience as a result of water withdrawals. The results of laboratory and field studies of impingement, entrainment, entrapment, and passage should be utilized to develop guidelines for predicting impact at the population or system level. These results will also support the development of more accurate methodology for future assessments of intake problems.

Problems associated with the hydrodynamics of outfalls are less severe than at the intakes but warrant some attention because of scouring of benthic communities and the attraction of fish.

Technology Time Frame

Ongoing and expanding

Program Unit Priority: A

(The severity of the intake structure problem may well be the greatest of all of the impacts of the fuel cycle on aquatic life.)

Estimated Program Unit Costs

\$1,800,000 to \$4,000,000 per year

PROGRAM UNIT TITLE: Effects of Drift from Cooling Towers on
Terrestrial Ecosystems Code Et-8

Technology: Fission and Other Fuels for Thermal Power
Plants

King-Muir Category: Ecological Processes and Effects

Scope

Because of the limited availability of water for once-through cooling of thermal power plants and the perceived risks to aquatic life associated with once-through cooling, most of the inland and some sea coast thermal power plants are now designed with evaporative cooling towers. The drift from these towers has a relatively high salt content, especially in the case of salt water towers, and contains trace quantities of biocides, corrosion-inhibiting chemicals (such as chromium) and possibly asbestos fibers. Research is needed to assess the deposition retention and effects of drift from the towers on the vegetation, soils and biota in the region.

Technology Time Frame

Ongoing and expanding

Program Unit Priority: A

(The urgency is high and the application widespread; the probable severity of effects is low and the need for information is intermediate.)

Estimated Program Unit Costs

\$500,000 to \$1,300,000 per year

PROGRAM UNIT TITLE: Biological Translocation of Radionuclides
from Disposal Sites Code Eat-9

Technology: Fission

King-Muir Category: Ecological Processes and Effects

Scope

Most of the large ERDA (former AEC) sites that have been involved in the production of weapons materials or large scale research and development have disposed of substantial quantities of radioactive wastes to ponds and to the ground. Some of these radioactive wastes are available to vegetation, insects, burrowing animals, fish and birds that may accumulate certain contaminants and move them from the intended disposal site to other locations where they can contribute direct radiation exposure, or be ingested by people. Although this problem is expected to be less severe in the case of fission power facilities, research is needed to determine the circumstances, including the kinds of ecosystems, that are most likely to result in problems, the degree of radiation risk involved, and what steps can be taken to eliminate or mitigate the translocation.

Technology Time Frame

Problems largely result from past practices. Less severe cases are anticipated in the future.

Program Unit Priority: A

Severity: A

Extent: C

Need for Information: A

Urgency: A

Estimated Program Unit Cost

\$1,000,000 to \$2,000,000 per year

INTEGRATED ASSESSMENT

PROGRAM UNITS

PROGRAM UNIT TITLE: Risk Assessment of Non-Reactor Components
of the Fission Fuel Cycle Code It-1

Technology: Fission

King-Muir Category: Integrated Assessment

Scope

The overriding public concern with respect to all phases of the fission fuel cycle is the issue of safety and to date no explicit risk analysis on the entire fuel cycle has been conducted and presented for public discussion. The "Rasmussen Report" has addressed the risk elements associated with reactor operations, and overtime and with considerable public debate, will contribute to increased public understanding and recognition of the risk/benefit ratio. To a degree public attention (led by intervenors) is now being focused on the issue of "ultimate disposal" of radioactive wastes, a fuel cycle component distinct from reactor operation per se. Nuclear technology may continue to be rejected by a substantial segment of the public unless confusion concerning the safety of this technology is resolved. Resolution will require clear identification of genuine hazards plus demonstration that these hazards are within socially acceptable limits.

The scope of this program unit are to 1) determine the total risk to human health resulting from all components at the fission fuel cycle, 2) to determine public perception of the risk, and 3) to develop means to narrow the gap between perceived and real risk.

Technology Time Frame

Widespread commercialization underway

Program Unit Priority: A

Severity: A Significant public resistance to construction of additional fission fuel cycle facilities is evident. Objective resolution of controversial issues, a major one being risk, is necessary.

Extent: A Controversies over nuclear safety are national in scope.

Need: A Objective and forthright discussion of fission fuel cycle hazards may provide the basis for resolution of major aspects of the nuclear controversy.

Urgency: A The fission fuel cycle is anticipated to be one of the major power sources within the next 25 years. Resolution of its acceptability is required shortly to commence planning and construction of power plants required in the near term.

Estimated Program Unit Costs

\$2,000,000 to \$3,000,000 per year

PROGRAM UNIT TITLE: Assessment of Alternative Methods for Determining Demand for Power Code Ii-2

Technology: All

King-Muir Category: Integrated Assessment

Scope

Considerable controversy surrounds methods employed to determine need for additional power generating capacity. Simple projection of past rates of increase in energy consumption for prediction of future demand is questionable. Projections of future demand have also been challenged as being self-fulfilling; i.e., the availability of energy stimulates its consumption. This latter effect, if true, may be attributable to pricing and regulatory policy. In addition, little is known of the effects of conservation, curtailment of other energy supplies, geography, price, economic climate, technological innovation, and regulatory policies on the present or future demand for energy. The objective of this research is to gain a thorough understanding of the effects of the foregoing factors on energy demand. Alternative methods for prediction of future energy demand should be identified and assessed, based on an understanding of controlling factors.

Technology Time Frame

Ongoing

Program Unit Priority: A

Severity: B Methods for estimating future requirements are available, although controlling factors appear to be poorly understood.

Extent: A Information resulting from this research would be universally applicable.

Need: A Factors controlling energy demand are poorly understood. Better understanding of these factors would facilitate future efforts at predicting and managing energy demand.

Urgency: B Results of this research would provide immediately useful information for formulation of national energy policy and would facilitate energy planning at all geographic levels.

Estimated Program Unit Cost

\$500,000 to \$800,000 per year

PROGRAM UNIT TITLE: Regional Power Planning

Code Ii-3

Technology: All

King-Muir Category: Integrated Assessment

Scope

The scope of this effort is to develop and assess alternative long-term regional strategies for the provision of power, including assessment of energy centers. Methods of determining optimal mixes and distribution patterns of power generation and associated support facilities should be identified and assessed. Considerations should include fuel availability, projected power demand and load characteristics, waste heat assimilation capacity, regional social values and economic climate, regional environmental quality and spatial configuration of the power market. Institutional considerations relevant to establishment of a continuing planning process should also be investigated.

Technology Time Frame

Ongoing and expanding

Program Unit Priority: A

Severity: A The results of this research are required to support regional power supply planning.

Extent: A All power generation systems are affected.

Need: A Current power planning efforts are typically restricted to limited geographical areas, to incomplete decision criteria and to consideration of the power generation elements of the various fuel cycles.

Urgency: A Integrated regional power planning should facilitate resolution of energy supply controversies prior to construction of individual

facilities, thus reducing costs associated
with project delay or cancellation.

Estimated Program Unit Cost

\$2,000,000 to \$3,000,000 per year

PROGRAM UNIT TITLE: Site Selection Methodologies

Code Ii-4

Technology: Fission

King-Muir Category: Integrated Assessment

Scope

The scope of this effort is to develop site selection methodologies for all classes of fission fuel cycle facilities. Refined site selection procedures should enhance the technical and social acceptability of sites selected for future fission fuel cycle facilities. Subjects which should be addressed by this research include:

- Development of a comprehensive set of siting criteria for fission fuel cycle facilities.
- Development of methods for assessing social value of criteria developed above.
- Explore costs and benefits associated with various locational strategies for fission fuel cycle facilities. Variables will be similar to siting criteria developed above.
- Assessment of the feasibility of site "stockpiling". Development of methods for site preselection, acquisition and holding. Considerations should include interim use of stockpiled sites, financial and institutional aspects of site acquisition and holding, effects on adjacent land resources, local and regional development.
- Explore methods for soliciting public attitudes regarding nuclear facilities. Examine methods for communication of technical concepts to the general public.
- Examine the compatibility of nuclear facilities with various on-site uses for land and water resources. Identify

land and water uses compatible with facility site constraints and develop methods for selecting and integrating suitable uses with plant design.

Technology Time Frame

Ongoing and expanding

Program Unit Priority: A

Severity: A Public controversy regarding site selection is inhibiting new installations.

Extent: A All future fission fuel cycle facilities are affected.

Need: B Several comprehensive site selection methodologies have been proposed; few seem to be based on in-depth analysis of social values.

Urgency: A Significant delays presently being experienced in establishing fission power generating capacity are in a large part attributable to site selection controversies.

Estimated Program Unit Cost

\$1,000,000 to \$1,500,000 per year

PROGRAM UNIT TITLE: Identification, Assessment and Management
of Economic Impacts Code Is-5

Technology: All

King-Muir Category: Integrated Assessment

Scope

The scope of this program unit is to gain an understanding of the regional and local economic impacts resulting from construction and operation of fission fuel cycle facilities. Economic impacts of nuclear facilities may be especially severe because of the small and isolated character of communities in which facilities are frequently sited, and the transitory presence of a large construction force followed by a much smaller operating force. Studies are needed to define and evaluate agents of economic impact and to develop methods for ameliorating negative impacts and exploiting positive effects. Pre-plant geographic, demographic and economic variations need to be considered.

Results of this research should be presented so as to resolve current controversies regarding impact of nuclear facilities as well as contributing to the site selection process (covered in another program unit). Long term observations of economic impact on communities experiencing construction of nuclear facilities should be initiated.

Technology Time Frame

Widespread commercialization is underway.

Program Unit Priority: A

Severity: B Substantial differences in public opinion regarding economic effects of nuclear facilities on local communities is evident. Identification, assessment, and management of

economic impacts should promote the acceptance of fission fuel cycle facilities.

- Extent: A Results of this research would apply to all fission fuel cycle facilities. Research results could be applied to other fuel cycles.
- Need: A Little definitive information on local economic impacts may be a significant factor contributing to local apprehensions concerning fission fuel cycle facilities. Research results are also required as input into future site selection.
- Urgency: A Controversies and uncertainties regarding economic impacts may be a significant factor contributing to local apprehensions concerning fission fuel cycle facilities. Research results are also required as input into future site selection.

Estimated Program Unit Costs

\$300,000 to \$1,000,000 per year

PROGRAM UNIT TITLE: Identification, Assessment and Management
of Social Impacts Code Is-6

Technology: All

King-Muir Category: Integrated Assessment

Scope

The scope of this program unit is to gain an understanding of local social impacts resulting from construction and operation of fission fuel cycle facilities. Social impacts may be especially severe for the case of nuclear facilities because of the large size of typical installations and the small and isolated character of communities in which they are frequently sited. Studies are needed to define and evaluate agents of social impact and resulting effects on social relationships. Methods for alleviating negative effects and exploiting potential positive effects should be investigated. Geographical variations should be considered. Subjects which should be addressed include:

- Social impact of unfamiliar cultural groups accompanying construction and operation of fission fuel cycle facilities.
- Definition of "lifestyle" and relative social values. Impacts of lifestyle resulting from construction and operation of fission fuel cycle facilities.
- Social impact of improved transportation and communication systems.
- Secondary social impacts resulting from changes in employment opportunities.
- Secondary social impacts resulting from changes in the availability of commercial, cultural, recreational and educational opportunities.

Results of this research should be presented so as to resolve current controversies regarding impact of nuclear facilities as

well as contributing to the site selection process. (Covered in a separate program unit.) Long-term observations of social impact on communities experiencing construction of nuclear facilities should be initiated.

Technology Time Frame

Widespread commercialization underway

Program Unit Priority: A

Severity: B Substantial public controversy regarding social effects of nuclear facilities on local communities is evident. Identification, assessment and management of social impacts should promote acceptance of fission fuel cycle and other energy facilities.

Extent: A Results of this research would be applicable to all fission fuel cycle facilities. Research results could be applied to other fuel cycles.

Need: A Little definitive information on social impacts of fission fuel cycle facilities appears to be available.

Urgency: A Controversies and uncertainties regarding social impacts may be a significant factor contributing to local apprehensions concerning fission fuel cycle facilities. Research results are also required as input into future site selection.

Estimated Program Unit Costs

\$300,000 to \$1,000,000 per year

PROGRAM UNIT TITLE: Analysis of Energy Supporting Resource
Availability and Utilization Trade-offs
Code It-7

Technology: All

King-Muir Category: Integrated Assessment

Scope

The generation of electrical power necessitates using natural resources in addition to the primary fuel material. Such resources include land and associated wildlife habitats, water, and airshed ventilation capacity. More often than not, alternative uses of these resources are in competition with energy production and use. Competing activities include agriculture, recreation, wildlife protection, etc.

Research is therefore necessary to inventory the availability of natural resources and assess the significance of competing demands.

Technology Time Frame

Ongoing and expanding

Program Unit Priority: A

Severity: A

Extent: A

Need: A

Urgency: A

Estimated Program Unit Cost

\$1,000,000 to \$2,000,000 per year

PROGRAM UNIT TITLE: Public Understanding and Acceptance of
Costs/Risks/Benefits of Alternative Electric
Energy Sources Code It-8

Technology: All

King-Muir Category: Integrated Assessment

Scope

National debates are currently underway and are expected to continue on a variety of issues that will markedly influence the acceptance of and course of development of the alternative energy technologies. These debates include such issues as nuclear moratoriums, abandonment of the Breeder Reactor Program, abandonment of plutonium recycle, and moratoriums on strip mining. Public understanding of the full implications of these or similar options is essential.

The program will be undertaken with the following tasks and milestones:

1. Complete an evaluation of national forecasts of demand for electric power without artificial constraints.
2. Complete an assessment of the contribution of the various energy resources to meeting the electric power demand without artificial constraints.
3. Summarize health, environmental, and socio-economic effects of electric energy generation technologies as a function of time and their share under conditions of 1) current expectations of nuclear power contribution, 2) moratorium on nuclear power, 3) moratorium on LMFBR, 4) moratorium on Pu recycle in LWR's.
4. Interpret results generated above in terms of concepts readily understood by the lay public.

Public Health	Cost Of Power	Environmental Quality
Cost of Living	BNP, Taxes	Quality of Life

Emphasis will be given to differential effects on these indices of constraints on the development of nuclear power.

5. Assess public perceptions and knowledge of energy technology effects and needs and desires for information, and assess the public view of credibility of sources.
6. Design and institute public information program including active public participation.
7. Regionalize the above information.

Milestones

1st year - Milestone 1 and 2 above
2nd year - Milestone 3 above
3rd year - Milestone 4 and 5 above
4th year - Milestone 6 above
5th year - Milestone 7 above

Technology Time Frame

Ongoing

Project Unit Priority: A

Severity: A
Extent: A
Need: A
Urgency: A
Readiness: B

Estimated Program Unit Costs

\$1,000,000 to \$2,000,000 per year

PROGRAM UNIT TITLE: Energy/Health/Environmental and Societal
Information Collection, Management and
Dissemination Code Ie-9

Technology: Fission (and other)

King-Muir Category: Integrated Assessment

Scope

This program involves the collection, management, and dissemination of energy related information. Understanding energy development and its associated environmental health effects necessitates the aquisition and management of very large quantities of data and information from a wide range of sources and involving a large number of disciplines. These data are applied for the analysis of a broad spectrum of issues involving, for example, future projections of energy needs, cost/benefit/risk assessment, trade-off studies, and policy alternative evaluation.

Technology Time Frame

Ongoing and expanding

Program Unit Priority: A

Severity of Program	A
Size of Affected Group	A
Need for Knowledge	A
Urgency for Knowledge	A

Estimated Program Unit Costs

\$2,500,000 to \$3,500,000 per year

PROGRAM UNIT TITLE: Identification and Assessment of Environmental Criteria and Institutional Strategies for Plant Decommissioning and Deposition

Code Ia-10

Technology: Fission

King-Muir Category: Integrated Assessment

Scope

It is anticipated that fission power reactors numbering in the hundreds, plus associated fuel cycle support facilities, will be operating in the U.S. by year 2000. With an estimated operating life of 25 to 40 years and the possibility of earlier obsolescence due to technological development, decommissioning and disposition (D&D) of retired facilities will become a problem of substantial health, technical, economic, and social magnitude within 50 years. Identification of acceptable D&D strategies and criteria will be required at a much earlier date, however, to ensure availability of adequate funding for disposition activities and to incorporate "disposability" into plant design where desirable. The objectives of this research are to establish health and environmental criteria for plant D&D, to identify costs associated, and to identify and assess institutional and legal requirements for implementing D&D.

Technology Time Frame

Widespread construction of fission fuel cycle components eventually requiring decommissioning and disposal is underway.

Program Unit Priority: B

Severity: B Based on assessment of conditions of existing retired nuclear facilities, decommissioning and disposal of retired commercial facilities will be a complex and costly process.

- Extent: B Existing commercial fission fuel cycle facilities will eventually require decommissioning and decontamination, although design lifetimes may vary.
- Need: B The proposed research should provide useful and comprehensive information in an area for which information is presently very incomplete.
- Urgency: C Methods to be developed by this research are needed within the near term (~5 years) in order to establish D&D funding schemes and to incorporate "disposability" into contemporary plant design.

Estimated Program Unit Costs

\$200,000 to \$400,000 per year

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