

40  
0-18-8.2  
⑧

① I-5946

Dr. 9/8

DOE/NE-0041

U.S. Department of Energy  
Assistant Secretary for  
Nuclear Energy  
Deputy Assistant Secretary for Nuclear  
Reactor Programs

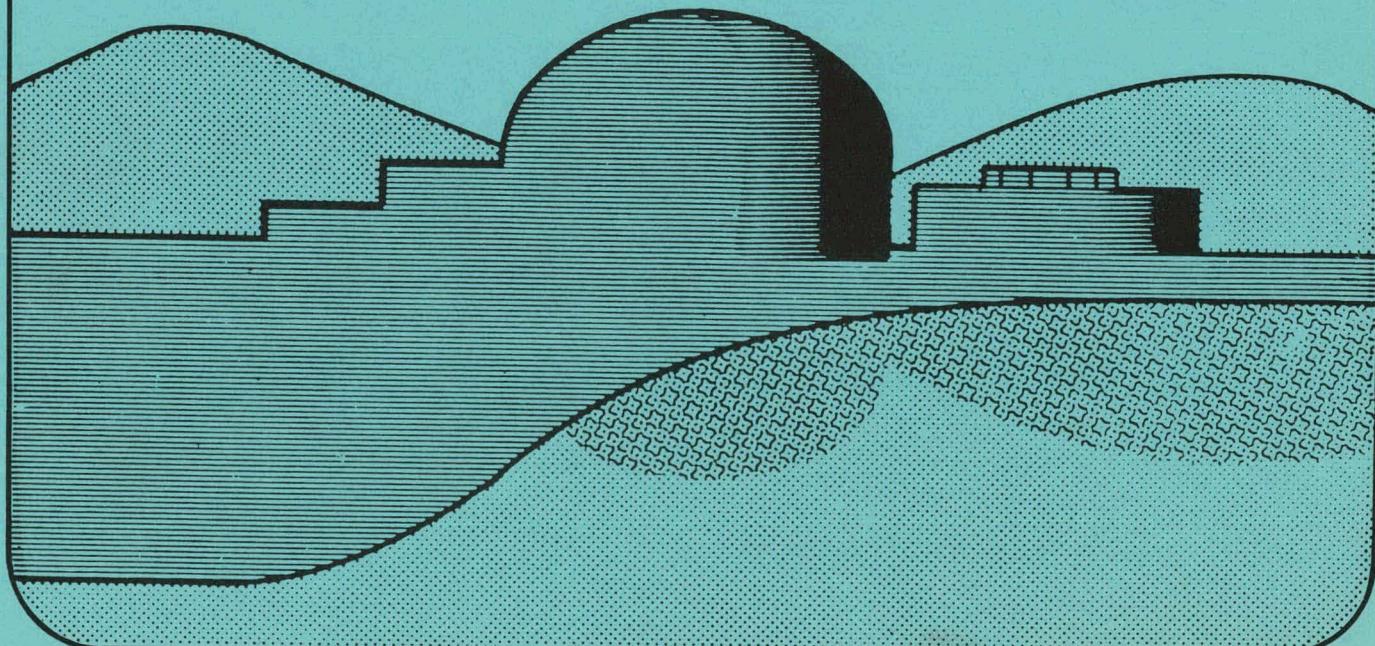
July 1982



## Program Summary for the Civilian Reactor Development Program

DO NOT MICROFILM  
COVER

MASTER



## **DISCLAIMER**

**This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.**

## **DISCLAIMER**

**Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.**

This report has been reproduced directly from the best available copy.

Available from the National Technical Information Service, U. S. Department of Commerce, Springfield, Virginia 22161.

Price: Printed Copy A04  
Microfiche A01

Codes are used for pricing all publications. The code is determined by the number of pages in the publication. Information pertaining to the pricing codes can be found in the current issues of the following publications, which are generally available in most libraries: *Energy Research Abstracts*, (ERA); *Government Reports Announcements and Index* (GRA and I); *Scientific and Technical Abstract Reports* (STAR); and publication, NTIS-PR-360 available from (NTIS) at the above address.

DOE/NE-0041

**U.S. Department of Energy**  
Assistant Secretary for  
Nuclear Energy  
Deputy Assistant Secretary for Nuclear  
Reactor Programs  
Washington DC 20545

July 1982

Dist Category UC 2, 22,23  
77,78,79,79i,80



## **Program Summary for the Civilian Reactor Development Program**

DOE/NE--0041

DE83 001005

### **DISCLAIMER**

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

**MASTER**

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

*Rey*

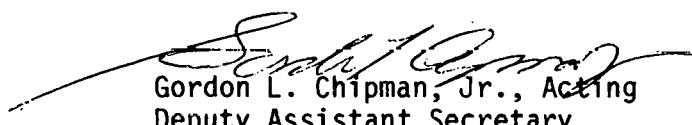


**Department of Energy  
Washington, D.C. 20545**

**PREFACE**

This document was prepared by the Office of the Deputy Assistant Secretary for Breeder Reactor Programs, Department of Energy. It presents a summary of the fission energy program implementation plan as of June 1982 and is based on the Reagan Administration's policies as set forth in Congressional testimony and budget narratives. As this report was going to press, the Office of the Assistant Secretary for Nuclear Energy was reorganized. Hence, the organizational structures shown are no longer correct.

Section I provides a statement of the overall program objectives and a general program overview. Section II discusses the objectives, implementation strategy, accomplishments, and funding and schedules of the civilian fission reactor power development programs. Section III details the program management, as well as the structure and methods used for program control. The Appendixes provide background information on fission energy and the civilian reactor development program.



Gordon L. Chipman, Jr., Acting  
Deputy Assistant Secretary  
for Breeder Reactor Programs  
Office of Nuclear Energy

## TABLE OF CONTENTS

	Page
<b>I. PROGRAM OVERVIEW</b> .....	1
<b>II. PROGRAM DESCRIPTION</b> .....	4
A. Converter Reactor Systems .....	4
1. Light Water Reactor Systems .....	5
2. Three Mile Island Activities .....	8
3. High Temperature Reactor .....	11
B. Breeder Reactor Systems .....	13
1.0 Liquid Metal Fast Breeder Reactor .....	13
1.1 Plant Projects .....	14
1.2 Breeder Technology Program .....	15
1.3 Test Facilities .....	18
2.0 Water Cooled Breeder Reactor .....	23
C. Special Nuclear Evaluations and Systems .....	24
1. Space and Terrestrial Applications .....	24
2. Advanced Technology and Systems Assessments .....	28
<b>III. PROGRAM MANAGEMENT</b> .....	30
A. Management Philosophy .....	30
B. Organization .....	30
C. Program Assurance, Safeguards and Security .....	34

## APPENDIXES

A. Program Participants and Field Distribution .....	36
B. Program Definitions .....	40
C. Program Acronyms and Letter Designations .....	47
D. Program Supporting Legislation .....	57

# PROGRAM SUMMARY FOR THE CIVILIAN REACTOR DEVELOPMENT PROGRAM

## I. PROGRAM OVERVIEW

This Civilian Reactor Development Program document has the prime purpose of summarizing the technical programs supported by the FY 1983 budget request. This section provides a statement of the overall program objectives and a general program overview. Section II presents the technical programs in a format intended to show logical technical interrelationships, and does not necessarily follow the structure of the formal budget presentation. Section III presents the technical organization and management structure of the program.

Today nuclear energy provides about 12 percent of our country's total electrical supply. This year it is projected to become the second largest generator of electricity, surpassed only by coal. By 1990, as additional plants in the pipeline begin operation, its contribution will increase to between 22 and 25 percent. The nuclear option is capable of providing hundreds of years of economic electrical power, independent of foreign energy sources, while allowing us to conserve our fossil fuel for other critical applications. Achievement of this goal is predicated on the establishment of a fully integrated nuclear fuel cycle and power generation system. The essential elements of this system include (1) a smoothly functioning light water reactor (LWR) industry; (2) a completed fuel cycle including effective reprocessing and waste management systems; and (3) the timely introduction of the breeder reactor. The Civilian Reactor Development Program is concerned primarily with the first and third of these elements.

On October 8th of last year, President Reagan announced a revised nuclear policy that recognizes both the potential of nuclear energy and the impediments currently restricting its full use. To remove these barriers and allow nuclear power to compete, free of constraint, in the marketplace, several major policy initiatives were announced. They include regulatory and licensing reform and resumption of breeder development, including completion of the Clinch River Breeder Reactor (CRBR). These directives provide the major thrust for the Civilian Reactor Development Program.

Highlights of the major areas comprising the Civilian Reactor Development Program are as follows:

### CONVERTER REACTOR SYSTEMS

The overall objective of the Converter Reactor Systems Program is to enhance the utilization of domestic

energy resources through the use of light water reactor technology already in widespread use. The principal ongoing programs in this area are the safety and fuel performance of LWRs and the cleanup and other remedial actions required at the Three Mile Island (TMI) plant.

**LWR Safety.** The objective of the LWR Safety program is to formulate, coordinate, and conduct R&D to improve reactor safety and to support revitalization of the LWR energy option. To achieve this objective, the Department will coordinate the development and implementation of a DOE/NRC/Industry cooperative program that (1) defines the institutional and technological issues of priority in achieving these goals; and (2) identifies the efforts required to resolve these issues.

**LWR Extended Burnup.** The principal purpose in extending the burnup of LWR fuel is to reduce the generation rate of spent fuel and thereby reduce spent fuel storage and reprocessing requirements. Extended burnup can improve fuel cycle economics and the utilization of uranium resources. In FY 1983 the subprogram will be focused to include proving through demonstration the performance of a single extended burnup fuel design up to established goal burnups, obtaining licensing data to support that and other extended burnup designs, and developing other necessary supporting technology.

**Three Mile Island.** The overall goal of the Department's Three Mile Island activities has been to develop and improve measures for enhancing safety and reliability of nuclear powerplants and to improve the capability to decontaminate nuclear powerplants. To accomplish this goal, DOE is pursuing a program of carefully examining and evaluating the TMI-2 accident and the response of the nuclear powerplant components and systems to accidents. In consonance with the Administration's policy of placing responsibility for commercial nuclear power activities in the private sector, the Department's TMI program is limited to necessary research and development only.

The TMI activity has two major program elements: (1) a TMI Reactor Evaluation and Waste Immobilization Program that was initiated in FY 1982, and (2) a TMI Data Acquisition Program that began in FY 1980.

### BREEDER REACTOR SYSTEMS

This Nation needs a breeder reactor industrial capability to meet future demands for electricity. Although future electric growth will likely be lower than the high rates

experienced before the 1973 oil embargo, the 2.5 to 3.5 percent electric growth rates typically projected for the long term will require a doubling of the current installed capacity of 640 GWe within the next 20 to 30 years. The breeder can be the most economical technology for supplying electricity when it reaches technical maturity, and it could become a valuable source of foreign trade benefits. Additionally, the breeder reactor can provide less environmental impact than current generation light water reactors (LWRs).

Development of the fast breeder reactor to meet long-term energy needs has been the ultimate goal of the Federal civilian nuclear program for the past two decades. However, there are nearer-term incentives because continued breeder development is also essential to future expansion of the current LWR nuclear system since it demonstrates the Government's commitment to nuclear energy, it will close the nuclear fuel cycle, and it will cap the cost of nuclear power by eliminating the need to mine uranium over the long term.

A Federal role is necessary because the costs and risks of development are higher than the private sector can bear, and the benefits are capturable only over a long period of time. The Nation's breeder program has benefited from over 30 years of successful research, development, and demonstration (RD&D) support. The achievements are part of a natural progression in size and complexity that will lead to decisions by the private sector on breeder industrialization and deployment.

The Federal role in the future of breeder reactors is to conduct the necessary research and development such that the potential benefits of the breeder can be captured by private industry at a venture risk level that is consistent with acceptable business endeavors. The responsibility for industrialization and deployment will rest with the private sector.

For more than two decades, the major breeder reactor research and development activities have concentrated upon the liquid metal fast breeder reactor (LMFBR). In 1965, a smaller program was established to examine the feasibility of a water cooled breeder.

**LMFBR Program.** The current LMFBR program began in the 1960's, and the goals of the program became more highly focused in the mid 1970's when the United States adopted the policy of developing several long-term options for providing energy from inexhaustible and renewable energy sources. Effort was concentrated on three technologies: fusion, solar electric systems, and the fast breeder reactor. Ninety-five percent of our total energy still comes from scarce and depletable resources; hence the need to develop inexhaustible technologies is even more vital today, nearly a decade later. While other inexhaustible electrical energy sources, such as fusion and solar electric, may become available to compete on an economic, technical, and commercial basis with the breeder, the advanced state of fast breeder technology relative to fusion

and solar make it the surest of the inexhaustible supply options.

The goal of the LMFBR program is to ensure that this long-term electricity supply option is available on a prudent time scale. To accomplish this goal, the U.S. LMFBR program will develop the technical, engineering, safety, environmental, economic, licensing, and industrial data base required to transfer design, construction, and operation capabilities of future LMFBR powerplants to the private sector. The program consists of three broad elements: (1) design, construction, and operation of developmental plants; (2) a supporting base technology program, including test facility construction and operation; and (3) a supporting fuel cycle program. The first two elements are closely integrated and are directed at breeder powerplant development, while the fuel cycle effort will provide the basis for integrating breeder reactors into an existing and expanded nuclear energy economy.

To bring this technology to a point of acceptable commercial risk requires that it be advanced and confirmed by constructing and operating plants in increasingly larger sizes. This approach was followed by the Atomic Energy Commission in cooperation with the electric utilities to achieve the successful commercialization of LWRs. This approach is also being used by the major foreign breeder development programs. The LMFBR program has successfully constructed and operated the 20 MWe EBR-II and the 133 MWe equivalent Fast Flux Test Facility (FFTF).

DOE is proceeding with the 375 MWe Clinch River Breeder Reactor Plant (CRBRP), and is entering a new phase in which Government is encouraging and supporting construction of a large-scale prototype breeder plant. The pre-commercial plant will be principally funded by the private sector.

The deployment of any new technology is a lengthy process; and timely development of all inexhaustibles is necessary so that their technical and economic viability can be demonstrated so that they can effectively compete and displace scarce energy resources in the marketplace. While we cannot say with certainty exactly when the breeder will be needed anymore than we can say when solar electric systems and fusion will be needed, the strategy of the current program is to continue development of fast breeder technology so that it will be available for commercial development by the private sector. This approach ensures the most effective use of resources and positions the technology so that it will be available early next century.

**Water Cooled Breeder.** The goal of this program is to develop technology for significantly improving the efficiency of nuclear fuel resource utilization by water cooled reactors. Operation of the Shippingport Atomic Power Station using a light water breeder reactor (LWBR) core will continue through the life of the present core. Following this period of operation, the performance of the core and the breeding ratio will be assessed.

## SPECIAL NUCLEAR EVALUATIONS AND SYSTEMS

**Space and Terrestrial Applications.** Work is continuing on the development of viable power systems for space missions to be launched in the mid-1980's, and on the demonstration of beneficial uses of radioisotopes in various terrestrial applications.

## FUNDING

Funding for the civilian reactor development program for FY 1981 and FY 1982 and the request for FY 1983 is shown in the following table, arranged in the order of presentation in this document.

### CIVILIAN REACTOR DEVELOPMENT PROGRAM

		<i>Budget Authority (Dollars in thousands)</i>		
		<i>FY 1981 OBLIGATIONS</i>	<i>FY 1982 APPROPRIATION</i>	<i>FY 1983 REQUEST</i>
				<i>INCREASE (DECREASE)</i>
<b>CONVERTER REACTOR SYSTEMS</b>				
Light Water Reactor Systems:				
Operating expenses .....	32,697	21,600 <sup>a</sup>	4,000	
Capital equipment .....	1,000	523	0	
Subtotal .....	33,697	22,123 <sup>a</sup>	4,000	(18,123)
Three Mile Island Activities:				
Operating expenses .....	5,800	23,750 <sup>b</sup>	21,000	
Capital equipment .....	1,000	7,000 <sup>c</sup>	6,000	
Subtotal .....	6,800	30,750	27,000	(3,750)
High Temperature Reactor:				
Operating expenses .....	36,465	33,500	0	
Capital equipment .....	2,004	1,800	0	
Subtotal .....	38,469	35,300	0	(35,300)
<b>BREEDER REACTOR SYSTEMS</b>				
Liquid Metal Fast Breeder Reactor:				
Operating expenses .....	501,167	499,422 <sup>d</sup>	486,934	
Capital equipment .....	9,630	21,374	17,900	
Construction .....	70,697	62,068	18,300	
Subtotal .....	581,494	582,864	523,134	(59,730)
Water Cooled Breeder:				
Operating expenses .....	58,000	50,500 <sup>e</sup>	41,800	
Capital equipment .....	1,200	1,000	200	
Subtotal .....	59,200	51,500	42,000	(9,500)
<b>SPECIAL NUCLEAR EVALUATIONS AND SYSTEMS:</b>				
Space and Terrestrial Applications:				
Operating expenses .....	35,100	33,600	27,500	
Capital equipment .....	2,600	2,800	1,800	
Subtotal .....	37,700	36,400	29,300	(7,100)
Operating expenses .....	1,800	0	0	0
Subtotal .....	1,800	0	0	0

<sup>a</sup> Reflects \$600,000 reduction transferred to Solar and Renewables programs.

<sup>b</sup> Reflects a \$1,000,000 reduction in operating funds in accordance with Fiske memo, dated 3/3/82, to cover severe reductions in Solar and Renewables Programs.

<sup>c</sup> Reflects a \$1,000,000 reduction in capital equipment funds in accordance with Fiske memo, dated 3/5/82, to cover critical funding shortage in the Departmental Administration account.

<sup>d</sup> Reflects reduction of \$2,200,000 for reprogramming to Solar and Departmental Administration.

<sup>e</sup> Reflects reduction of \$500,000 for reprogramming to Solar.

## II. PROGRAM DESCRIPTION

This section provides the objectives and description of each major element of the nuclear reactor program; discusses program implementation and strategy; and presents accomplishments, milestones and budget resources.

### A. CONVERTER REACTOR SYSTEMS

The current generation of commercial power reactors in the United States are converter reactor systems which utilize low-enrichment uranium oxide fuel and are light water moderated and cooled. Converter reactors are those characterized by a fuel conversion ratio less than one; i.e., fissile material is consumed by the reactor faster than it is generated. This type of reactor currently produces almost all of the nuclear energy commercially available in the United States. A more detailed description of converter reactors, as well as all types of fission energy systems, is given in Appendix B.

This chapter describes the DOE programs concerned with converter reactor systems and their continued use as a source of safe, economic, and reliable nuclear power.

#### Overview

**Background.** In the early 1950s, the existence of the light water reactor (LWR) technology developed through research work conducted in the naval propulsion reactor program, the uranium enrichment capacity built during World War II, and a large quantity of indigenous uranium resources led quite logically to the development of light water reactors as electric power producers. The resulting commercialization of nuclear power using LWRs was promoted by Federal policies, as exemplified by the Atomic Energy Act of 1954, which encouraged the peaceful uses of atomic energy by the private sector. By the early 1970s, these policies and the economic advantages and reliability of nuclear plants had resulted in a selfsufficient industry capable of producing a number of commercial nuclear powerplants each year.

**Funding.** The following table shows the operating funding levels by program element for the FY 1981 through FY 1983 period.

#### CONVERTER REACTOR SYSTEMS

PROGRAM ELEMENT	BUDGET AUTHORITY (DOLLARS IN THOUSANDS)			
	OBLIGATIONS FY 1981	APPROPRIATIONS FY 1982	REQUEST FY 1983	INCREASE (DECREASE)
LIGHT WATER REACTORS	32,697	21,600	4,000	(17,600)
THREE MILE ISLAND	5,800	23,750	21,000	(2,750)
HIGH TEMPERATURE REACTOR	36,465	33,500	0	(33,500)
TOTAL	74,962	78,850	25,000	(53,850)

**Objective.** The principal objective of the Converter Reactor Program is to improve the efficient and safe use of domestic nuclear energy resources through improvements in LWR technology and by contributing to the resolution of the nuclear industry's institutional problems.

**Strategy.** The major programs being implemented are the Light Water Reactor Systems program and Three-Mile Island (TMI) activities. The High Temperature Reactor (HTR) program has also been included in this program area through FY 1982, but is proposed for cancellation in FY 1983. In the LWR and TMI programs, improved technologies are being developed, particularly in the safety area. The results of these efforts are expected to enhance the attractiveness to utilities of increasing the deployment of conventional nuclear power.

**Management.** The DOE Headquarters organizations responsible for directing these programs are shown in the upper level work breakdown structure (WBS) and Department of Energy (DOE) responsibility matrix of Figure 1.

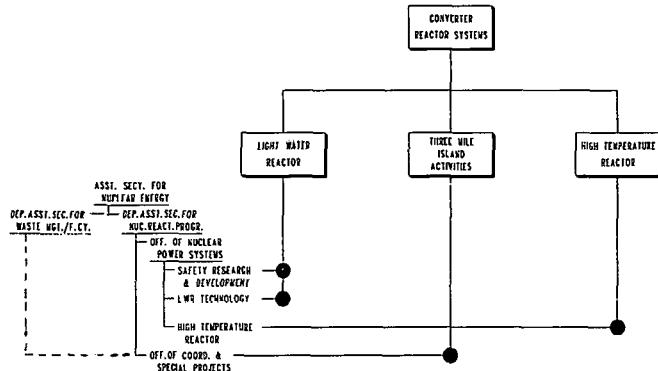


Figure 1. Converter Reactor Systems upper level work breakdown structure and DOE responsibility matrix.

# 1. Light Water Reactor Systems

Since FY 1976, the Light Water Reactor (LWR) program has been concerned with developing and demonstrating advances in the technology as a means for preserving and enhancing the LWR option in the United States. The current emphasis of the LWR Systems Program is to support revitalization of the LWR energy option by contributing to the resolution of the nuclear industry's institutional problems. When electric demand dictates, additional nuclear capacity will be sought provided that institutional and financial obstacles are overcome. These obstacles are difficulties in capital formation by utilities, instability of regulatory process, and public perception of nuclear power. There is no intrinsic reason why it should take between 10 and 15 years to bring nuclear plants into operation in the United States, when plants in France and Japan can be licensed and constructed in about 5-7 years. One correctable reason this condition exists is the uncertainty that a utility must face throughout the entire regulatory process, including the construction period and even after plant operation begins. The utilities and their investors cannot cope with the resulting uncertainty and significant costs over a 10-15 year time period. In addition, it impacts the public's confidence and perceptions of the ability of industry to provide reliable, economic, and safe nuclear power. The Vice President's Task Force on Regulatory Reform offers an opportunity to correct much of this problem. The strategy for DOE is to coordinate and participate in the development and implementation of a DOE/NRC/Industry cooperative program that identifies the institutional and technological issues that must be resolved and defines the efforts required to resolve these issues.

The LWR program is comprised of three elements: The LWR Safety Program, LWR Extended Burnup Program, and the Radiation Dose Reduction Program.

## a. Light Water Reactor Safety Program

**Objectives.** The objectives of the LWR Safety Program are to encourage development of a technical basis to support LWR industry institutional improvements, in particular, nuclear regulatory reform; and, consistent with requirements of the Nuclear Safety Research, Development, and Demonstration Act of 1980 (Public Law 96-567), to develop a technical basis to effect improvements in the ability of LWR industry to produce reliable, economical, and safe nuclear power.

**Description.** To achieve the above objective, the Department will coordinate the development and implementation of a DOE/NRC/Industry cooperative program that:

- Defines the institutional and technological issues of priority in achieving these goals; and
- Identifies the efforts required to resolve these issues.

A key effort in this program is the development of a systematic and integrated approach to LWR safety.

The program is divided into two phases--a program definition phase and a program implementation phase.

Program needs and priorities are being defined by utilizing working groups composed of representatives from DOE, NRC, industry, and national laboratories to assist the DOE in both the program definition and program implementation phases. DOE has convened eight of these working groups and their membership and schedule of activities have been provided to Congress in our response to Public Law 96-567. Current activities are indicated in the accomplishments section.

**Implementation/Strategy.** The ultimate responsibility for safe economic generation of nuclear power lies with the utility owners of nuclear powerplants. In some instances because of the institutional structure, the respective roles of the utilities and regulators in assuring the safety of nuclear powerplants have become unclear and the utilities have not been able to discharge this responsibility in an optimum fashion. Efforts to modify nuclear power institutions to improve the ability of the nuclear industry to produce safe, economical power are focused on reestablishing and clearly delineating the proper authorities and responsibilities of the industry and regulatory bodies. To accomplish this, a systematic integrated approach to LWR safety is being developed, demonstrated, and implemented.

In response to Public Law 96-567, and to meet the objectives of the program, the Department will coordinate this comprehensive LWR Safety R&D Program with industry, NRC, national laboratories, other Government bodies, and foreign programs.

**Accomplishments.** Major accomplishments in FY 1981 were:

- Transfer of advanced analytic safety technology to industry through cooperative projects in the areas of risk/cost/benefit methodology, task analyses of reactor operations, nuclear plant reliability, and safety parameter display system formats.
- Development of an approach for modifying the LWR nuclear plant fission product source term vital in plant siting and emergency preparedness.

Major accomplishments in FY 1982 include the submittal by the Department to the Congress of the three specific studies required by Public Law 96-567:

- A Comprehensive Program Management Plan
- A study of the need and feasibility of a National Reactor Engineering Simulator
- A study of the sufficiency of U.S. efforts to provide specially trained operators for nuclear plants.

The completed or planned FY 1982 accomplishments also include:

- Successful completion of the containment sump emergency performance experimental program at Aluden Research Laboratory to provide a definitive data base to remove this longstanding NRC generic safety issue from the "unresolved safety issue" list.

- Complete development of a fire hazards analysis technique that will provide an optimum approach to protect essential nuclear powerplant safety systems from fire hazards.
- Complete development of a Probabilistic Risk Assessment Guidebook to provide guidance for performing risk analyses. This effort is jointly sponsored with the Nuclear Regulatory Commission, the Institute of Electrical and Electronics Engineers, and the American Nuclear Society.
- Complete the evaluation of the Boiling Water Reactor Safety Parameter Display System with the utility owners group on a powerplant simulator to assess the actual advantages of incorporating this system in the control room in response to a proposed NRC rule.
- Complete the demonstration of a common cause failure analysis technique through a cooperative program with the Duke Power Company and Idaho National Engineering Laboratory.
- In cooperation with the Institute of Nuclear Power Operations (INPO), conducted an overall assessment of utility manpower and training and an analysis of operator skill and job requirements. In addition, assisted INPO by developing an operating procedure evaluation handbook in FY 1982.

The LWR Safety Program's planned activities in FY 1983 will:

- Continue efforts to examine and take actions to ameliorate regulatory impacts, such as determining if sufficient technical basis exists in data already available from Government sponsored programs to warrant relaxation of the overly conservative assumptions in 10 CFR 50 Appendix K.
- Coordinate and maintain the comprehensive LWR Safety Program plan as directed in Public Law 96-567.
- Continue R&D efforts to simplify plant control and operations in order to provide more effective management of off-normal events.

## b. LWR Extended Burnup

**Objectives.** The objective of the Extended Burnup program is to develop and demonstrate the technology to extend the burnup of LWR fuel. Extended burnup serves to reduce the volume of spent fuel generated by LWR's, which relieves the pressure on the back end of the LWR fuel cycle.

**Description.** The Extended Burnup program is an element of the former Uranium Utilization program under which major projects involving all 5 domestic fuel vendors were initiated with 11 U.S. utilities for irradiation demonstrations in 11 power reactors. In FY 1982 the program was narrowed to develop and demonstrate extended bur-

nup for various fuel designs including advanced designs capable of achieving the program target values or higher. In FY 1983, to achieve the program's objective at minimum cost, the Extended Burnup program will continue the demonstration of only one fuel design, and work on all other designs will be closed out. Several technology development projects generating basic generic data on extended burnup phenomena needed for design and licensing will also be continued at a low funding level. With the completion of these projects, much of the fuel performance and design information required to permit major increases in burnup from today's discharge level should be obtained. Burnup increases to the program target levels of 50,000 MWd/Mt for pressurized water reactors (PWR's) and 45,000 MWd/Mt for boiling water reactors (BWR's) will result in an annual reduction in spent fuel of 40 percent, a reduction in nuclear fuel cycle cost of over 10 percent, a reduction in near-term uranium requirements of 15 percent, and a reduction in separative work unit requirements of 2 percent.

**Implementation/Strategy.** The approach is to demonstrate extended burnup for one fuel design, develop the basic data needed for design and licensing, and rely on competitive market forces for industry-wide implementation.

**Accomplishments.** Significant accomplishments that have been made prior to FY 1983 include the following:

- Four lead test assemblies with an advanced high burnup fuel design were placed under irradiation in Arkansas Power and Light Company's Arkansas Nuclear One reactor.
- Following irradiation of four lead test assemblies, core-wide implementation of axial blankets was initiated in Sacramento Municipal Utility District's Rancho Seco reactor.
- Following irradiation of four lead test assemblies and completion of test reactor irradiations, a large-scale demonstration of 144 assemblies with cladding resistant to pellet-cladding interaction failures was initiated in Commonwealth Edison Company's Quad-Cities Station, Unit 2 reactor.
- Two assemblies of current design fuel with burnups in excess of 40,000 MWd/Mt were continuing irradiation to burnups in excess of 50,000 MWd/Mt, one in Duke Power Company's Oconee Nuclear Station Unit 1 reactor and one in Omaha Public Power District's Ft. Calhoun Station reactor.
- The irradiation of two assemblies of current design fuel to 45,000 MWd/Mt was completed in Northern States Power Company's Monticello reactor.
- The irradiation of advanced fuel rod designs for high burnup was initiated in Arkansas Power and Light Company's Unit 2 reactor.
- Irradiation was completed on 59 fuel rods to high burnup and irradiation continued on 359 fuel rods to

demonstrate pellet-cladding-interaction remedies in Consumers Power Company's Big Rock Point reactor.

- Irradiation of one assembly to 42,500 MWd/Mt was completed in Virginia Electric and Power Company's Surry 2 reactor.

The planned accomplishments for the Extended Burnup program in FY 1983 and beyond include the following:

- Select the single extended burnup fuel design to be proved out under Department sponsorship and initiate the contract actions (principally cancellations of similar work on other designs) to implement this selection.
- Continue to prove the performance of a single extended burnup fuel design up to established goal burnups.
- Continue to obtain generic design and licensing data and other necessary supporting technology.
- Complete four projects in the areas of fission gas release, PCI remedies, fuel storage, and fuel shipping.

### **c. Radiation Dose Reduction Technology**

**Objective.** The objective of this program element has been to develop and demonstrate technology to reduce the occupational radiation exposure to LWR plant personnel.

**Description.** The broad approach to reducing radiation exposures has two major thrusts: (1) to develop and demonstrate techniques to reduce the radiation sources, thereby reducing the radiation fields where the work is performed, and (2) to develop and demonstrate techniques that reduce the time or need for a worker to be in the radiation field. By reducing the sources of radiation and/or time spent in radiation fields, the continuing increases in total LWR radiation exposures and the resulting adverse impact on availability of sufficient manpower to operate and maintain these plants can be arrested.

#### **(1) Reduction of Radiation Source Level**

Radiation source reduction has the objective of preventing accumulation of radioactive contaminants. This program subelement involves work to help eliminate the physical source of the problem—the radioactive material itself. This can be accomplished through material control, filtration, chemistry, and operational controls or decontamination.

In FY 1982, there were two projects in the chemical decontamination area. One involves the development and demonstration of a process for decontamination of the reactor vessel head. The other involves the demonstration of a thorough hard decontamination process for a defueled BWR to be applied at the Dresden-1 reactor. A feasibility study of dilute chemical processes that can be applied quickly, involve minimum waste disposal, do not involve removal of fuel, and use the primary coolant as part of the solvent has been completed.

#### **(2) Reduction of Time in Exposure Fields**

The major approach to reducing the time in exposure fields is the development of techniques to help eliminate and minimize the need for workers to go into radiation zones to perform special inspections or repair unexpected breakdowns. Another approach to reducing the time in exposure fields is to reduce incidents of failed components or improve the operational and maintenance practices.

Remote surveillance and diagnostics efforts are being completed in two areas: (a) on-line monitoring of whole systems to help plan preventative maintenance, and (b) remote monitoring of particular problem components. Projects were conducted on acoustic emission monitoring of BWR components with Philadelphia Electric Company, rotating machinery monitoring with Mississippi Power and Light Company, and reactor coolant pump monitoring with Toledo Edison Company.

Under the strategy to limit radiation exposure by reducing the incidence of component failures, efforts will be completed to reduce flow induced vibration failures, eliminate BWR piping stress corrosion cracking, and prevent PWR steam generator tube failures. The single activity in improvement to operational and maintenance practices has been the development and demonstration of an advanced technique for managing and controlling radiation exposure during outages.

**Implementation/Strategy.** In FY 1982, the funding was reduced to a level that allows the orderly closeout of the Dose Reduction program. Existing projects that were in place at the end of FY 1981 will be completed with FY 1982 and prior-year budget authority. This strategy permits key results to be salvaged, most of the past investment to be protected, and many of the national benefits of the program to be attained, consistent with a rapid but still feasible transition of key projects to private sector sponsorship.

**Accomplishments.** In FY 1982, the Dose Reduction program began an orderly wrap-up and no new projects were initiated. Of the eight remaining projects, four were completed in FY 1982 and the other projects will be completed by the end of FY 1985.

The significant accomplishments for FY 1982 are the following:

- Issuance of industry-wide design guides on reducing flow induced vibration failures in plants.
- Issuance of an NRC waiver for substitution of remote acoustic emission monitoring for manual inservice inspection of piping at Peach Bottom-3.
- Completion of safety and environmental review by the NRC staff in preparation for a strong chemical decontamination of the defueled Dresden-1 reactor.
- Technical and economical feasibility studies of on-line and off-line methods for preventing PWR steam generator tube failures.
- Demonstration at Dresden-2 of a process for preventing BWR piping stress corrosion cracking.

**Resources.** The following table shows the operating funding levels by program element for the FY 1981 through FY 1983 period.

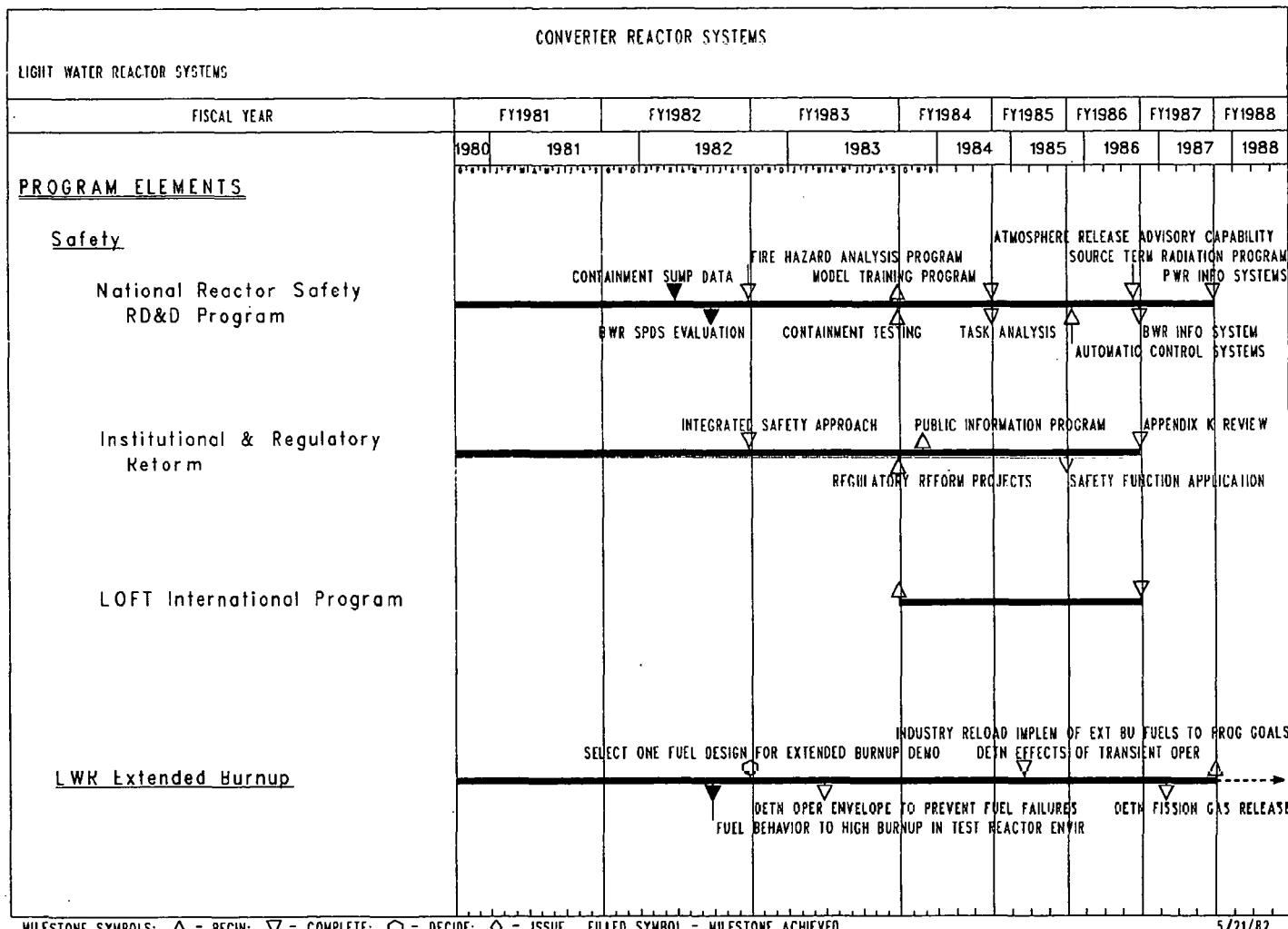
**LIGHT WATER REACTOR SYSTEMS**

PROGRAM ELEMENT	BUDGET AUTHORITY (DOLLARS IN THOUSANDS)			
	OBLIGATIONS FY 1981	APPROPRIATIONS FY 1982	REQUEST FY 1983	INCREASE (DECREASE)
SAFETY	7,398	10,300 <sup>a</sup>	1,000	(9,300)
EXTENDED BURNUP	16,595	11,000	3,000	(8,000)
RADIATION DOSE REDUCTION <sup>b</sup>	8,704	300	0	(300)
<b>TOTAL</b>	<b>32,697</b>	<b>21,600<sup>a</sup></b>	<b>4,000</b>	<b>(17,600)</b>

<sup>a</sup> Reflects \$600,000 reduction transferred to Solar and Renewable Resources.

<sup>b</sup> In prior years this program element was designated Radiation Dose Reduction/Productivity.

**Milestones.** Major milestones for the Light Water Reactor Systems program are given in the following chart.



## 2. Three Mile Island Activities

The Three Mile Island (TMI) Unit 2 accident of March 28, 1979, was and is of great concern to the electric industry, its customers, regulatory and other Government agencies, and the country as a whole. While the accident resulted in very limited radiation exposure to the population

surrounding the powerplant (the Kemeny Commission concluded that the average radiation dose to a person living within 5 miles of TMI was about 10 percent or less than the annual background radiation), extensive damage resulted to the plant itself, with high radiation contamination within the reactor and supporting systems and facilities. The TMI-2 accident presents unique opportunities to ac-

cumulate information for the enhancement of nuclear powerplant safety and reliability of generic benefit to nuclear power technology. The environmental conditions within the containment and the reactor and auxiliary systems pose technically challenging decontamination and radioactive waste management situations. These circumstances represent opportunities for state-of-the-art advancement not available through normal research, development, and test programs. Consequently, the program should obtain significant information to result in the general improvement of light water reactor plant safety, reliability, regulation, and operation.

**Objectives.** The overall objective of the TMI program is to develop and improve measures for enhancing the safety and reliability of nuclear powerplants, and to improve the capability to decontaminate civilian nuclear powerplants.

The DOE program has two major elements:

(1) TMI Waste Immobilization and Reactor Evaluation (WIRE) Program—The objectives of this program are: (1) to conduct research and development on immobilization of abnormal reactor waste products, and (2) to examine the TMI-2 reactor and core components and to conduct research and development associated with the reactor defueling to provide data for evaluating licensing criteria and requirements, analyzing causes and consequences of accidents, and improving the reliability of the design and operation of LWR's.

(2) TMI Data Acquisition Program (DAP)--The objective of this program is to obtain important research and development data that are of generic value to the safety of light water reactors.

**Description.** The Department of Energy is moving forward with a Three Mile Island research and development program to provide valuable data related to nuclear safety and cleanup technology. This program will also provide technical support to the General Public Utilities (GPU) Company for prompt, safe, and efficient fuel removal and waste handling operations.

The waste management and immobilization activities will initially be focused on an effort to demonstrate the feasibility of vitrifying zeolite ion exchange materials. The program will have demonstrated this feasibility in FY 1982. In addition, the majority of the Submerged Demineralizer System (SDS) liners and the EPICOR-II liners will be shipped from TMI to Government facilities for R&D purposes.

Beginning in FY 1983, this program will focus on other techniques for the treatment of abnormal wastes produced at TMI, including alternative immobilization concepts, confidence testing, and long term sample observation to provide a more extensive data base. The knowledge gained from this program will contribute substantially to the technology for processing and disposing of unique waste forms resulting from commercial nuclear powerplant abnormal operations and accidents.

The reactor evaluation activities include the examination, removal, and disposition of the reactor core and inter-

nals; the development of the special systems, equipment, facilities, and processes needed to accomplish these tasks; and the conduct of supporting onsite and offsite fuel examinations, tests, and evaluations. Through-the-head visual examination of accessible parts of the reactor upper internals and core will be accomplished prior to defueling.

In FY 1983, preparations will be made for reactor head and plenum removal and defueling. The purpose of this activity is to obtain data and information on the condition of the reactor core and other internal components, to conduct the development needed for a thorough examination, and to effectively complete the defueling in as low as practical radiation environment. In addition, it is planned to perform offsite examinations of the fuel and debris to characterize the accident effects.

The knowledge gained from this program will provide data required for evaluating present licensing criteria and requirements; developing future licensing criteria; assessing and developing computer models used to analyze the course and consequences of severe accidents and means to mitigate the effects of such accidents; and evaluating improvements to reactor design, operation, and maintenance.

In FY 1983, the data acquisition activities will continue, focusing on additional examination of electrical equipment, radionuclide analysis of samples removed from containment, and developing fuel and core examination techniques. The electrical equipment information will be used to upgrade qualification standards, regulatory guides, and operating and maintenance standards in order to improve operation of nuclear powerplants during transients. The data on radioactive samples will be valuable in assessing the existing models for fission product release that are used in nuclear powerplant licensing.

**Implementation/Strategy.** The TMI program is being implemented in accordance with a memorandum of understanding signed by DOE, NRC, EPRI, and GPU. The efforts of GPU (owners of TMI-2) are aimed primarily at plant cleanup and recovery. DOE has developed a program work scope which will obtain information that would not normally be obtained from the cleanup efforts. DOE's program is being conducted in a manner which avoids delaying the GPU cleanup schedule.

**WIRE**—In consonance with the Administration's policy of retaining responsibility for commercial nuclear power activities in the private sector, the Department's TMI program is limited to necessary research and development only. Responsibility for the costs of TMI cleanup remain with the owner, the GPU Company. In FY 1983, some of DOE's TMI research activities, such as in-situ inspection of the reactor core, are expected to have indirect benefits to GPU, and to offset some of their cleanup costs. Such activities will only be conducted if they offer the opportunity to obtain significant generic research information.

In accordance with a Memorandum of Understanding between the Department of Energy and the Nuclear Regulatory Commission, DOE will acquire radioactive waste from TMI for research and development, and for disposal.

In those cases where there is no research value associated with the waste acquired by DOE, the owner, GPU, has agreed to pay all costs associated with shipment and disposal.

DAP—DOE and EPRI are each sharing responsibility for portions of this R&D program scope. Specifically, DOE is funding data gathering, research and development, and information transfer in the following major areas: instrumentation and electrical equipment survivability; behavior of radioactive products; data system and specimen archiving; and offsite fuel debris examination. EPRI has similar responsibility for mechanical and structural component reliability, pressure boundary recharacterization, and decontamination and dose reduction associated with the primary coolant system.

**Accomplishments.** Major accomplishments prior to FY 1982 were:

- A Technical Integration Office was established at TMI to manage the Government's activities under DOE's direction with EG&G, Idaho, as lead contractor.
- A citizen's monitoring program was sponsored by DOE in cooperation with the State of Pennsylvania. This gave area residents the capability to monitor the levels of radioactivity that might be present in their respective communities prior to, during, and subsequent to venting of krypton from TMI-2.
- A joint computerized data bank was established with EPRI to store and transfer data obtained during this program.
- Many electrical instruments were tested in-situ. Selected instruments were removed for further testing to determine failure modes and effects. Generic design and installation changes were suggested.
- Solid, liquid, and gaseous radioactive samples were taken to determine the pathways for radionuclide release.
- The damage to the reactor building was assessed by

means of photographs, visual inspections, and radiation surveys.

- An EPICOR-II liner was shipped to Battelle Columbus Laboratory and examined.
- Vitrification was demonstrated as a feasible means of immobilizing the liners from the Submerged Deminer-alizer System.
- National and international seminars were presented to provide program status and results to the nuclear community.

The planned FY 1982 accomplishments include:

- A new initiative was mounted to examine the TMI-2 reactor and core components and to conduct R&D on immobilization of abnormal reactor waste products.
- A large-scale decontamination experiment was conducted.

The planned FY 1983 accomplishments include:

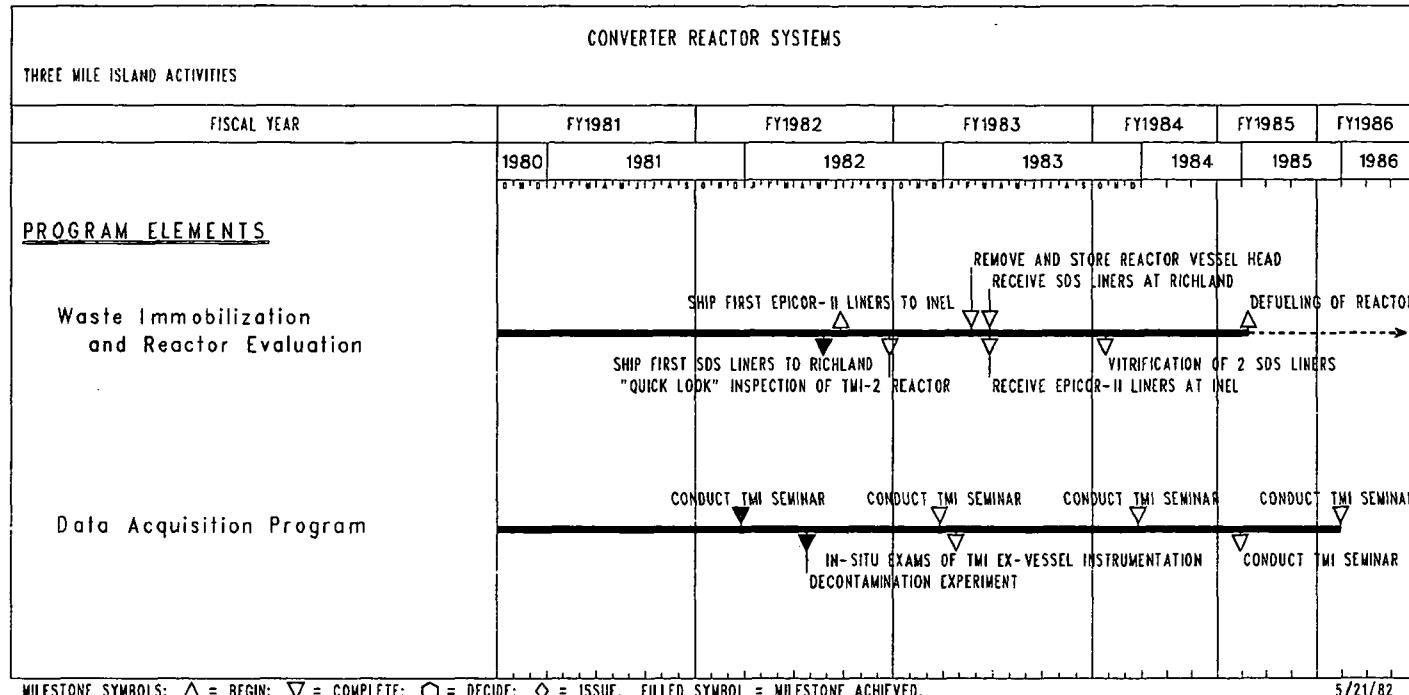
- A high integrity container for disposal of an EPICOR-II liner will be fabricated and tested.
- A program will be implemented to develop an understanding of the hydrogen burn that occurred in the TMI-2 containment.
- The reactor and core components will be examined in-situ. The reactor will be defueled and selected portions and components shipped to hot cells for further examination.

**Resources.** The following table shows the operating funding levels by program element for the FY 1981 through FY 1983 period.

#### TMI ACTIVITIES

PROGRAM ELEMENT	BUDGET AUTHORITY (DOLLARS IN THOUSANDS)		
	OBLIGATIONS FY 1981	APPROPRIATIONS FY 1982	REQUEST FY 1983
WASTE IMMOBILIZATION AND REACTOR EVALUATION	0	14,750	13,000
DATA ACQUISITION PROGRAM	5,800	9,000	8,000
TOTAL	5,800	23,750	21,000
			(2,750)

**Milestones.** Major milestones for the TMI program are given in the following chart.



### 3. High Temperature Reactors

The High Temperature Reactor (HTR) is unique among current reactor technologies in its ability to generate nuclear-derived energy in temperature regimes previously limited to fossil fuels. Operating in the lower region of temperature capability ( $<1300^{\circ}\text{F}/700^{\circ}\text{C}$ ), the HTR can be used to generate high-quality steam at conditions equivalent to those produced by conventional fossil-fired steam boilers. In the upper range of temperature capability ( $>700^{\circ}\text{C}$ ), an added potential exists for advanced HTR systems. High temperature direct heat can be provided via molten salt or helium and, at temperatures above about  $850^{\circ}\text{C}$ , the reforming process can be used to produce synthesis gas for long range energy transport or as input to various chemical processes.

**Objectives.** The objectives of the HTR Program are to develop technology for HTR systems to serve unique energy markets and reduce requirements for oil, natural gas, and coal; and to conduct international cooperation activities where appropriate.

**Description.** The HTR is classified as an advanced fission converter concept because it provides better fuel utilization than the LWR but not as much as the breeder. It can operate on a variety of uranium and uranium/thorium fuel cycles with both highly enriched uranium and low enriched uranium ( $<20$  percent). Two versions of the HTR are being evaluated for their potential for near-term commercialization. The low temperature version ( $<1300^{\circ}\text{F}$ ) is called the steam cycle/cogeneration (HTR-SC/C) design. The high temperature version ( $>1500^{\circ}\text{F}$ ) of greatest potential is the reformer system (HTR-R).

In the HTR-SC/C design, reactor thermal energy is used to generate high temperature, high pressure steam

for either high efficiency electricity production or for the cogeneration of steam and electricity for process applications. The HTR-SC/C design has evolved through an extensive background of early gas-cooled reactors and demonstration plants.

The HTR-SC/C can serve a large potential market that ranges from baseload electricity generation to industrial cogeneration with central, baseloaded industrial applications such as petroleum refining, enhanced oil recovery, metal refining, and synfuels. In the cogeneration application, the HTR-SC/C differs from the electrical generation application only with respect to how the steam is utilized.

At core outlet temperatures above approximately  $850^{\circ}\text{C}$  ( $1560^{\circ}\text{F}$ ), the HTR offers a further potential for nuclear process heat. In the HTR-R concept, a portion of the reactor thermal energy is converted to a storable/transportable energy form through the use of a highly endothermic, reversible chemical reaction. (The balance of the reactor thermal energy is used for process steam or for baseload electricity through the conventional steam cycle.) It is this distinguishing feature--the capability of storing and transporting reactor energy--which offers the potential for widespread displacement of fossil fuels (notably gas and oil) by nuclear energy in utility and industrial applications. Since peak reforming temperatures in excess of about  $705^{\circ}\text{C}$  ( $1300^{\circ}\text{F}$ ) are required for suitable conversion efficiencies, the HTR is uniquely capable of supplying these requirements with nuclear energy. The HTR-R may ultimately provide the nuclear heat source alternative to fossil energy systems in synthetic fuel production, steelmaking, and hydrogen production.

**Implementation/Strategy.** The strategy for commercialization of the HTR as an energy option is based on the

following requirements:

- Identification of a sufficient market that serves as a necessary impetus for commercialization.
- Specific utility/users support and commitment that is based on the benefits the HTR system offers.
- An industrial base of vendor/suppliers that are committed to supporting the commercial deployment of the HTR systems.
- Stable Government support and commitment that is based on national benefits and compatibility with other national energy development programs.

In 1980-1981, the technical and economic merits and market characteristics of various HTR systems were evaluated. Through this effort, the 2240 MWt HTR-SC/C system was selected as the primary candidate for near-term commercialization. In cooperation with utility organizations, studies were conducted in four regions of the country which showed promise for deployment of HTR steam cycle systems.

Concurrent with the regional studies, a decision package was prepared that forms the basis for negotiations between the utility/user organizations and the Government for a commitment to construct a Lead Plant. The decision package consists of a lead project strategy plan; a design and cost report; a design and technology development plan; a licensing plan; a management plan; and a conceptual design description.

The Lead Plant project is a four-phase program with a decision point at the end of each phase on whether to

continue the project. The Department's decision not to support the HTR Program in FY 1983 is based upon not having developed a favorable industrial commercialization commitment as well as severely constrained budgets. Such an industrial commitment was indicated by the Congress to be a requirement for continued funding. It is our understanding that an industrial response to this Congressional request is being prepared and will be given to the Congress later by them.

**Accomplishments.** The major accomplishments in FY 1981-82 are:

**Lead Plant**

- Conceptual design of a 2240 MWt HTR steam cycle/cogeneration lead plant is 60 percent complete.
- Technical review of the Lead Plant by program participants, utility representatives, EPRI, and consultants.
- Completion of the regional application survey studies.
- Preparation of the Project Decision Package.

**Technology**

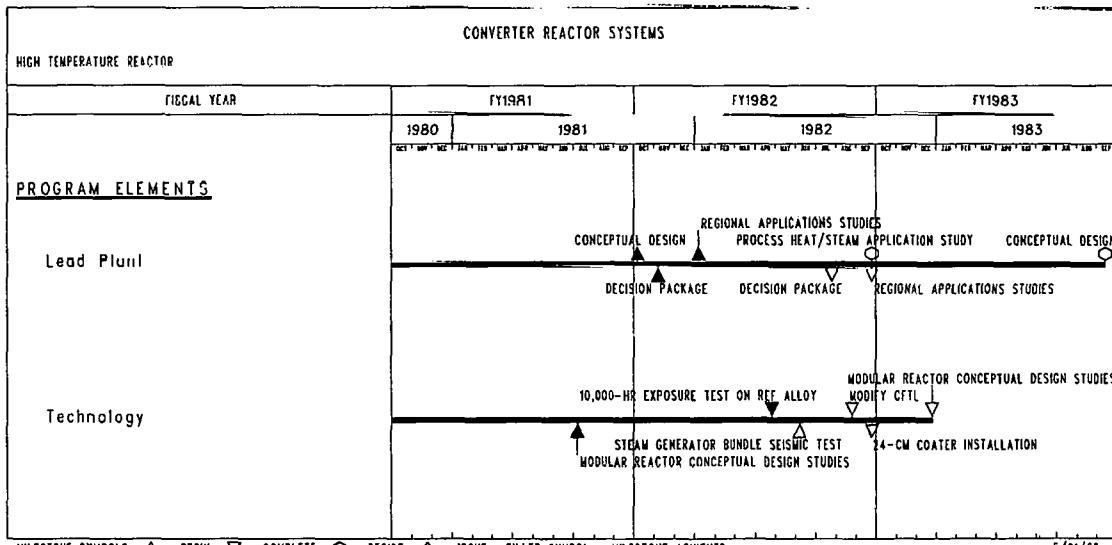
- Completed Fort St. Vrain improvement program activities.
- Initiated conceptual design on process heat and process steam versions of the modular reactor system.
- Continued with the evaluation of graphite and structural metals for very high temperature applications (850°-950°C).
- Continued with the development of the reference LEU uranium oxycarbide (UCO) fuel particles.

**Resources.** The following table shows the operating funding level by program element for the FY 1981 through FY 1983 period:

**HIGH TEMPERATURE REACTORS**

PROGRAM ELEMENT	OBLIGATIONS FY 1981	BUDGET AUTHORITY (DOLLARS IN THOUSANDS)		INCREASE (DECREASE)
		APPROPRIATIONS FY 1982	REQUEST FY 1983	
Lead Plant	0	9,590	0	(9,590)
Technology	36,465	23,910	0	(23,910)
<b>TOTAL</b>	<b>36,465</b>	<b>33,500</b>	<b>0</b>	<b>(33,500)</b>

**Milestones.** Major milestones for the HTR program are given in the following chart.



## B. BREEDER REACTOR SYSTEMS

Nuclear fission using breeder reactors is capable of providing an inexhaustible energy supply. This section describes DOE's program for breeder reactor development. Programmatic descriptions are included for the Liquid Metal Fast Breeder Reactor (LMFBR) and the Water Cooled Breeder (WCB) Reactor.

### Overview

**Background.** The potential for fission energy to provide essentially inexhaustible supplies of civilian electric power through the use of breeder reactor systems was recognized in the 1940s. Development has proceeded since that time, with the priority effort concentrated on the LMFBR concept since the 1960s. A number of experimental facilities have been constructed and operated in the United States, notably:

- the Experimental Breeder Reactor No. 2 (EBR-II), which continues to provide electricity to DOE's Idaho National Engineering Laboratory after almost 20 years of operation, and
- the Fast Flux Test Facility (FFTF), which began routine

testing operation in April 1982 as a major fuel testing facility.

Abroad, LMFBR development has been carried through the demonstration plant stage in France, the UK and the USSR, and the first commercial-scale LMFBR is now under construction in France.

**Objective.** The overall objective of the breeder reactor program is to ensure that this long-term electricity supply source is available on a prudent time scale.

**Strategy.** The Federal role in the future of breeder reactors is to conduct the necessary research, development, and demonstration such that the potential benefits of the breeder can be assumed by private industry at a venture risk level that is consistent with acceptable business endeavors. The responsibility for industrialization and deployment will rest with the private sector.

**Management.** Figure 2 shows the delegation of responsibility for the breeder reactor systems programs. Further breakdown of these delegations are shown in similar charts in the following sections which describe the individual programs.

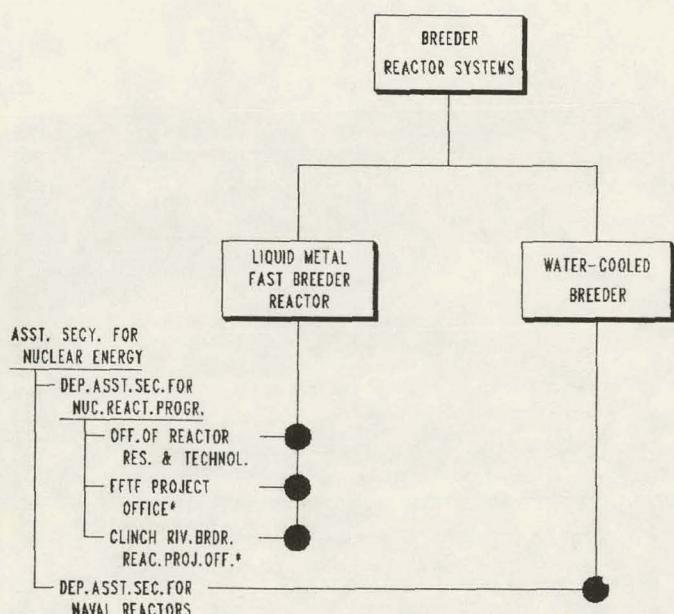
**Funding.** The following table shows the operating funding levels by program element for the FY 1981 through FY 1983 period.

#### BREEDER REACTOR SYSTEMS

PROGRAM ELEMENT	BUDGET AUTHORITY (DOLLARS IN THOUSANDS)			
	OBLIGATIONS FY 1981	APPROPRIATIONS FY 1982	REQUEST FY 1983	INCREASE (DECREASE)
LIQUID METAL FAST BREEDER REACTOR	501,167	499,422 <sup>a</sup>	486,934	(12,488)
WATER COOLED BREEDER	58,000	50,500 <sup>b</sup>	41,800	(8,700)
TOTAL	559,167	549,922	528,734	(21,188)

<sup>a</sup> Reflects reduction of \$2,200,000 for reprogramming to Solar and Departmental Administration.

<sup>b</sup> Reflects reduction of \$500,000 for reprogramming to Solar.



NOTE: \*FIGURE SHOWS PROGRAMMATIC RELATIONSHIPS ONLY;  
PROJECT OFFICES REPORT DIRECTLY TO THEIR LOCAL OPERATIONS OFFICES.

Figure 2. Breeder Reactor Systems upper level work breakdown structure and DOE responsibility matrix.

### 1.0 Liquid Metal Fast Breeder Reactor

The liquid metal fast breeder reactor (LMFBR) is the reactor system most capable of exploiting the vast energy resources of natural uranium. Its advantage over other breeders stems primarily from the excellent heat transfer properties of the sodium coolant that enables the LMFBR to operate at high temperature without resort to pressurized systems. The practical result is a plant with high thermal efficiency—about 40 percent for an LMFBR as compared with 32 percent for light water reactors. In contrast to other high technology “inexhaustible resource” options, pilot LMFBR units are now in successful operation.

The LMFBR is a “breeder” because it produces more fissile material than it consumes. This means that it not only produces enough fuel for its own continued operation, but also generates additional fuel for other reactors. The LMFBR converts uranium-238 (a fertile material) which is not directly usable as reactor fuel into reactor grade plutonium, which is fissionable and, therefore, usable as reactor fuel. This conversion is especially significant, since the present light water cooled reactors achieve their heat energy primarily from the fission of relatively scarce uranium-235, which is present in natural uranium only to the extent

of about 0.7 percent; more than 99.9 percent of the remainder is uranium-238. The breeder ultimately makes available 60 percent or more of the energy potential of natural uranium. The major fuel supply for breeders will be the spent fuel and depleted uranium tailings not currently being used. There is already mined and available enough fertile uranium to supply the equivalent of the nation's electricity needs for 700 years.

- Objectives. The objective of the United States LMFBR program is to industrialize the breeder.
- Description. The LMFBR Program consists of plant projects; engineering and technology efforts in reactor fuels and materials, components, physics, and safety; and the operation of test facilities. The program is focused on the construction and operation of the intermediate-sized Clinch River Breeder Reactor Plant (CRBRP). A conceptual design of a Large Developmental Plant (LDP) was previously produced. Continued planning and design efforts for a commercial-scale LMFBR will continue if an international cooperative effort is concluded.

## 1.1 Plant Projects

The existing plant developmental projects are:

- Clinch River Breeder Reactor Plant; and
- Large Developmental Plant.

The CRBRP is a joint Government/industry effort to construct a 375-MWe demonstration breeder reactor powerplant at Oak Ridge, Tennessee. The LDP is a 1000-MWe LMFBR currently in the advanced conceptual design phase.

**Clinch River Breeder Reactor Plant Project.** To bring LMFBR technology to a point of acceptable commer-

cial risk requires that the technology be advanced and confirmed by constructing and operating plants of increasingly larger sizes. CRBRP is the next LMFBR plant in the deliberate sequence of plants of increased size. The overall objective of the CRBRP project is to design, construct, and test the Nation's first intermediate-scale (375-MWe) LMFBR powerplant and operate the plant as part of a utility system. Its size represents a technically significant yet prudent scale up in plant technology. The CRBRP will provide important information regarding the safety, environmental, and economic potential of LMFBRs as an essentially inexhaustible, domestic energy source. An artist's conception of the plant is shown in Figure 3. Construction is planned for a site adjacent to the DOE reservation at Oak Ridge, Tennessee, where it will be operated as a part of the Tennessee Valley Authority (TVA) electrical supply network.

President Reagan in his October 8, 1981, policy statement on nuclear power stated that completion of the Clinch River plant is essential to ensure our preparedness for long-term nuclear power needs. The CRBRP project is presently authorized under Public Law 91-273, as amended. Under the subject law, Congress authorized the Department to enter into a definitive cooperative arrangement for an LMFBR plant. That cooperative arrangement, called the quadripartite contract between the Department of Energy, Project Management Corporation (PMC), Tennessee Valley Authority (TVA), and Commonwealth Edison (CE), has been in effect since 1973.

The Department of Energy's role in the CRBRP project consists of overall project management and major financial support. Government financial support to the project is applied to all elements of the project including design, development, equipment, and plant costs. DOE will provide all project funding in excess of the utilities'

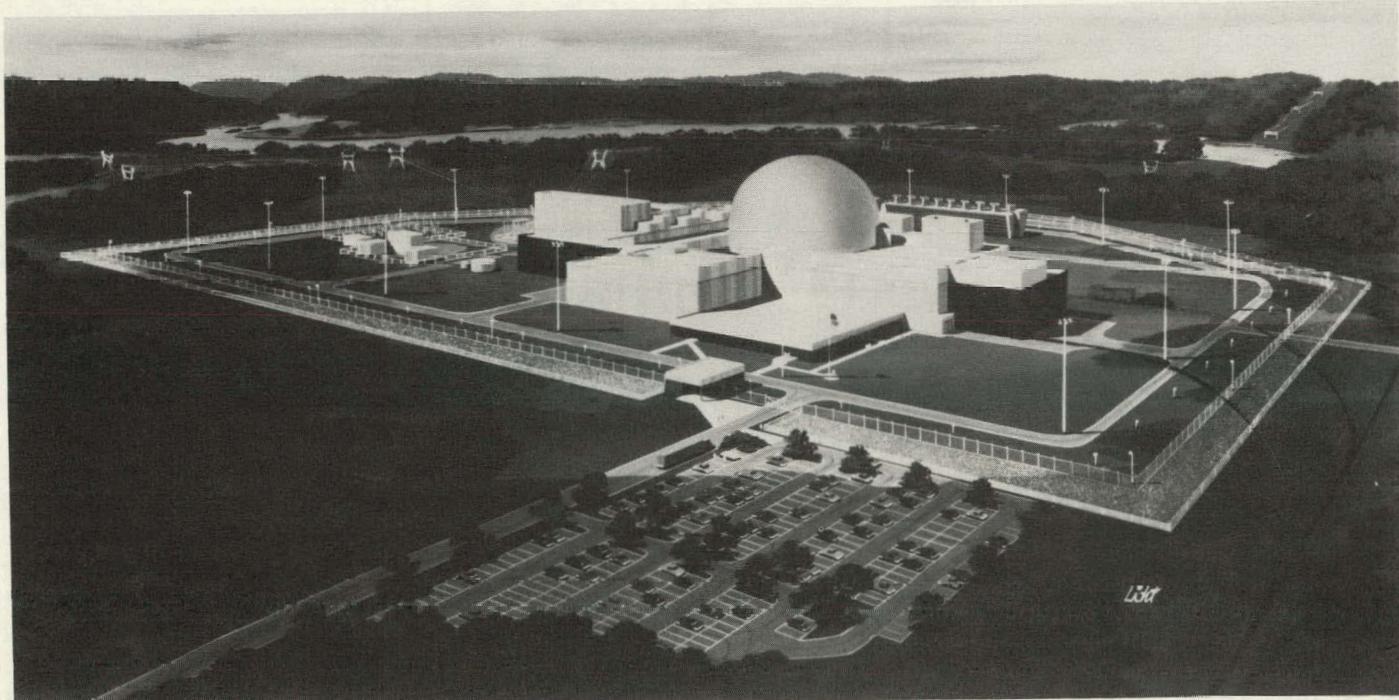


Figure 3. Artist's conception of CRBRP

contributions of approximately \$261,000,000 and the reactor manufacturers' and vendors' contributions of approximately \$10,000,000 and the interest earned on the contribution from the utilities.

The utilities provide management and technical assistance and financial support to the CRBRP project. Commonwealth Edison of Chicago and TVA are the principal utilities that provide management and technical assistance through their participation in the activities of the PMC, a nonprofit group formed especially to represent the interests of the utility industry in the day-to-day management of the project. A second nonprofit group, the Breeder Reactor Corporation (BRC) provides senior counsel on behalf of the utility industry and keeps the public and the electric power industry informed on project matters. BRC is composed of 753 electric systems from the public, private, municipal, and cooperative sectors of the electric power industry that support the project and that have pledged contributions to the project of \$261,000,000.

The CRBRP Project is well advanced. Design is almost 90 percent completed. Approximately 60 percent of the hardware required for the plant is on order or has already been completed. The Nuclear Regulatory Commission is actively reviewing the project's license application. The Project is in a position to start site clearing and construction activities upon receipt of the required approvals from the NRC. Completion of the plant and the attainment of initial criticality is planned for the late 1980's. The plant will then be operated for a 5-year demonstration period.

**Large Developmental Plant Project.** DOE efforts supporting a large developmental plant are entering a new phase in which the Government will provide support and encouragement to a newly initiated utility activity to define the design, cost, schedule, and implementation plans for a developmental plant whose construction will be principally funded by the private sector. A major activity that will be undertaken in concert with the private sector is an effort to develop international participation in the project so as to minimize program costs and to allow maximum utilization of international technological advances. If satisfactory progress is achieved in FY 1982 in development of cooperative arrangements with foreign nations and the private sector, continued Government support for the planning and design of a large-scale prototype breeder in FY 1983 will be provided.

In this light, the LDP project is proceeding in FY 1982 with the advanced conceptual design, preparation of detailed cost and schedule estimates, and the definition of the research and development required to support a large-scale prototype LMFBR plant. Highlights of this project during the last year include efforts to optimize the overall plant design and to reduce the estimated plant capital cost. Also, the design and research and development results of the FFTF, the Clinch River project, and the breeder base program are being incorporated into the large plant advanced conceptual design.

In FY 1983, appropriate utility criteria and plant requirements will be incorporated into the advanced conceptual design, and consolidation of the Government/utility

efforts in support of the large plant will be implemented. An integral part of this consolidation effort is the evaluation of the potential benefits to the large plant of expanded foreign cooperation. Areas identified as having the potential for significant benefits will be pursued through negotiations with appropriate foreign nations. Agreements signed during FY 1982 with foreign nations will provide the mechanism under which such negotiations will be conducted. Considering inputs from the utility participants and foreign nations, the FY 1983 effort will also include advancement of the design of key systems; continuation of cost reduction optimizations; and the update of project criteria, specifications, planning schedules, and the cost estimate.

## 1.2 Breeder Technology Program

This portion of the LMFBR program has as its purpose the industrialization of the breeder. It is concentrated in areas of technology development that are within existing Federal capability but beyond the capability of the private sector. The program elements are:

- Safety;
- Component development for testing;
- Materials and structures;
- Physics; and
- Fuels and materials.

**Safety.** This program is directed toward public safety considerations associated with LMFBRs. The mission of the program is to provide an adequate data base for assessment of risk to the public from reactor accidents, and to enhance the safety-related design of LMFBRs. Program effort falls into two main areas--prevention of accidents and mitigation of accident consequences. It will provide a technology base fully responsive to safety considerations in the design, evaluation, licensing, public acceptance, and economic optimization of LMFBRs for electric power generation.

A major reactor accident cannot take place unless a sequence of failures occurs within the reactor system. The safety goal depends upon developing technology in four generic and integrated segments (Lines of Assurance), each of which relates to a sequential barrier preventing accident progression, thus preventing release of any significant amount of radioactivity to the environment. These are described as follows:

<u>Major events in core-disruptive accidents</u>	<u>Line of Assurance (LOA)</u>	<u>Barrier to progression</u>	<u>Example of threat to barrier</u>
Initiating fault	LOA-1: Prevent accidents	Fuel cladding	Fuel melting
Initiation of fuel melting	LOA-2: Limit core damage	Subassembly boundary	Loss of coolable core geometry
Whole-core melting	LOA-3: Maintain containment integrity	Primary and secondary containment systems	Energy and pressure sources from core meltdown
Radioactivity release	LOA-4: Attenuate radiological consequences	Engineered systems and inherent mechanisms	Unanticipated events

Conservatism and quality assurance in the design, construction, and operation of nuclear powerplant components and systems are major contributors to prevention of accidents. Thus, Breeder Technology elements other than Safety, i.e., Components, Materials and Structures, Physics, and Fuels and Materials, play a significant role in accident prevention. The extensive in-reactor performance testing of reactor fuel and the zero-power reactor core physics experiments are representative examples of accident prevention R&D carried out by elements other than Safety. The Safety element focuses, therefore, on accident prevention (LOA-1) activities not supported by other Breeder Technology elements.

Safety R&D in LOA-1 involves demonstration of reactor system reliability in preventing the occurrence of accidental events requiring prompt reactor shutdown, and demonstration of highly reliable reactor shutdown and shutdown heat removal should such events occur. An example of work in LOA-1 is the evaluation of plant status and maintenance control system operational experience in FFTF. This system represents a state-of-the-art advancement in reactor plant man-machine interface technology.

LOA-2 R&D aims to demonstrate that faults in the shutdown and shutdown heat removal systems, and local faults within the core itself, can be accommodated with only limited damage to the core. An example of LOA-2 work is the post-test examination and analysis of a failed fuel blockage test previously conducted in the Sodium Loop Safety Facility.

Safety R&D in LOA-3 and LOA-4 covers investigation of the potential of hypothetical core-disruptive accidents (HCDA's) to damage reactor and containment structures, development of engineered systems to reduce potential releases of radioactive material from containment, and studies of the inherent attenuation of airborne radioactive materials. Current LOA-3 and LOA-4 work includes Transient Reactor Test Facility (TREAT) tests of preirradiated LMFBR fuel pins under simulated accident scenarios, validation of computer codes that predict accident energetics and describe the behavior of containment structure under accident conditions, development of a recommended approach to accommodation within the reactor vessel of debris from core melting, and large-scale aerosol behavior tests in the HEDL Containment Systems Test Facility, with a supporting computer code validation study.

**Components.** The Components program encompasses development of the technology required for critical components of LMFBR heat transport systems and auxiliary systems, as well as the development of the data, processes, and analytical methods needed to support the design, fabrication, and operation of safe and reliable components and systems. Experience with breeder reactor plants in this country (EBR-II and Fermi) and abroad (the British Prototype Fast Reactor, French Phenix, Russian BN-350, and BN-600) has shown that the heat transport components have been the major source of plant operational deficiencies, resulting in greatly reduced plant reliability and availability. Therefore, the program stresses the development of essential heat transport components,

which involve unproven concepts such as sodium-to-water steam generators and main coolant pumps.

The component development program has been structured to provide the technology for reliable and economic equipment through the design, fabrication, and testing of equipment models and by providing the supporting technology needed for component and system design and fabrication. Important data and information from design, fabrication, test, and operation of components for EBR-II, FFTF, and CRBRP are continuously utilized in the program. Component vendors design and fabricate model components and perform the concept-dependent supporting development. Tests and generic-type development are conducted by the national and engineering laboratories and the reactor manufacturers.

In the international LMFBR community, it is recognized that the sodium-to-water steam generator is the most complex and demanding component from engineering design and system reliability viewpoints. The U.S. steam generator program includes the development of two different steam generator designs—a singlewall, helically coiled tube concept by the Babcock and Wilcox Company, Barberton, Ohio, and a double-wall straight tube concept by Westinghouse Electric Corporation's Nuclear Components Division, Pensacola, Florida. For each concept, testing of critical component features, small model testing, and manufacturing development are followed by fabrication and delivery for testing of a 70-MWt model in the Sodium Components Test Installation (SCTI) at the Energy Technology Engineering Center (ETEC), Canoga Park, California. In addition, development and testing of leak detection systems for steam generators is being conducted to assure the capability of rapidly detecting and terminating a leak before it develops into a large leak.

In the U.S. pump development program, work is underway at the Westinghouse Electric Corporation's Electro-mechanical Division, Cheswick, Pennsylvania, for development of a two-stage primary pump; at Borg Warner Corporation's Byron Jackson Pump Division, Carson, California, for development of a single stage intermediate pump; and at Rockwell International's Energy Systems Group, Canoga Park, California, for the development of an inducer primary pump. Test units of the two-stage primary pump and single stage intermediate pump are being fabricated for testing in the ETEC Sodium Pump Test Facility (SPTF). To evaluate the suitability of the inducer for use with sodium, an inducer pumping element was installed on a spare FFTF primary pump and tested in the SPTF in 1981, and sodium and water tests of small models of the pump are on test at ETEC in 1982.

In the supporting development program area, experiments and analyses are conducted to develop validated design and analysis procedures to predict and minimize such potentially detrimental conditions as flow induced vibration, flow maldistribution, and stratification in components and systems.

**Materials and Structures.** The Materials and Structures program encompasses the development and transfer to designers and manufacturers experimentally verified

structural design and materials technologies aimed at assuring the economic, safe, and reliable performance of LMFBR components and systems. The program will provide technology to assure with high probability that LMFBR components and systems will be free from significant structural failures during their design lifetimes. This includes development of design methods and criteria, materials property data, and procedures that are verified and practical to apply.

The technology areas covered are those for high-temperature structural design, seismic design, mechanical properties design data, fabrication, nondestructive testing, tribology (friction, wear, and self-welding), advanced structural alloys, materials properties documentation, and coolant technology.

The output of the program is used in specific LMFBR projects such as CRBRP as well as in other development programs such as components and safety. The overall strategy includes: 1) providing timely guidance to design teams, 2) performing all necessary R&D in support of the ultimate design choices, 3) maximizing use of information derived from previous generic and specific research and development (EBR-II, FFTF, and CRBRP), and 4) maximizing the use of information derived from foreign exchange arrangements.

The products of the program are technical guidelines, design rules, data, and documentation. Thus, the deliverables include reports, guideline documents, contributions to NE (RDT) standards, contributions to consensus standards (e.g., ASME-BPV Codes and ASTM Standards), and the Nuclear Systems Material Handbook, which is a repository for LMFBR material related to design data.

**Physics.** The Physics program is directed toward the development of the fast reactor neutronics capabilities required to provide reliable design data, accurate safety analyses, well-qualified fuel management, and reactor start up, testing and operating procedures. The Physics program provides experimental determinations of core and shield properties, nuclear data measurements and evaluations, and development of computational methods for accurately and economically predicting core performance, shield effectiveness, and safety parameters. Program activities will result in significant improvements in core design accuracy and significant savings in reactor construction and operating data by development of the most favorable design options and fuel cycles for FFTF, CRBRP, and longer-term interests. Emphasis in the near term is placed on analysis of the FFTF neutronic performance and changes due to core reload and test requirements. A program of mockup, benchmark, and interpretive critical experiments establishes the neutronic characteristics of those LMFBR cores selected for first-of-a-kind reactors. Much of the experimental work is carried out at the ZPPR critical facilities. Selected shielding experiments are performed at the tower shielding facility. Neutron interaction and scattering properties of reactor materials are measured at the FNG and ORELA facilities over a wide range of energies and angles to enable reliable core design calculations. Properties of fission products such as

decay heating, neutron absorption, and neutron emission are determined for many required reactor design applications. State-of-the-art experimental and analytical physics capabilities are applied to improve understanding of reactor fuel burnup.

**Fuels and Materials.** The Fuels and Materials program encompasses the development of fuel, blanket, and control core components for LMFBRs; the development of materials for use in these components; and the development of equipment, processes, and facilities to fabricate fuel and assure a supply of such fuels for program breeder reactors.

The core components and materials program comprises two parallel activities: (1) conduct surveillance of the FFTF core for confirmation of previous development work on reference FFTF fuel-system materials (i.e., uranium/plutonium oxide fuel and Type-316 stainless steel cladding and ducts) to validate its performance, the calculations, codes and design methodologies that were used in its design, to establish performance limits, to provide confidence for the predicted performance of the CRBRP core which is similar to FFTF, to support the safe and reliable operations of FFTF as a test reactor, and (2) conduct sufficient investigations on advanced fuels, blankets, and absorber concepts to narrow the options to the point where prime systems can be selected and developed. The program depends heavily on irradiation testing of fuels and materials conducted in the EBR-II and to be conducted in the FFTF. Significant aspects of the irradiations program in EBR-II have included: (a) carrying advanced fuels tests to and beyond goal burnups to identify ultimate performance limits, (b) continuing irradiations of advanced cladding and duct materials to high exposures, and (c) performing Run-Beyond Clad-Breach (RBCB) tests. Key aspects of the irradiations to be conducted in FFTF include: (a) qualifying FFTF driver fuels, (b) testing candidate advanced cladding and duct materials, and (c) testing full-scale advanced fuels and blanket pins. These experiments will lead to tests of full-scale assemblies of prime candidate advanced fuels and blanket concepts, which will be followed by partial core loadings of such assemblies for qualification of safe and reliable operation.

The program for qualifying the performance of replaceable core components for FFTF will be conducted principally within the framework of a systematic driver fuel and absorber evaluation plan involving periodic removal of reference driver fuel assemblies for thorough post-irradiation examination. This evaluation will extend through the first 3 years of FFTF operation. Performance surveillance will continue during subsequent operation, but on a more routine basis.

The advanced core components effort involves the development of long-lived, highly reliable components that will enhance plant efficiency, performance, and reliability. Major emphasis is placed on obtaining a comprehensive base of component performance information, derived for a wide variety of design options and a broad range of operating conditions. The experimental portion of this activity consists of a series of tests of pin and assembly variables

that will provide a broad coverage of fuel parameters, advanced cladding and duct materials, pin and assembly design, and analytical capabilities.

Fuel fabrication process development efforts focus on the Secure Automated Fabrication (SAF) program. Major emphasis is directed toward applying SAF technology to the production of fuel for CRBRP and FFTF. The program incorporates advanced automation and remote processing technologies that will reduce personnel exposure, reduce costs, enhance special nuclear materials safeguards and accountability, minimize personnel access to materials, increase productivity and quality, and incorporate scrap and waste handling procedures; as well as the process control and safety systems required to meet the program's goals. The initial application of SAF technology will be a fuels fabrication line (SAF line) (see Figure 4), which will be installed in the Fuels and Materials Examination Facility (FMFF) under construction at Richland, Washington.

### 1.3 Test Facilities

Test facilities are an essential part of the LMFBR program in that they provide the capability to test systems and components developed under the breeder technology program, as well as prototypes and models of components to be incorporated into plant projects. Through operation of irradiation facilities such as the FFTF (Figure 5) and EBR-II (Figure 6), and operation of large non-nuclear sodium facilities, plant performance information on operation and maintenance is also generated to support plant projects. Emphasis is added to the need for test facilities by the increase in size being considered for plants beyond CRBRP. The size extrapolation from FFTF components by

a factor of seven or more and for CRBRP components by a factor of nearly three will require adequate testing to identify and minimize risks.

In keeping with the national interest, safeguards and security measures at all facilities involved with special nuclear materials (SNM) must be maintained and upgraded as necessary to assure adequate protection of SNM against diversion, theft, or terrorist activity.

Major test facilities covered by this element are located at the following Government-owned sites: Argonne National Laboratory (ANL), Energy Technology Engineering Center (ETEC), and Hanford Engineering Development Laboratory (HEDL). Existing test facilities are operated and maintained, modifications to existing facilities are made, and new facilities are provided in support of the plant projects and breeder technology elements of the LMFBR program in accordance with technical requirements, priorities, and scheduler needs identified under those elements, consistent with safe, efficient operation and acquisition practices.

Table 1 lists the elements of the LMFBR program, the major test facilities supporting each element, and the facility locations. Those facilities, which support more than one program element, are listed several times.

**Implementation/Strategy.** All the other advanced nuclear nations--France, Great Britain, West Germany, U.S.S.R., and Japan--are proceeding towards the commercial breeder. For example, France expects to have a 1200-MWe breeder on line in 1984. The Reagan Administration also supports the orderly development of the breeder, but in such a manner as to be cost effective from a Federal investment point of view and to allow the private sector to determine when to commercialize this reactor

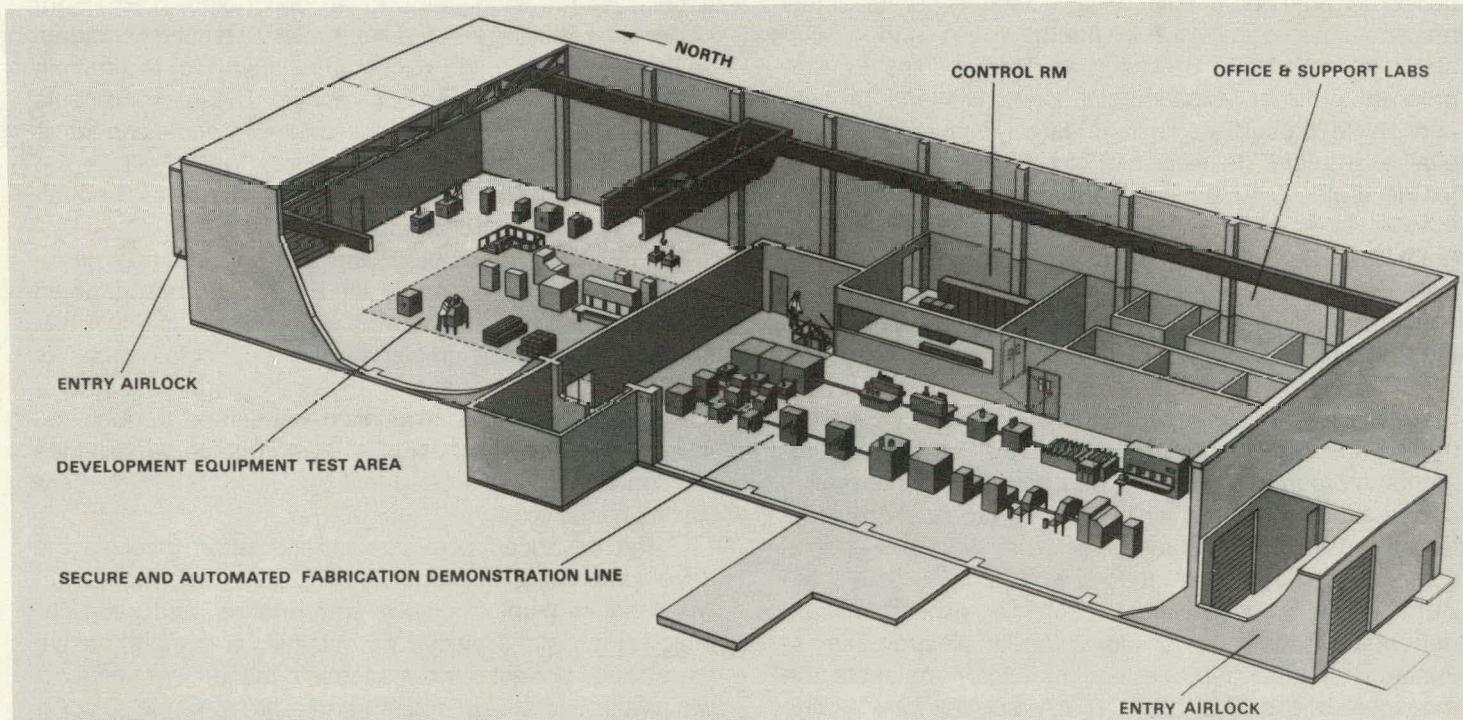


Figure 4. Secure Automated Fuels Fabrication Line Demonstration Facility at HEDL

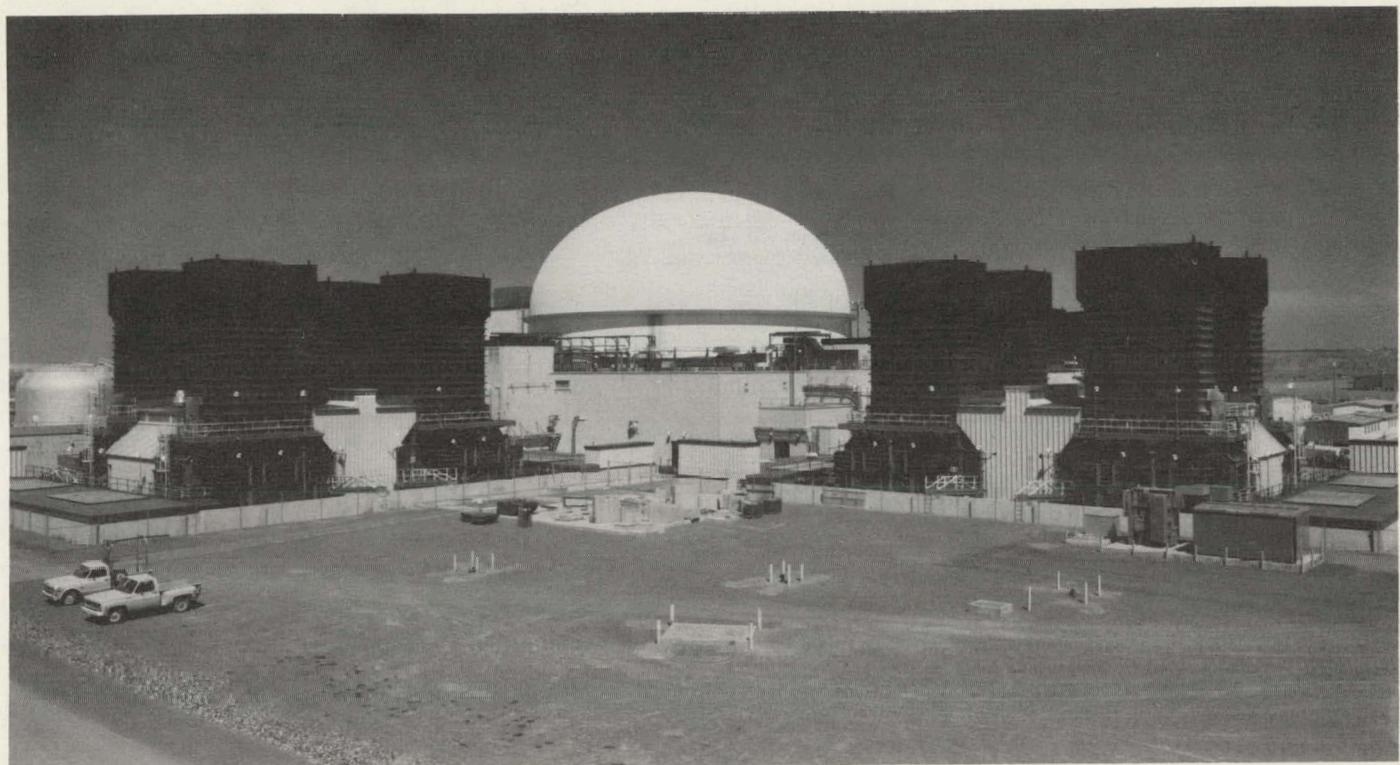


Figure 5. Fast Flux Test Facility at HEDL

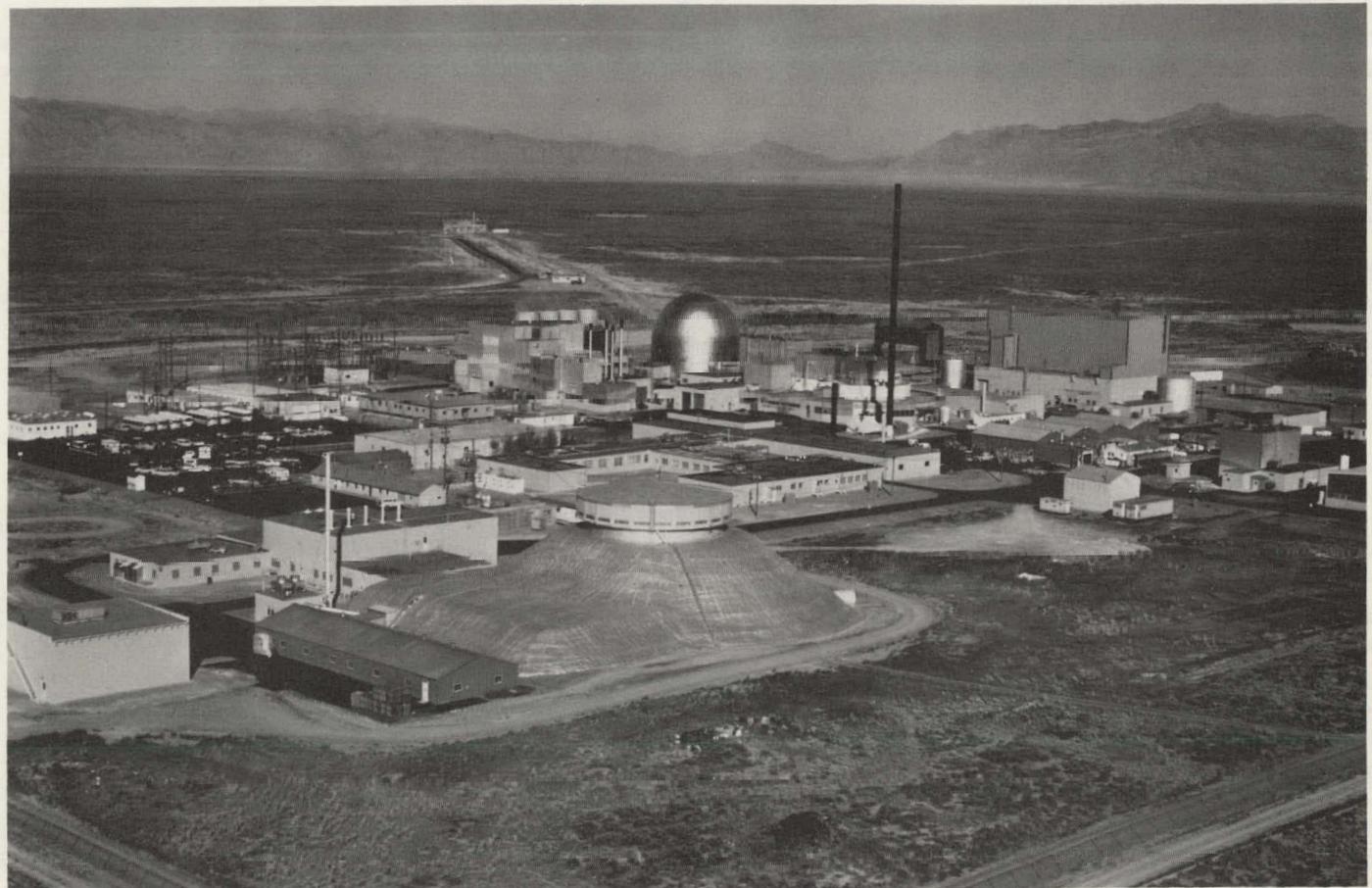


Figure 6. ANL-West Site including EBR-II, ZPPR, HFF, and TREAT

Table 1  
Major Test Facilities in Support of LMFBR Program Elements

Program Element	Test Facility	Site
Plant Projects	Fast Flux Test Facility (FFTF) Maintenance and Storage Facility (MASF) Fuel Storage Facility (FSF) Experimental Breeder Reactor No. II (EBR-II) Sodium Pump Test Facility (SPTF) Sodium Component Test Installation (SCTI)	HEDL HEDL HEDL ANL-W ETEC ETEC
Breeder Technology		
Safety	Fast Flux Test Facility (FFTF) Experimental Breeder Reactor No. II (EBR-II) Transient Reactor Test Facility (TREAT) Hot Fuel Examination Facility (HFEF)	HEDL ANL-W ANL-W ANL-W
Components	Fast Flux Test Facility (FFTF) Experimental Breeder Reactor No. II (EBR-II) Sodium Components Test Installation (SCTI) Sodium Pump Test Facility (SPTF) Components Handling and Cleaning Facility (CHCF) Small Circumferential Test Loop (3CTL) Static Sodium Test Facilities (SSTF)	HEDL ANL-W ETEC ETEC ETEC ETEC ETEC
Materials and Structures	Fast Flux Test Facility (FFTF) Experimental Breeder Reactor No. II (EBR-II)	HEDL ANL-W
Physics	Fast Flux Test Facility (FFTF) Zero Power Plutonium Reactor (ZPPR)	HEDL ANL-W
Fuels and Materials	Fast Flux Test Facility (FFTF) Experimental Breeder Reactor No. II (EBR-II) Hot Fuel Examination Facility (HFEF) Fuels and Materials Examination Facility (FMEF) Transient Reactor Test Facility (TREAT)	HEDL ANL-W ANL-W HEDL ANL-W

system. It is in this context that the liquid metal fast breeder reactor strategy has been developed.

It is important to note that this program strategy does not plan on Federal funding for an eventual commercial-size plant. Rather, this strategy sees the Federal role ending when the technology base is judged to be sufficiently developed to permit the private sector to assume responsibility for LMFBR industrialization and commercial deployment.

The technologies needed for development of the LMFBR will be the end result of a planned sequence of development breeder and other reactor facilities that began with Experimental Breeder Reactor I (the world's first source of nuclear-generated electric power); followed by the 20-MWe Experimental Breeder Reactor II; the 65.9-MWe Enrico Fermi Atomic Power Plant (the first LMFBR plant to supply electricity to a commercial utility test grid); the 133-MWe (equivalent) Fast Flux Test Facility, which is now operating and will be used principally as a fuels and materials testing facility; and the 375-MWe Clinch River Breeder Reactor Plant. In addition to major zero-power reactors for determining the configurations and nuclear characteristics of LMFBR cores and blankets, the breeder program was also supported by the 20-MWt Southwest Experimental Fast Oxide Reactor, which was operated essentially for physics experiments and has since been decommissioned.

To attain the objective of developing the technology to a point where the risk is acceptable to the private sector, vigorous effort will be resumed on the construction and operation of the CRBRP and a strong base technology program will be maintained. The Nuclear Regulatory Commission's environmental and safety reviews of the CRBRP

project have been resumed and are currently proceeding. It is expected that the NRC staff will complete its environmental review this fiscal year and complete its safety review in Fiscal Year 1983. These reviews will be followed by public hearings with the expectation that a construction permit will be issued in mid-1984.

The CRBRP will be supported by a base research and development program that provides the necessary engineering and safety analysis, along with the technology improvements required for plant scale-up. The combination of the base research and development program and the CRBRP project will furnish the driving force to develop the engineering infrastructure and the technology required for the private sector to pursue LMFBR commercialization.

For the LDP, the next step beyond CRBRP, DOE is now attempting to develop the framework for beneficial cooperation in a large LMFBR plant project with the private sector and with various foreign countries. Progress in this area to date is very encouraging. If broad cooperation can be successfully achieved in a large plant project, the risks and costs of proceeding with the development of the breeder could be significantly reduced. Cooperative international arrangements also offer the potential for developing a sound basis for institutional fuel cycle arrangements needed to support the breeder.

**Accomplishments.** Major accomplishments in FY 1981 were:

- The Fast Flux Test Facility reactor achieved full design power operation of 400 MWt (December 21, 1980).
- The Conceptual Design Study of a 1,000 MWe LMFBR was submitted to Congress (March 1981).
- Design of the Clinch River Breeder Reactor Plant was 86 percent complete.

- Completed ZPPR engineering mockup critical experiments to validate CRBRP design and licensing analyses.
- Major accomplishments planned for FY 1982 include:
- Complete Sodium Pump Test Facility upgrade for testing CRBRP double suction pump.
- Start routine FFTF reactor fuels and materials test operations.
- Complete installation of CRBRP steam generator and pump prototypes in ETEC facilities.
- Completion of the advanced conceptual and preliminary designs at the Secure Automated Fabrication (SAF) Line.
- Ten tests of fuel failure and failure propagation were conducted in the TREAT test reactor, and preparations for the later conduct of seven tests were completed.

The major accomplishments expected in FY 1983 include:

- Complete the fabrication of the single-wall steam generator model at Babcock and Wilcox and the two stage primary pump test unit at WEMD.
- Complete testing of the CRBRP prototype hockey stick steam generator and prototype double suction pump at ETEC.
- Continued routine operation of FFTF.
- Complete preparations for sodium natural convection testing in THORS facility at ORNL.
- Receive Limited Work Authorization from the Nuclear Regulatory Commission for CRBRP.
- Continue large-scale aerosol behavior tests in the Containment Systems Test Facility to support computer code validation activity.

**Resources.** The following table shows the operating funding levels by program element for the FY 1981 through FY 1983 period.

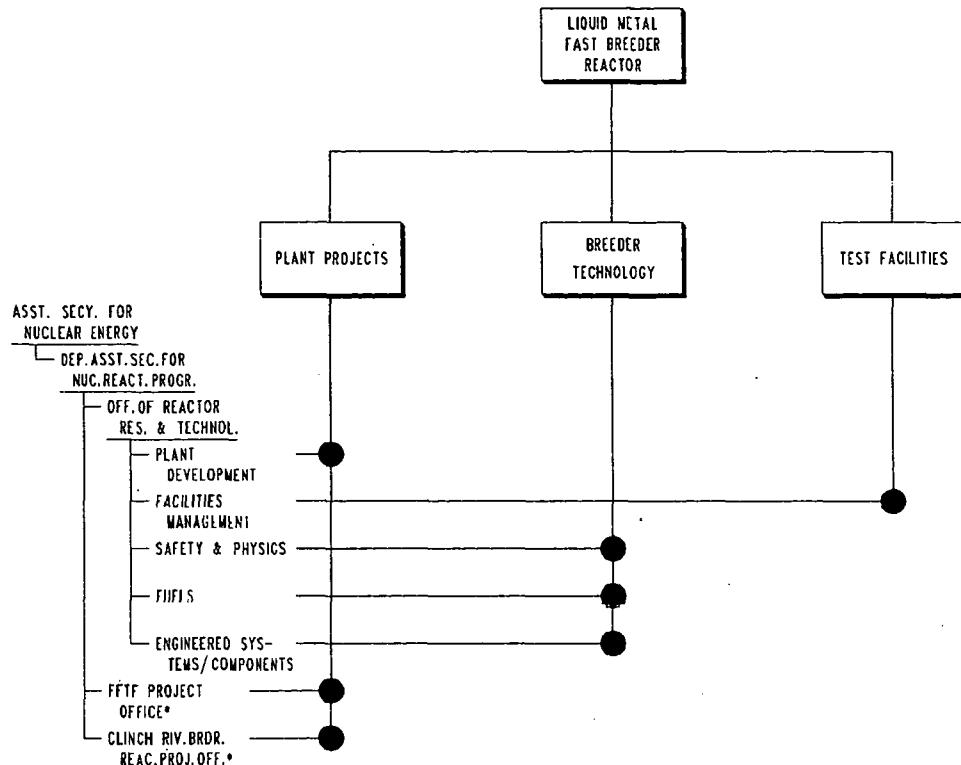
**LIQUID METAL FAST BREEDER REACTOR**

PROGRAM ELEMENT	OBLIGATIONS FY 1981	APPROPRIATIONS FY 1982	BUDGET AUTHORITY (DOLLARS IN THOUSANDS)	
			REQUEST FY 1983	INCREASE (DECREASE)
CLINCH RIVER BREEDER REACTOR PLANT	210,822	193,922	252,500	58,578
LARGE DEVELOPMENTAL PLANT	16,744	15,000	0 <sup>c</sup>	(15,000)
TECHNOLOGY PROGRAM	129,430	129,885	109,634	(20,615)
TEST FACILITIES <sup>a</sup>	137,645	155,415	119,800	(35,615)
SAFEGUARDS AND PROGRAM ASSURANCE	5,168	5,200	5,000	(200)
INVENTORIES	1,358	0	0	0
<b>TOTAL</b>	<b>501,167</b>	<b>499,422<sup>b</sup></b>	<b>486,934</b>	<b>(12,488)</b>

<sup>a</sup> Includes operation of the Fast Flux Test Facility and Experimental Breeder Reactor II.

<sup>b</sup> Reflects reduction of \$2,200,000 for reprogramming to Solar and Departmental Administration.

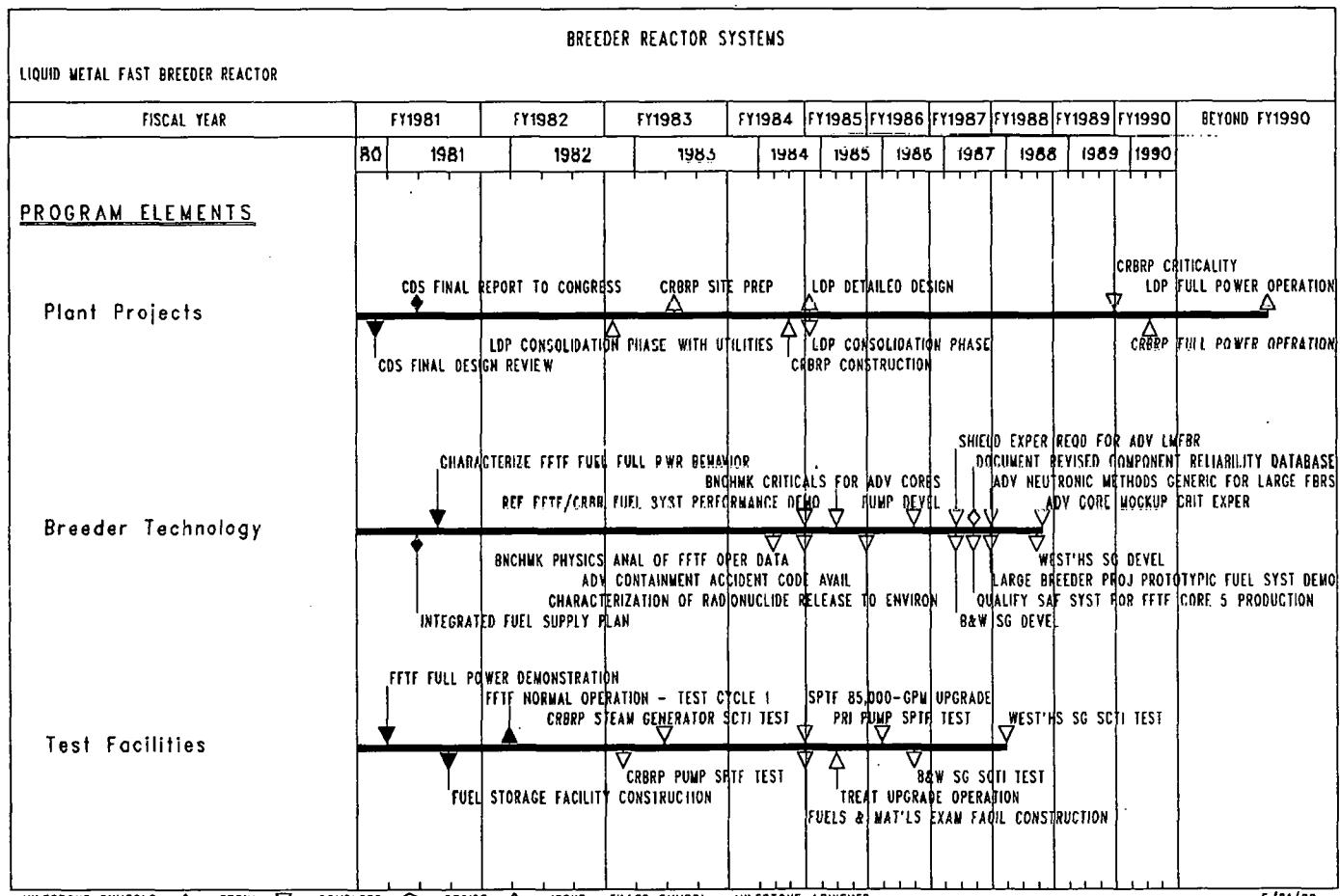
<sup>c</sup> Up to \$15,000,000 will be provided for the planning and design of a large-scale prototype breeder if an international cooperative arrangement is established.



NOTE: \*FIGURE SHOWS PROGRAMMATIC RELATIONSHIPS ONLY; PROJECT OFFICES REPORT DIRECTLY TO THEIR LOCAL OPERATIONS OFFICES.

Figure 7. LMFBR program work breakdown structure and DOE responsibility matrix.

**Milestones.** Major milestones for the LMFBR program are given in the following chart.



MILESTONE SYMBOLS:  $\triangle$  = BEGIN;  $\nabla$  = COMPLETE;  $\square$  = DECIDE;  $\diamond$  = ISSUE. FILLED SYMBOL = MILESTONE ACHIEVED.

5/21/82

## 2. Water Cooled Breeder Reactor

In the early 1960s, the Knolls and Bettis Laboratories under the direction of the Naval Reactors Division, U.S. Atomic Energy Commission (now DOE), determined that it might be possible to develop a practical self-sustaining breeder cooled with ordinary (light) water and fueled with uranium-233 and thorium.

Since light water reactor technology has been demonstrated to be practical in over 25 years of experience, the principal development necessary is the breeder core itself, permitting developmental efforts to concentrate on breeder core technology. Such a breeder would have the advantage of using the well-established technology of light water reactors, which is the basis of most of the present commercial nuclear power industry, and could therefore be developed without the uncertainties and cost of developing a new kind of powerplant. This early work led to the establishment of the Light Water Breeder Reactor (LWBR) program in 1965.

**Objectives.** The overall objective of the Water Cooled Breeder (WCB) Program is to develop technology for significantly improving the efficiency of nuclear fuel resource utilization by water cooled reactors used for electrical power generation. The WCB program in 1983 will be divided into two elements:

- Shippingport Atomic Power Station (SAPS), and
- Light Water Breeder Reactor (LWBR).

The Shippingport Atomic Power Station program objective is to advance pressurized water reactor technology through testing of advanced reactor concepts. The Light Water Breeder Reactor (LWBR) program objective is to accomplish the following: prove that breeding can be achieved in a light water nuclear reactor using the uranium-233/thorium fuel system; confirm a practical way to use thorium, a plentiful source of fuel for which there has been no major energy-related use; show the feasibility of installing prebreeder and breeder cores of the LWBR type in existing and future pressurized water reactor plants using existing types of plant components and systems; and make the technology developed under the program available to commercial industry. Another technical benefit of this program is the significant improvement in the efficiency of using nuclear fuel resources that is expected to be realized from LWBR technology.

**Description.** The concept being demonstrated by the WCB program is a self-sustaining breeder reactor, cooled and moderated with ordinary (light) water and fueled with uranium-233 and thorium. Successful confirmation of breeding in the Shippingport Light Water Breeder Reactor core will provide the basic technology which would make available for power production about 50 percent of the energy in the nation's thorium reserves, a source of energy many times greater than the known fossil fuel reserves. This concept is the only known approach using the proven technology of the light water reactor system for increasing fuel utilization efficiency significantly beyond the approximately 1 percent achievable with present types of light water thermal reactors.

**Implementation/Strategy.** In October 1982, the Shippingport plant will cease routine power operation with the Light Water Breeder Reactor core and will begin end-of-life testing followed by reactor defueling. Completion of this effort will take approximately 2 years. The end-of-life testing includes core physics and engineering tests to characterize the physics and engineering properties of the LWBR core and to provide data to use as a reference point in the end-of-life examination at the Naval Reactors Expanded Core Facility (ECF). The Shippingport plant will continue to be maintained for the period necessary to complete defueling activities. Upon completion, the Shippingport Atomic Power Station will be turned over to the DOE Office of Waste Management for decommissioning activities.

The LWBR core spent fuel modules will be shipped to the ECF for a detailed core examination to verify core performance. Core examination is expected to take about 4 years. Overall, the remaining work is expected to take about 5 years.

**Accomplishments (Past, Present, Future).** The Shippingport Atomic Power Station, 25 miles northwest of Pittsburgh, Pennsylvania, was the first large-scale central station nuclear powerplant in the United States and the first plant of such size (initial operation 60 MWe net) in the world operated solely to produce electric power. The project was started in 1953 by the U.S. Atomic Energy Commission (now DOE) to confirm the practical application of nuclear power for commercial purposes. Initial criticality of the first Shippingport reactor core was achieved December 2, 1957. Operation of the Shippingport plant with pressurized water reactor cores has provided much of the technology for designing and operating commercial central station nuclear powerplants now in use.

The Shippingport plant is now operating with its third core, the LWBR core. Confirmation that breeding occurred in this core will establish the basic technology that could make available for power production the energy in the nation's thorium reserves. Installation of the LWBR core required minimal modifications to the existing Shippingport plant. The startup and acceptance test program for the LWBR core was completed, and the plant was released for routine operation to supply power to the Duquesne Light Company distribution system on December 2, 1977. The LWBR core at Shippingport has completed 4-1/2 years of operation, accumulating more than 25,900 effective full power hours.

Since start-up, the LWBR core has operated successfully in both sustained operations at high power and periodic swing-load operations during which reactor power has been varied as would be required to meet power load demands. As of late August 1980, the core had accumulated more than the design objective of 18,000 effective full power hours and provided valuable test data, not only on the useful life and performance of the core, but also on the long-term performance of all aspects of light water reactors, their systems and components.

Following completion of core operation, the LWBR core fuel assemblies will be removed from the Shipping-

port reactor vessel and the spent fuel will be shipped to the Naval Reactors Facility in Idaho for a detailed core examination to verify core performance including breeding characteristics. After having produced power well beyond design life, the expended core is expected to contain more than 1 percent more fissile fuel material than the initial loading.

The Argonne National Laboratory, under the Division of Nuclear Power Development, will provide chemical dissolution and analysis services for assaying LWBR spent

fuel in support of the assessment of LWBR core breeding performance.

Under the Advanced Water Breeder Applications program, technical problems have been explored and technical information developed and disseminated through published technical reports. This effort ends at the end of FY 1982.

**Resources.** The following table shows the operating funding levels for the WCB program by program element for the FY 1981 to FY 1983 period:

WATER COOLED BREEDER				
PROGRAM ELEMENTS	BUDGET AUTHORITY (DOLLARS IN THOUSANDS)			
	OBLIGATIONS FY 1981	APPROPRIATIONS FY 1982	REQUEST FY 1983	INCREASE (DECREASE)
SHIPPINGPORT ATOMIC POWER STATION (SAPS)	\$11,000	\$12,000	\$12,000	\$ 0
LIGHT WATER BREEDER REACTOR (LWBR)	18,000	30,500	29,800	(700)
ADVANCED WATER BREEDER APPLICATIONS (AWRA)	29,000	8,000	0	(8,000)
TOTAL	\$58,000	\$50,500	\$41,800	(\$8,700)

## C. SPECIAL NUCLEAR EVALUATIONS AND SYSTEMS

This section describes two diverse program elements that deal with specialized applications of nuclear energy technology. These elements take the form of applied research in the following two areas:

- Space and Terrestrial Applications
- Advanced Technology and Systems Assessment

The research done in these areas is designed to promote the use of nuclear power for specialized applications in the most economic, safe, and productive ways possible.

### Overview

**Background.** The two programs described in this section deal with specialized areas of applied nuclear technology research and development. These activities have provided various user agencies with solutions to their special power needs by supplying specialized nuclear powered energy sources. Also, studies have been made to determine the most economic and productive ways to use nuclear power commercially.

**Objectives.** The principal objectives of this program area are:

- Conduct research and development activities to provide specialized nuclear power systems for use in individual user applications, such as required by NASA for the space program.
- Conduct economic, technical, and commercial feasibility evaluations for the development and deployment of conventional, advanced, and specialized nuclear systems.

**Strategy.** The broader-based efforts of previous years have been narrowed in scope so that funding support in FY 1983 has been requested for only one program:

- A program to advance the application of nuclear systems for space exploration and specialized terrestrial applications.

**Management.** The DOE Headquarters organizations responsible for directing these programs are shown in the upper level WBS/DOE responsibility matrix in Figure 8.

**Funding.** The table on the following page shows the operating funding during FY 1981 through FY 1983.

### 1. Space and Terrestrial Applications

The unique characteristics of nuclear-powered electric generators—their compact size, light weight, and long life—enable operation of the sensing, analytical and communication systems of spacecraft, satellites, and other remotely located devices for long time periods without relying on external sources of energy. As a result of research and development, environmentally acceptable, operationally safe, and technically qualified nuclear energy systems have been delivered to Federal user agencies for earth-

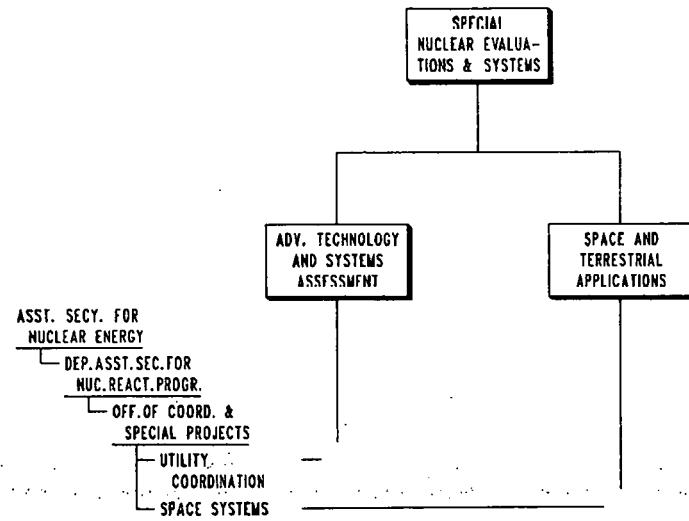


Figure 8. Special Nuclear Evaluations and Systems upper level work breakdown structure and DOE responsibility matrix.

### SPECIAL NUCLEAR EVALUATIONS AND SYSTEMS

PROGRAM	OBLIGATIONS FY 1981	APPROPRIATIONS FY 1982	REQUEST FY 1983	BUDGET AUTHORITY (DOLLARS IN THOUSANDS)	INCREASE (DECREASE)
				(DOLLARS IN THOUSANDS)	
SPACE AND TERRESTRIAL APPLICATIONS	\$35,100	\$33,600	\$27,500	\$6,100	
ADVANCED TECHNOLOGY AND SYSTEMS ASSESSMENTS	1,800	0	0	0	
<b>TOTAL</b>	<b>\$36,900</b>	<b>\$33,600</b>	<b>\$27,500</b>	<b style="text-align: center;">\$6,100</b>	

orbital and outerplanetary space missions, as well as for terrestrial applications.

**Objectives.** The principal objectives of the space and terrestrial systems applications program are:

- To provide the U.S. with a viable nuclear option for space power by continuing development of technology and qualification of isotope systems and reactor power systems.
- To develop and deliver qualified nuclear energy systems for use on approved U.S. space missions.
- To demonstrate the beneficial use of radioisotopes in various terrestrial applications.

The program currently consists of three projects: (1) Static Outerplanetary Radioisotope Thermoelectric Generator (RTG) Project, developing RTG's for NASA's Galileo mission and the International Solar Polar Mission; (2) Space Reactor Technology Program (SP-100), an advanced technology readiness program; and (3) a terrestrial RTG project that is classified.

In FY 1983, program activities have been narrowed to the major program element dealing with space applications of nuclear power sources. Beginning in FY 1982, responsibility for the terrestrial applications efforts on the Beneficial Uses of Radioisotopes has been transferred to Defense Waste Management.

**Description.** The Space and Terrestrial Applications Program has evolved from efforts to develop nuclear power for aerospace applications since the early 1950's. The Department and its predecessor agencies have provided nuclear expertise for missions of the National Aeronautics and Space Administration, the Department of Defense, and other Federal users.

A radioisotope thermoelectric generator basically utilizes the heat from a radioactive material, plutonium-238, to produce electrical power. The heat source is one of the two major components of an RTG, the other being the thermoelectric converter. The converter uses silicon-germanium elements to provide the spacecraft unregulated DC power. The design is modularized to allow for ease of increase in power for future designs. The General Purpose Heat Source (GPHS) represents a significant increase in the state of the art of thermoelectric conversion. Compared to the Multi-Hundred Watt (MHW) RTG used in the Voyager I and II missions, the GPHS yields almost 40 percent more power per pound. The power, between 255 and 290 watts, is used to operate equipment aboard the spacecraft, such as transmitters and cameras, as well as heat critical components during long-term exposure to the extremely

cold temperatures of outer space. Since the first satellite and terrestrial missions in 1961, the RTG's have met or exceeded all design goals with over 99 percent reliability.

The Space Nuclear Systems program is divided into flight systems development and flight systems support elements.

#### **a. Flight Systems Development**

This program element includes the design, development, fabrication, and assembly of the isotope space power converter subsystems for the NASA Galileo and NASA/European Space Agency International Solar Polar Mission (ISPM) spacecraft. The isotope qualification converter and several flight converters will be supported by this subprogram element throughout the flight acceptance and qualification levels of tests at Mound Facility. The Updated Safety Analysis Reports for both missions are planned to be published. DOE has initiated discussions with NASA to expand reimbursable work to include the qualification and spare flight units.

As currently programmed, the Space Reactor Technology Program (SP-100) will be continued in collaboration with NASA. Coordination with NASA and the Defense Advanced Research Projects Agency (DARPA) is now underway with a view to establishing an expanded tri-agency program (DOE, NASA, and DOD) with the DOE as the lead agency responsible for technology and development of the space reactor subsystem. Experimental work to demonstrate technology readiness of the reactor core heat pipe heat transfer system, material characterization and compatibility, irradiation component testing, and reactor control activities will be pursued. Current space reactor component attributes are targeted for a power system at the 100 kW(e) level in the 1800 kg to 2500 kg weight range. Overall system performance characteristics are aimed toward NASA and DOD missions in the 1990's.

#### **b. Flight Systems Support**

This program element supports fuel form production, encapsulation, heat source component manufacturing and assembly, environmental testing of the fueled flight units, and the overall independent safety and safety testing activities. In FY 1983, a significant manufacturing and testing program must be pursued both to meet the tight delivery schedules and the rigorous quality and safety requirements of the program. Iridium blanks fabricated at the Oak Ridge National Laboratory will be provided to the Mound

Facility where the iridium is formed into fuel capsule containers. The Savannah River Plant will manufacture 63-watt thermal pellets of plutonium-238 and encapsulate them into the iridium containers provided by the Mound Facility.

Graphitic heat source parts will be procured, fabricated, and assembled for final installation into the thermoelectric converter hardware by Mound Facility staff. Safety analyses and safety testing by the Los Alamos National Laboratory will be conducted on representative flight isotope hardware components to assess the safety margin of the system.

Certain ongoing activities will not be conducted beginning in FY 1983. The independent technical and quality assurance efforts, which support both the flight development and research work, will be phased out. Also, reduction of fuel form production and encapsulation operations at Savannah River Plant is under consideration, in addition to the reduction of assembly and testing operations of flight fueled units at the Mound Facility, and converter fabrication work at General Electric, Valley Forge, Pennsylvania. In addition, the advanced modular isotope generator technology program will not be continued.

Mission system development work is usually performed by industrial contractors. Fuel and safety research and development, special metals technology research, capsule hardware fabrication, and heatsource assembly are done in Government-owned contractor-operated laboratories and plants because these operations depend on the nuclear facilities, equipment, and expertise maintained for nuclear fuel and weapons programs. Other activities performed by industrial or institutional contractors include: quality assurance and reliability monitoring; isotope materials and capsule development; environmental impact and safety evaluation; advanced studies on thermoelectric materials and mission-requirement projections; technical consultation; and development and delivery of qualified nuclear energy systems for use on approved U.S. space missions; i.e., the NASA Galileo Mission scheduled for launch in March 1985, and the International Solar Polar Mission scheduled for launch in 1986. This includes related fuel form production, encapsulation, safety testing and analysis.

Continuing progress is being made in developing power systems of greater compactness, lighter weight, and improved conversion efficiency and safety. The Flight Systems Development program uses all available innovations in materials and design to accommodate the increasing power requirements of specific planned missions. In addition, the requirements of this program stimulate and guide the related power systems technology and support activities, as well as those of space power system safety and fuel development and production.

**Implementation/Strategy.** DOE provides for the initial design, development, demonstration, and quality assurance of space nuclear power systems to meet user mission objectives. As the space nuclear systems become more routine in character, user agencies will take on the respon-

sibilities to plan and budget for follow-on systems and DOE will support such activities on a reimbursable basis.

For space nuclear systems, management policy permits funding of the first-of-a-kind nuclear systems, with the costs for follow-on flight systems being reimbursable to DOE. In certain cases, planning carries a developmental system through to a point of technology readiness only; the remaining flight development and demonstration costs are borne by the user agency.

Program logic includes the coordination of the space nuclear power development program with the user agencies to assure that the program activities are in keeping with user needs. Formal interagency agreements are used on specified space missions.

The directions the program takes are determined both by user agency product requests and by initiatives indicated by user trends and technology developments. Before a major application effort starts, cost/benefit analyses are conducted when the development risks and potential benefits can be meaningfully identified in advance. These analyses include mission and commercial requirements; environmental, health, and safety requirements; and specific needs (such as reliability, longevity, survivability, and quality assurance); and consider non-nuclear as well as nuclear alternatives. Program work is undertaken in concert with appropriate interagency formal agreements. Liaison between DOE, NASA, and other user agencies is pursued at several management levels through the medium of coordinating boards with both technical and administrative membership. These interagency coordinating groups provide the information on which the direction of the advanced research and technology activities is focused.

As the technology and support programs advance and are integrated into a system technology, user hardware requirements are specified and the system development and fabrication activities begin. The appropriate environmental assessments and impact statements, preliminary and final safety analysis reports, safety testing, evaluations, and fuel fabrication and assembly are done concurrently with the system development. Upon completion and acceptance testing, the end product is delivered to the user for operational use.

**Accomplishments.** The recent spectacular flights by Jupiter and Saturn of the NASA spacecraft VOYAGER and PIONEER have also marked additional milestones in the continuing successful and safe use of nuclear electric power in outer space. Since 1961, the United States has launched 22 NASA and military spacecraft having all or part of their power requirements supplied by nuclear power sources. Twenty-one of these spacecraft were powered by RTG's and one by a nuclear reactor. The history of these sources has shown that they can be safely and reliably built and launched to meet a variety of mission objectives. Future missions committed to nuclear power include NASA's GALILEO mission, which will launch an orbiter and atmospheric probe to Jupiter and the International Solar Polar Mission which will obtain scientific data on the sun and solar wind from high latitudes.

Within the last 6 years, significant progress has been made in increasing the thermal output from the radioisotope heat sources, and improving the efficiency in the static thermoelectric converters. For example, the heat sources aboard the Viking landers on Mars each delivered about 680 thermal watts, yielding a power output of 40 watts at a conversion efficiency of approximately 6 percent. In contrast, the Multi-Hundred-Watt (MHW) heat sources powering the LES 8 and 9 communications satellites for the USAF and the NASA Voyager spacecraft for outerplanetary exploration each delivered 2400 thermal watts, yielding nearly 160 watts at an efficiency just under 7 percent. The dramatic photographs transmitted from Jupiter and Saturn by the Voyager spacecraft were possible only through the use of such nuclear power systems.

The major accomplishments in FY 1981 were:

- Continued development of advanced thermoelectric materials and power modules.
- Identification and evaluation of applications for space nuclear power systems for missions up to the year 2000.

- Completed fabrication of radioisotope heater unit components.
- Delivered MHW fuel sphere assemblies for safety testing.

Major planned accomplishments in FY 1982 are:

- Begin testing of the qualification GPHS-RTG.
- Continue fabrication and testing of Galileo and ISPM components.
- Continue SP-100 space reactor development.
- Continue safety analysis reviews for Galileo and ISPM.

Major planned accomplishments in FY 1983 are:

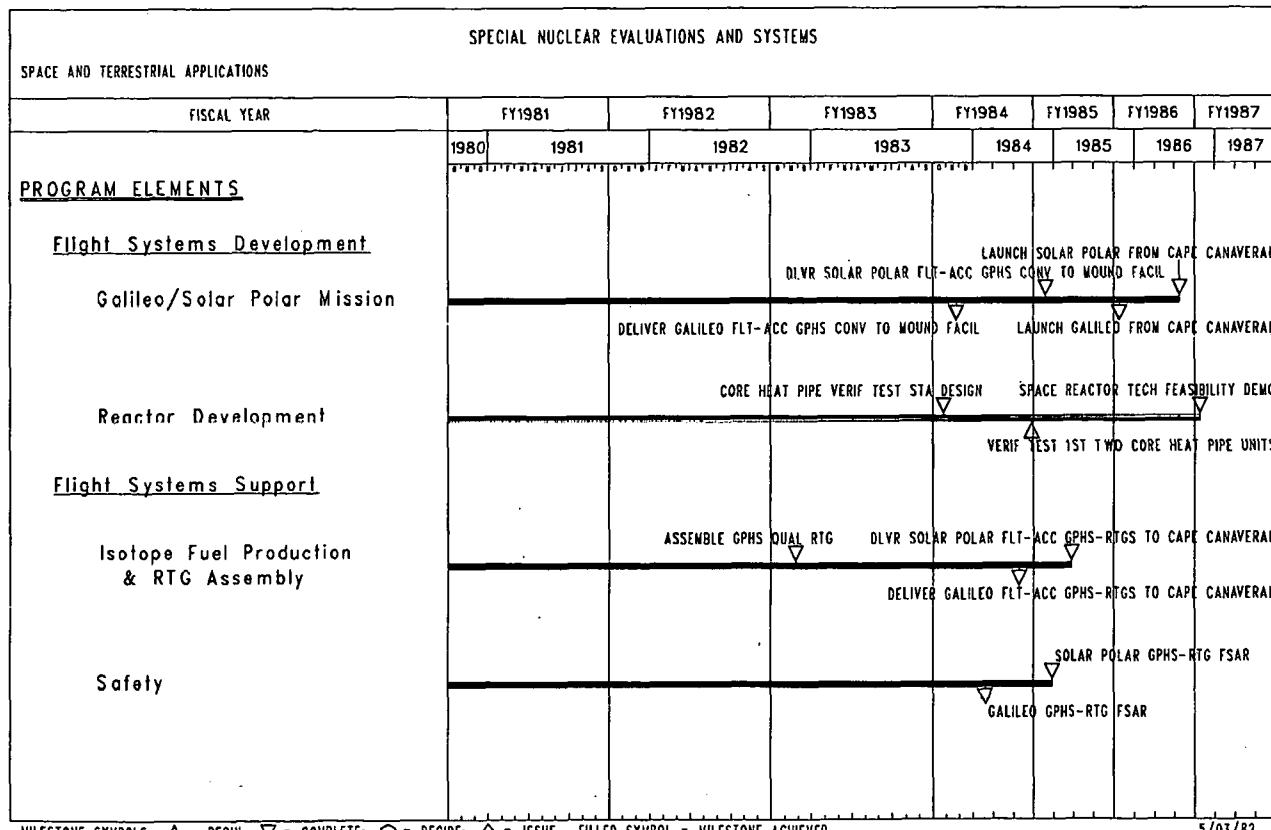
- Complete GPHS-RTG qualification test.
- Fuel and test first flight unit.
- Prepare development plan, recommend baseline design, and initiate component testing for SP-100.
- Conduct heat source fabrication, generator fueling, and acceptance testing for Galileo to ISPM.

**Resources.** The following table shows the operating funding levels for the FY 1981 through FY 1983 period.

SPACE AND TERRESTRIAL APPLICATIONS

PROGRAM ELEMENT	BUDGET AUTHORITY (DOLLARS IN THOUSANDS)			INCREASE (DECREASE)
	OBLIGATIONS FY 1981	APPROPRIATIONS FY 1982	REQUEST FY 1983	
FLIGHT SYSTEMS DEVELOPMENT	11,700	10,500	13,500	3,000
FLIGHT SYSTEMS SUPPORT	20,900	20,900	14,000	(6,900)
TERRESTRIAL APPLICATIONS	2,500	2,200	0	(2,200)
TOTAL	35,100	33,600	27,500	(6,100)

**Milestones.** The key milestones for the Space Nuclear Systems program are shown in the summary milestone chart below.



## 2. Advanced Technology and Systems Assessments

Every energy production plant began with a concept that was investigated, developed, and ultimately brought to the marketplace. Nuclear technology, no exception to this process, has nurtured many new ideas, some of which are improvements to existing technology; others foresee completely new technologies. It was the function of the work described in this section to compile the data and to conduct the analyses required to evaluate these new concepts.

**Objectives.** The basic objective of the Advanced Technology and Systems Assessments program is to provide to energy-related organizations, both in the Federal and non-Federal sectors, assessments of advanced nuclear systems and their applications to meet a broad range of the Nation's energy needs. These assessments include the technical, economic, environmental, social and institutional aspects and impacts of development and/or application. Associated with this objective was support of confirmatory research as required for assessment purposes.

**Description.** This assessment activity, which had been on-going for a number of years, has been terminated with completion of all activities planned in FY 1982 using, as far as practicable, prior year funding. The activity was structured principally to provide a screening mechanism to evaluate proposed new systems and systems applications, and to provide a basis for selection of those which have the potential of meeting both near-term and far-term needs for energy in the United States. New or advanced systems, and their associated applications, have been assessed and work terminated or emphasized, depending on the perceived potential for significant advances in specific energy-related areas. The sources of new approaches or ideas were not restricted, to help ensure that promising concepts would not be eliminated or overlooked.

This program for improving the applicability of nuclear energy was focused on two related elements: (1) applications to improve thermal utilization of energy produced by power reactors such as the concurrent production of electricity and use of thermal energy for district heating or for industrial processes; and (2) methods to increase the siting acceptability of power reactors, such as nuclear energy centers, advanced cooling systems for application in water-short regions, establishment of powerplant siting criteria to mitigate the impacts of waste heat releases, and the maintenance and update of a computerized system to predict where and when less water consumptive cooling methods would be needed in the U.S.

**Implementation/Strategy.** In the area of increased thermal utilization, planning and design studies in the co-generation area directed towards implementation of a 200 MWt hot water district heating system in St. Paul were completed in FY 1981, with partial support by the Department of Energy. The construction phase for this system for St. Paul is being pursued by the city, using an existing coal-

fired powerplant as the energy source. However, since the Twin Cities area (Minneapolis and St. Paul) could require up to the order of 4000 MWt if full hot water district heating were employed, a study has been initiated to evaluate the possible economic and technical feasibility of retrofitting the two existing Prairie Island nuclear powerplants near Red Wing, Minnesota, to supply the required thermal energy. This study is planned for completion in early FY 1982. It should be noted that the 35-mile distance from these two plants to the Twin Cities is well within the acceptable distance for hot water transmission based on established European experience. It is of principal importance that the Prairie Island study will provide generic data on the technology of retrofitting central station nuclear plants for co-generation, as a national option.

Past studies of cogeneration for industrial process heat using intermediate size (1200-MWt) nuclear powerplants indicated that they have the capability of displacing oil and natural gas and producing industrial process steam at lower cost than alternative methods. In this regard, studies of a cogeneration energy source to provide both electric power and process steam for a "grass roots" model industrial center in the Gulf Coast area will be completed in FY 1982. In such a center, the steam requirements of the industries would be compatible with those available from co-located powerplants.

One of the major concerns related to the use of nuclear power (in fact, all central station power) is plant siting. Although nuclear plants do not emit combustion gases and particulates, they do require large quantities of water for cooling and large areas of land for exclusion boundaries. They also reject large quantities of heat and moisture when evaporative cooling is utilized. The meteorological impacts of such heat and moisture releases need to be assessed in order to mitigate any undesirable environmental effects through improved plant siting techniques. Such effects

may be enhancement or redistribution of rainfall or snowfall, fogging, or cloud shadowing. In addition, siting of powerplants in water short areas or areas where there are major competing demands for water calls for less water consumptive cooling methods such as dry or wet/dry cooling. Increased population limitations and other reasons may also favor the clustering of a number of nuclear plants at a single location termed a nuclear energy center.

Particular projects to be completed in FY 1982 in the area of increased siting acceptability are the study of a 9-unit nuclear energy center located at Green River, Utah (cooperatively conducted with the State of Utah), and a 5-year project on the meteorological effects of thermal energy release (METER) including validated predictive atmospheric models. Support of operations of the DOE/Electric Power Research Institute/utilities advanced wet/dry powerplant cooling system test unit at a Pacific Gas and Electric power station site will be terminated at the end of FY 1982, as will support of the cooling water availability/use data bank at the Hanford Engineering Development Laboratory.

**Accomplishments.** The following activities were completed in FY 1981:

- Planning phase for St. Paul 200 MWt district heating system.
- South Carolina energy center study.
- Large-scale field tests of the effects of cooling tower heat and moisture releases on meteorology.
- Revised assessment of water resources for cooling electric generating units.
- Data acquisition system, safety analysis, and test plan for advanced powerplant cooling test unit.

The FY 1982 accomplishments are directly associated with the completion of the following activities during this fiscal year.

- Utah Energy Center Study.
- Feasibility of retrofitting the Prairie Island nuclear plants for cogeneration/district heating.
- Support of the DOE/EPRI/utilities wet/dry cooling test unit.
- Analysis of nuclear cogeneration/process heat at a new industrial site.
- Analysis of the future need for and location of advanced cooling systems.
- Analysis of meteorological effects of powerplant heat and moisture releases.

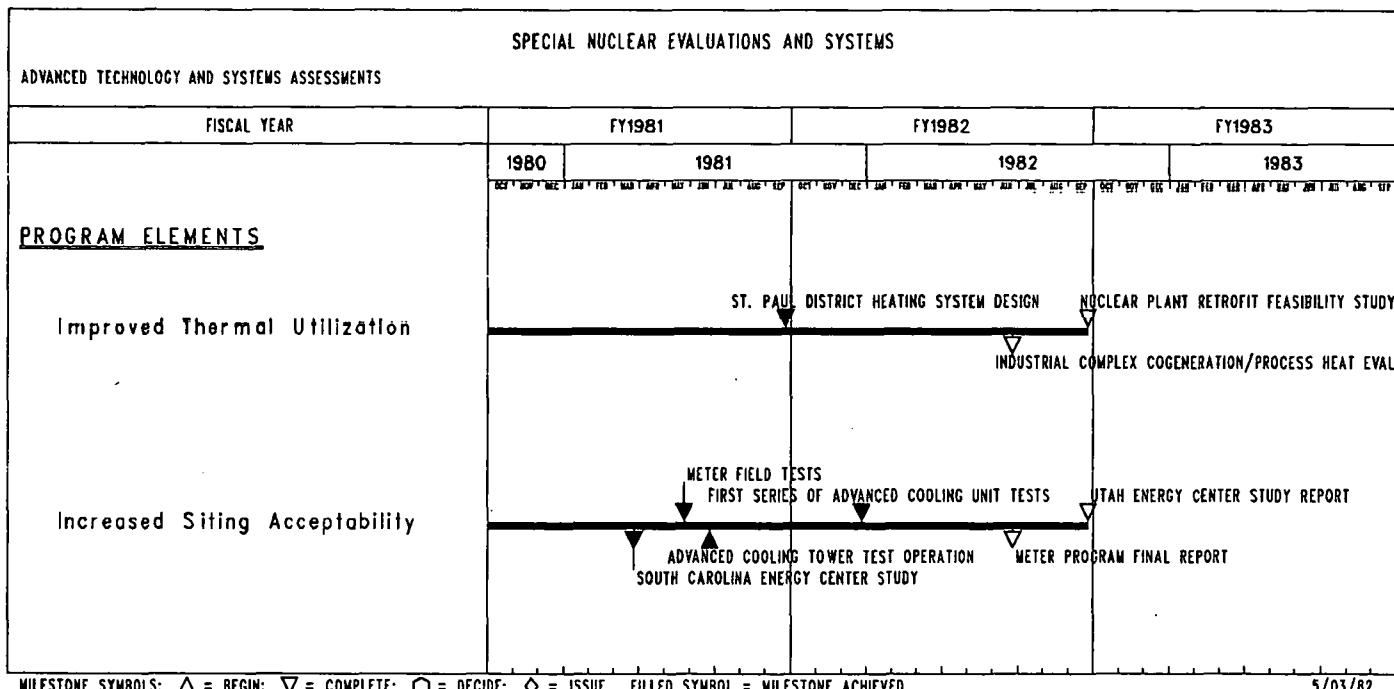
No program activities are planned for FY 1983.

**Resources.** The following table shows the operating funding levels for the FY 1981 through FY 1983 period.

#### ADVANCED TECHNOLOGY AND SYSTEMS ASSESSMENTS

PROGRAM ELEMENT	BUDGET AUTHORITY (DOLLARS IN THOUSANDS)		
	OBLIGATIONS FY 1981	APPROPRIATIONS FY 1982	REQUEST FY 1983
IMPROVED THERMAL UTILIZATION	700	0	0
INCREASED SITING ACCEPTABILITY	1,100	0	0
<b>TOTAL</b>	<b>1,800</b>	<b>0</b>	<b>0</b>

**Milestones.** Major milestones for the Advanced Technology and Systems Assessment program are shown in the chart below.



# III. PROGRAM MANAGEMENT

This chapter describes the structure of the fission energy program and summarizes the management approach and tools used in its execution and control.

## A. Management Philosophy

The management philosophy used in the civilian reactor development program is a product-oriented, management-by-objectives system. The principal management functions and their interrelationships, as shown in Figure 9, are to:

- Establish program goals in accordance with national energy policy;
- Establish a comprehensive plan and schedule to achieve these goals;
- Determine and secure resources required to execute the plan;
- Separate the total program scope into manageable work segments and assign responsibility and resources to contractors for work segment execution;
- Monitor and measure progress of the program against resources expended, taking corrective action as necessary; and
- Revise the overall plan and redirect subordinate plans as necessary to accommodate changes imposed by:
  - external forces, such as, changes in national energy policy, projected need dates, budget actions, etc., and
  - internal events, such as, new technological findings in the program, unforeseen delays, etc.

The organizational structure and management approach used by the civilian reactor development programs are described in Section III-B. Program assurance, safeguards and security aspects common to all fission energy programs are discussed in Section III-C.

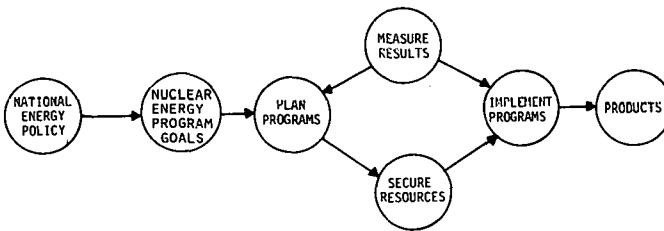


Figure 9. Fission energy program management functions and interrelationships.

## B. Organization

### 1. Program Functional Elements

The three generic functional elements in the civilian reactor development program are:

- Developmental and demonstration projects;
- Base technology programs; and
- Supporting facilities.

A complete developmental program contains all three elements. Developmental and demonstration projects bring all elements of the program together, resulting in the necessary technology needed by industry for commercialization. The scope and timing of the projects drive the remainder of the program. Technology development (in such areas as nuclear fuels, safety, and components) supports specific project requirements and provides the basis for continued progress between successive projects. Test facilities are necessary to support both the base technology programs and to confirm performance of project systems. The relationships of projects, base technology programs, and facilities are illustrated in Figure 10.

The DOE fission energy program elements include a varying range of balance among the three basic functional elements; i.e., some program elements include substantial work in all three, while others are limited to basic technology development with no plans for demonstration projects. However, the intent in most cases is to develop a supporting technology base through basic development activities, utilize test facilities as appropriate to contribute to the technology program, and ultimately to demonstrate the technology on a scale that ranges from testing in existing commercial facilities to constructing and operating dedicated Government-owned facilities.

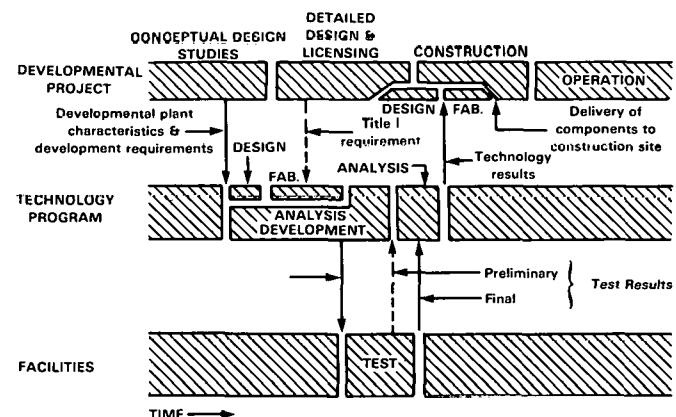


Figure 10. Relationships among projects, technology programs, and facilities.

## 2. Work Breakdown Structure

The work breakdown structure (WBS) is one of the most useful and important tools in the planning and control of fission energy programs and projects. By definition, a WBS is a product-oriented logic diagram depicting the hardware, services, and data that comprise a program. In such a diagram, the work elements relate to one another through an integrated hierarchy leading to the end product. Thus, the WBS diagram graphically represents the various efforts required, how they interact, and the sequence that is required for success.

Delineation of a WBS begins with the broadest definition of the program (e.g., fission energy) or project to be described. Each of the work elements required for completion is successively subdivided into progressively smaller units until at the lowest level each element in the WBS represents a discrete package of relatively short duration, with a definite beginning and end, and to which a specific budget can be assigned. Completion of all these packages constitutes completion of the program or project, and the summation of the costs of the individual packages yields the total cost of the project.

Thus, a WBS is both a planning tool, in which all activities required for the completion of a program are carefully planned in advance, and a control mechanism that enables close monitoring of progress in terms of objectives (milestones), schedule, and cost. The WBS approach has been adopted as an integral part of the technical and budgetary management of the entire fission energy program and its subdivisions.

Within the Department of Energy, the Assistant Secretary for Nuclear Energy (ASNE) administers the research and development programs associated with fission energy and the management of radioactive wastes. Waste management activities and uranium enrichment and resource activities are covered in separate program summary documents.

The civilian reactor development R&D activity is divided into three categories under the supervision of the Deputy Assistant Secretary for Nuclear Reactor Programs and the Deputy Assistant Secretary for Naval Reactor Programs: Converter Reactor Systems, Breeder Reactor Systems, and Special Nuclear Evaluations and Systems. Figure 11 shows the first three levels of the fission energy WBS for civilian nuclear programs. The uppermost Level 1 includes all the activities under the cognizance of the Deputy Assistant Secretary for Nuclear Reactor Programs, and one activity under the cognizance of the Deputy Assistant Secretary for Naval Reactors. Level 2 defines the major subdivisions of the program. Each of these has fission as a common element, but they differ in basic application or uses. Subdivisions at Level 3 are identified by a particular end product (e.g., LWR or LMFBR). Each major subdivision at Level 2 is described in a separate section in this document, and each of the end products in Level 3 constitutes an individual program.

Levels 4 and below show projects and their supporting activities. A WBS for a typical major construction project,

which would be represented at Level 4 or below, is shown in Figure 12. Further breakdowns of the Level 3 program elements are presented in the sections of this document in which those elements are described.

## 3. Organizational Structure and Delineation of Responsibilities

With the exception of the water cooled breeder program, the Deputy Assistant Secretary for Nuclear Reactor Programs implements the civilian reactor development program in accordance with policy established by the Assistant Secretary for Nuclear Energy. Figure 13 is an organization chart showing the offices under this Deputy Assistant Secretary. The water cooled breeder program is implemented by the Deputy Assistant Secretary for Naval Reactors.

A task-responsibility matrix depicting the relationship between the WBS and the organizational structure is shown in Figure 14. The WBS program structure down to Level 3 is shown along the top, and the organizational units (to the office level) responsible for the work are shown along the left side. Responsibilities are indicated by circles at the intersections of the horizontal and vertical lines.

It is DOE policy to decentralize program and project management activities. While overall program responsibilities are retained at Headquarters, project management responsibilities are delegated to DOE Field and Project Offices.

**Headquarters role.** Headquarters is responsible for the overall implementation of the fission energy program in accordance with upper DOE management policies. Headquarters does this by:

- Developing program plans, budgets, and resource allocation requirements;
- Working with the Office of Management and Budget, Congress, Federal and State agencies, industry, universities, the governments of other nations, and international organizations to coordinate fission energy activities;
- Providing program guidance and resources to DOE Field and Project Offices for implementation; and
- Monitoring program execution with DOE Field and Project Offices to ensure that programs are being implemented as planned.

**Field and Project Office roles.** The DOE Field and Project Offices are responsible for implementing the programs in conformance with the guidance and resources provided by Headquarters. The Field and Project Offices do this by:

- Developing detailed program and project plans, budgets and resource allocations needed to execute the programs as planned;
- Contracting for the goods and services required to conduct the programs; and

- Measuring actual cost and schedule performance versus planned performance, and taking or recommending corrective action as necessary.

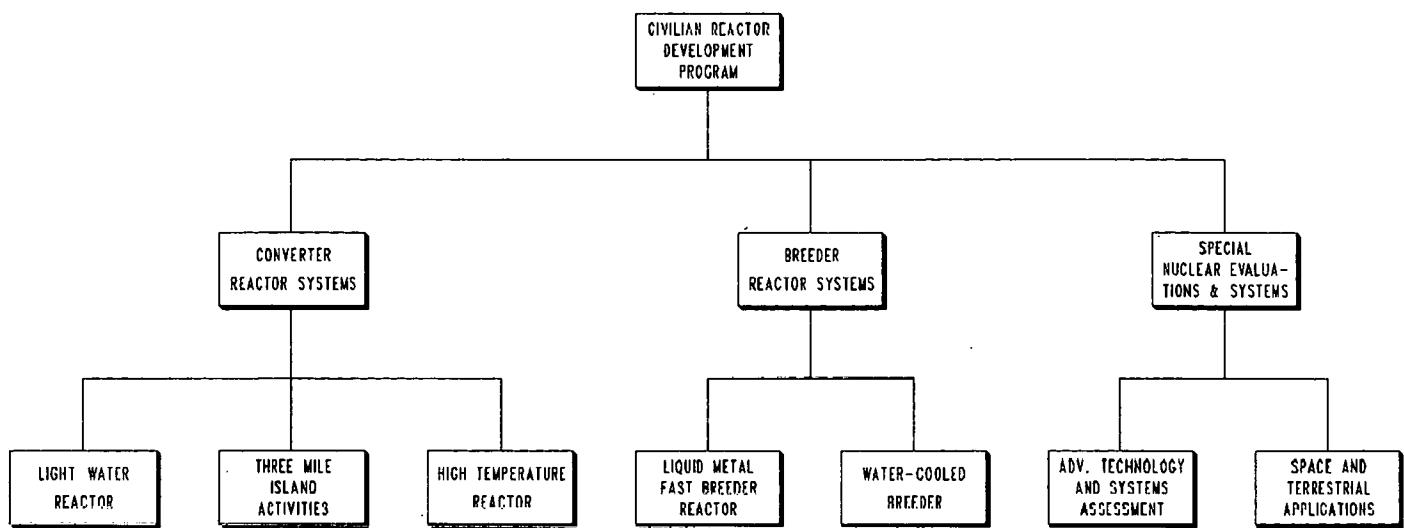


Figure 11. Civilian reactor development program upper-level work breakdown structure.

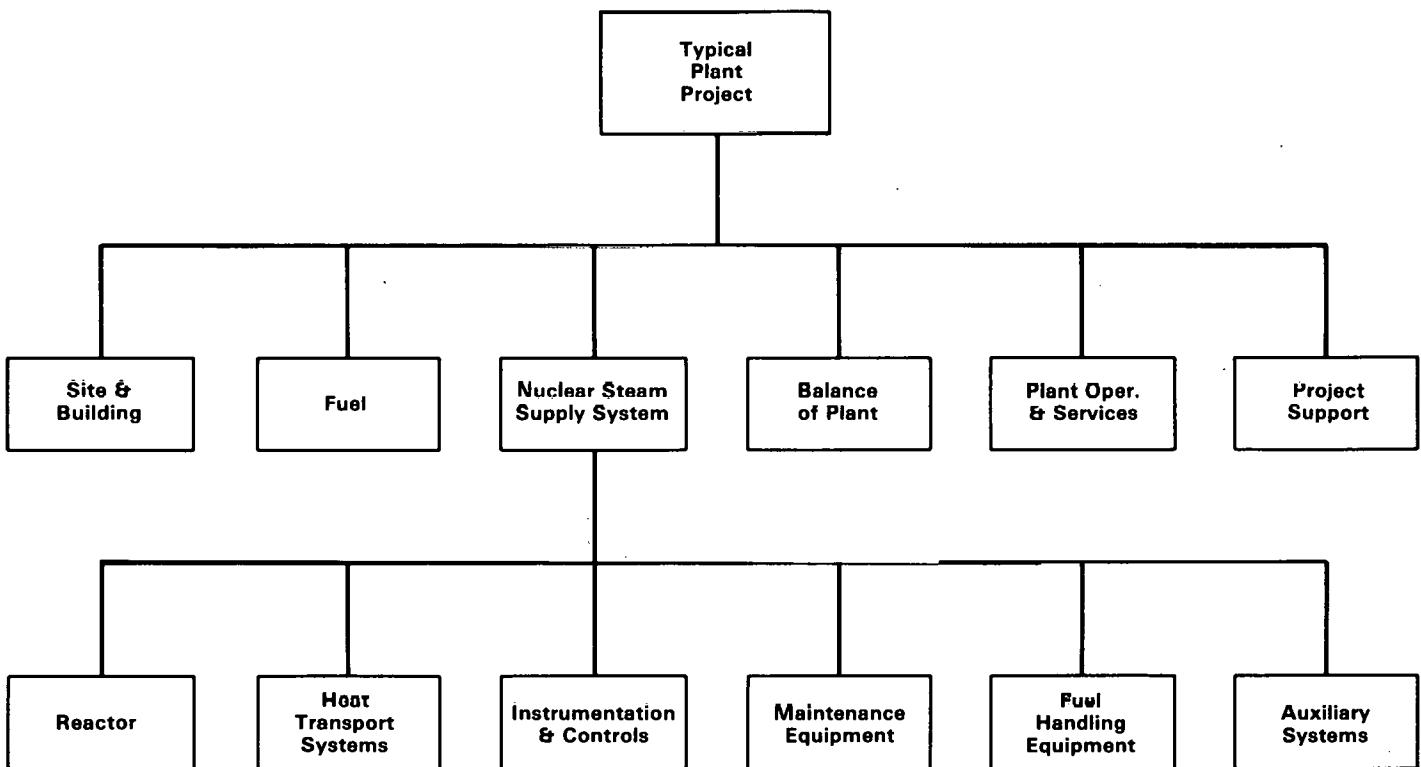
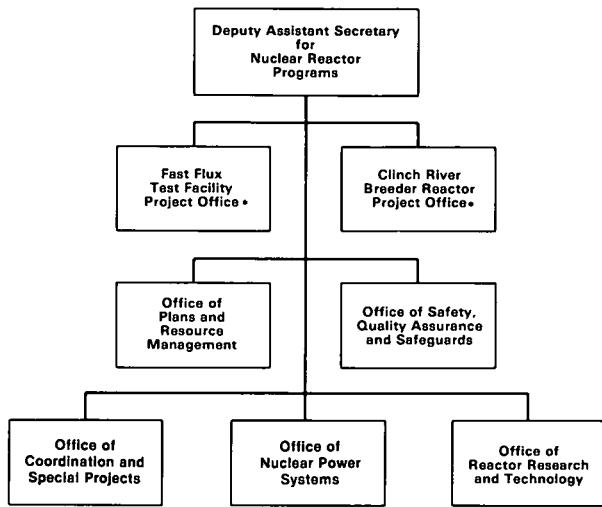


Figure 12. Work breakdown structure for a typical plant project.



\*Figure shows Programmatic Relationships Only; the Project Offices Report Directly to Their Local Operations Offices.

Figure 13. Organization of the Office of the Deputy Assistant Secretary for Nuclear Reactor Programs.

**Contractors' roles.** The contractors, which include national laboratories, universities, and industry, are responsible for program execution. They accomplish this by:

- Initiating proposals or responding to requests for proposals from DOE Field and Project Offices;

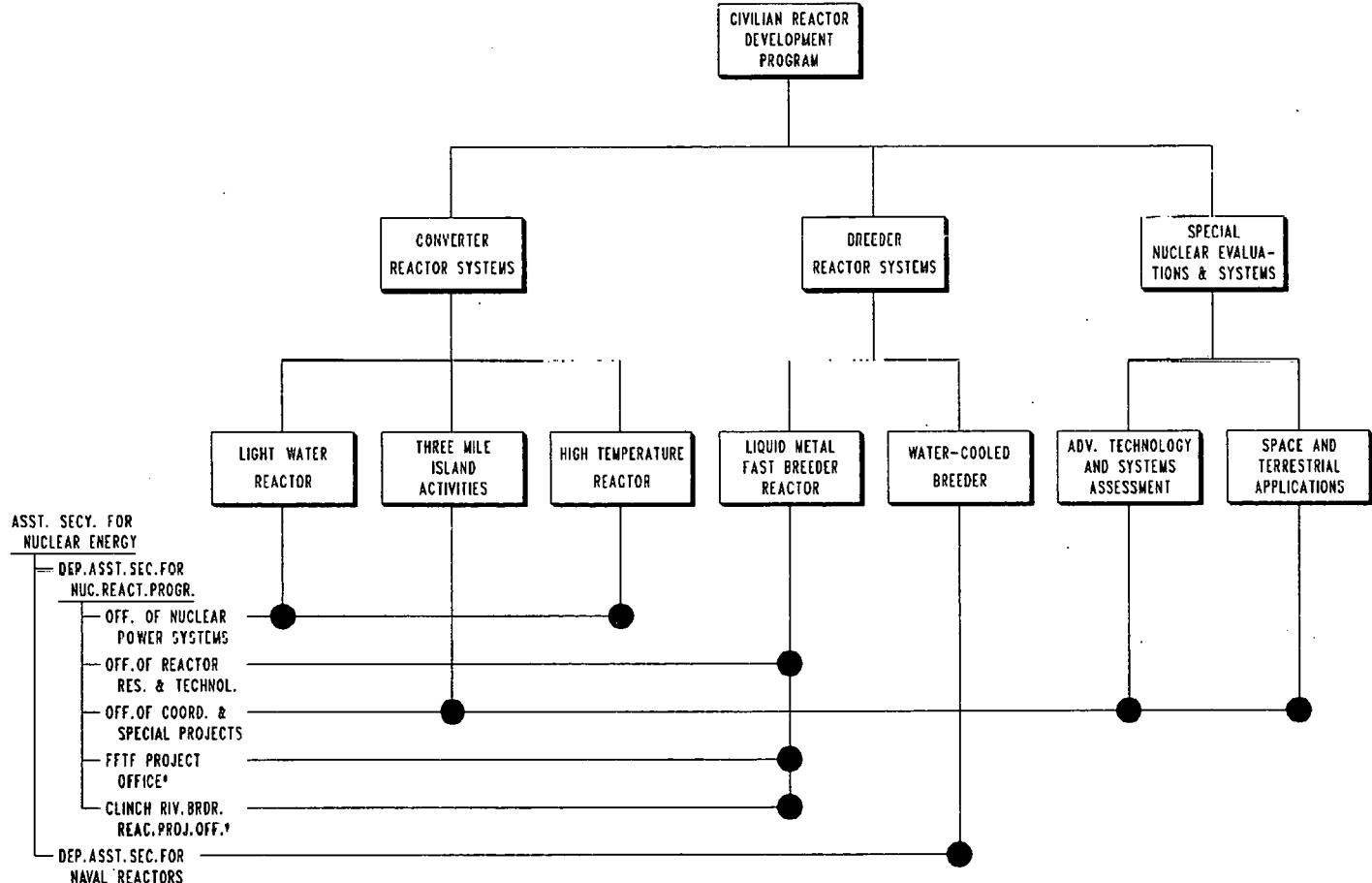
- Assisting in the development of detailed program plans; and
- Carrying out the technical program in accordance with the guidance provided by the Field and Project Offices.

#### 4. Program Planning, Budgeting and Control

The Department of Energy provides a mechanism for the systematic consideration of program and resource allocation issues, with strong focus on multiyear programs. To accomplish this, formal documentation is prepared to present plans in programmatic resource terms.

The fission energy program planning documents provide clear visibility as to the course to be followed, and serve as contracts between organizational units--both vertically and laterally in the management structure. Plans and planning documentation are not static, however. They must accommodate changes resulting from events both external and internal to the program. Such program changes are made in an orderly and coherent manner with full recognition of programmatic and budgetary impacts.

The documentation identified in Figure 15 constitutes a hierarchy of planning documents for managing the program. Detail and numbers of documents increase from top to bottom of the planning hierarchy. This architecture pro-



NOTE: \*FIGURE SHOWS PROGRAMMATIC RELATIONSHIPS ONLY; PROJECT OFFICES REPORT DIRECTLY TO THEIR LOCAL OPERATIONS OFFICES.

Figure 14. Relationship between Civilian Reactor Development Program organizational structure and program WBS.

vides the structure through which policy and technical and fiscal guidance are communicated downward and through which program progress, cost, schedule, and technical data are reported upward. All major planning documents are updated no less than annually in accordance with the planning and budget cycle of the Federal Government. As shown in the figure, overall guidance is provided through national energy policy emerging from both the Executive and Legislative branches of the Government.

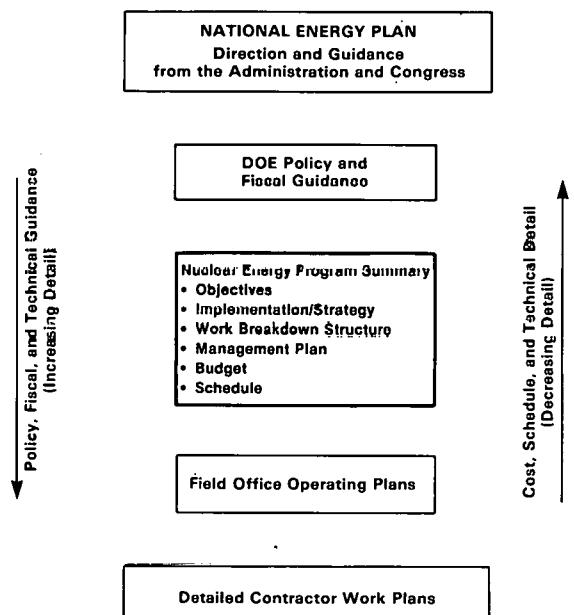


Figure 15. Hierarchy of management planning documents.

Program control is achieved through the use of an established hierarchy of milestones emerging from the various levels of the work breakdown structure. Milestones have been arranged in terms of their relative importance to allow their control at appropriate management levels. The presentation of milestones in this document reflects these efforts.

## C. Program Assurance, Safeguards and Security

### 1. Program Assurance

A program assurance function is conducted to help assure that nuclear energy programs under the jurisdiction of the ASNE are carried out in a safe, reliable, and effective manner. Included are activities directed at assuring the safe operation of nuclear energy projects and programs; at the development and implementation of quality assurance programs; and at the development and application of engineering standards. In all three of these activities, the basic responsibility lies with the cognizant line program management organization. The program assurance function is responsible for establishing overall policies and guidelines for all ASNE activities; providing technical and

managerial assistance to the line organizations; and advising the ASNE relative to these matters.

In the safety area, the responsibility is executed primarily by developing policies for nuclear safety; performing safety assessments for Safety Analysis Reports and other safety-related documentation; conducting safety appraisals of selected facilities; and reviewing, as necessary, field office nuclear safety programs. Two Safety Assessment Offices, one located at Argonne National Laboratory (ANL) and the other at Hanford Engineering Development Laboratory (HEDL), provide technical assistance in this area.

In the quality assurance area, the responsibility is executed by assisting nuclear energy managers in the establishment of effective quality assurance programs; in the development of quality assurance training programs; in the development of program-specific quality assurance methods, standards and requirements; in preparing quality assurance information on acceptable practices, generic problems and solutions, and lessons learned; and in planning and participating in ASNE program quality assurance audits. The Nuclear Quality Assurance Program Office, located at HEDL, provides technical assistance in this area.

In the nuclear standards area, the responsibility is executed by assisting nuclear energy line program managers in the development and application of engineering standards; in the processing of changes to program-specific standards; in the management of the interface with voluntary consensus standards organizations; in the development of standards policy guidance and procedures; and in maintaining a nuclear energy standards data base. The Nuclear Standards Management Center, located at Oak Ridge National Laboratory, provides technical assistance in this area.

### 2. Safeguards and Security

Safeguards and security activities are being conducted to maintain and upgrade physical security systems, techniques, and procedures in conjunction with improved methods of control and accountability at ANL, HEDL, and the Idaho National Engineering Laboratory (INEL). These activities are being carried out to achieve integrated safeguards systems for DOE facilities dedicated to civilian nuclear energy programs that acquire, use, store, and dispose of special nuclear materials. It is intended that these upgrading activities will provide, to the maximum extent practicable, the protective measures necessary to detect and prevent loss or diversion of special nuclear materials from unauthorized use by insiders; prevent theft by outsiders; and protect nuclear materials and facilities against malevolent acts, attack, or intrusion.

The primary policies and guidelines for implementing these safeguards activities are set forth in DOE Orders which are currently being strengthened and updated to meet the more rigorous demands of today's environment. The overall scope of these guidelines encompasses a wide spectrum of operations, equipment, and construction activities that will ultimately be integrated and implemented in conformance with safeguards plans designed to meet the

specific needs and characteristics of each facility or site. A significant portion of these upgrading efforts consists of line item construction projects which, because of budgetary considerations, have been implemented on a phased basis. Major construction at ANL, HEDL, and INEL was initiated during FY 1978, 1979, and 1980, respectively. An additional safeguards construction item will be initiated at

ANL during FY 1983 and it is planned that future efforts, including construction, will be implemented to further comply with emerging new requirements in DOE to meet such things as changing threat patterns and potential new obligations which may evolve from the December 1980 US/IAEA Treaty Agreement.

## APPENDIX A

### Program Participants and Regional Distribution

This appendix describes the types of contractors, their geographic distribution, and the roles of DOE's national and engineering laboratories in the civilian reactor development program.

#### 1.0 TYPES OF CONTRACTORS

Table A-1 shows the breakdown of the fission energy program elements among the national and engineering laboratories, major industrial and utility contractors, and universities. In general, 40-50 percent of the work is carried out in the laboratories. The data in Table A-1 tend to underestimate the role of industry in the program, because over 65 percent of the program being conducted in DOE laboratories is performed in laboratories operated for the Government by industrial contractors, as opposed to those operated by universities. This is shown in Table A-2. When the total industry and university involvements are compared, the ratio is over five to one in favor of industry.

This is a most important aspect of fission energy program implementation, as the heavy industrial participation, even in the early laboratory development work, facilitates the transfer of technology when commercialization be-

comes desirable. Table A-3 lists the operators, and Figure A-1 shows the locations of the major laboratories engaged in the fission energy program.

#### 2.0 GEOGRAPHIC DISTRIBUTION

The geographic distribution of the program is shown by states in Table A-4. Significant activities are being carried out in 15 of the 50 states, but the heaviest concentrations are in the states where AEC (now DOE) laboratories were established during the early years of the program:

	\$-millions (in FY 1983)
Tennessee	\$263.4
Washington	84.7
Idaho	57.1
Pennsylvania	54.6
Illinois	41.4
California	34.2
New Mexico	14.8
<b>TOTAL</b>	<b>\$550.0</b>

Tables A-5, A-6, and A-7 list the program participation by the major Government installations, major contractors (other than laboratory operators), and universities, arranged by the states in which the work is carried out.

**Table A-1. Civilian Reactor Development Program Participation by Type of Institution**

<i>Type of Institution</i>	<i>FY 1983 participation in program, \$-million</i>				
	<i>LWR Technology</i>	<i>LMFBR</i>	<i>WCB</i>	<i>Space &amp; Terrestrial Applications</i>	<i>Total</i>
National laboratories and other Government-owned installations	19.4	203.5	31.2	9.8	263.9
Major industrial and utility contractors*	1.7	278.5	10.6	17.7	308.4
Universities*	0.5	0	0	0	0.5
Subtotal	21.6	482.0	41.8	27.5	572.8
Minor and undesignated contractors	3.5	4.9	0	0	0.4
<b>Total</b>	<b>25.0</b>	<b>486.9</b>	<b>41.8</b>	<b>27.5</b>	<b>581.2</b>

**Note:** Figures do not total exactly because of rounding.

\*Excluding contract operation of Government-owned installations.

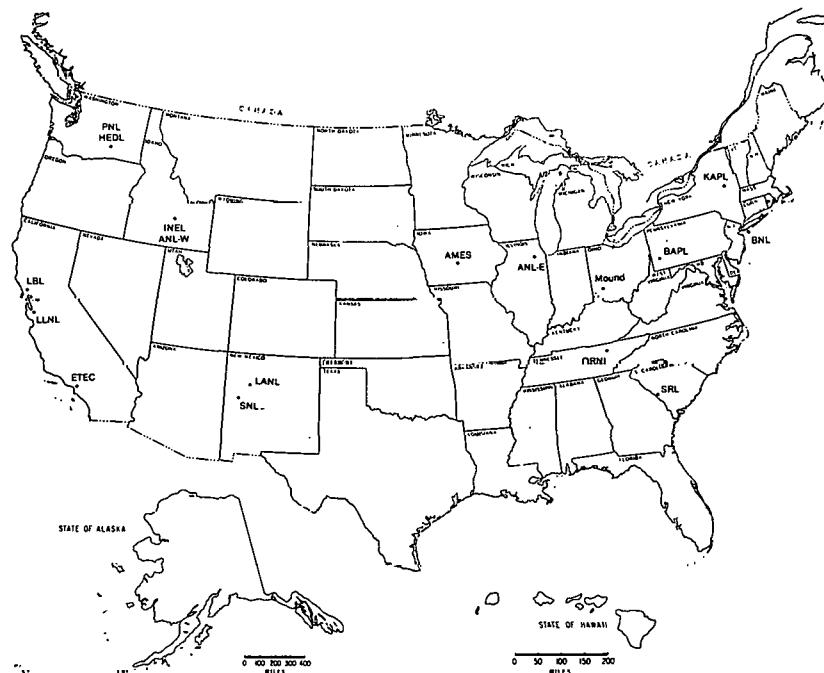
**Table A-2. Civilian Reactor Development Program Distribution Between Industry and Universities**

Sector	FY 1983 participation in program, \$-million				
	LWR Technology	LMFBR	WCB	Space & Terrestrial Application	Total
<b>Industry</b>					
DOE-installation operation	19.2	120.6	31.2	5.2	176.2
Specific projects	1.6	278.5	10.6	17.7	308.4
Total industry	20.8	399.1	41.8	22.9	484.6
<b>Universities</b>					
DOE-installation operation	0.2	82.9	0	4.3	87.4
Specific projects	0.5	0	0	0	0.5
Total universities	0.7	82.9	0	4.3	87.9
<b>Other federal agencies</b>					
Subtotal	21.5	482.0	41.8	27.5	572.8
Minor and undesignated contractors	3.5	4.9	0	0	8.4
Total	25.0	486.9	41.8	27.5	581.2

**Note:** Figures do not total exactly because of rounding.

**Table A-3. Operators of DOE National and Engineering Laboratories**

Laboratory	Map ref. (fig. A-1)	Operator
Ames Laboratory	AMES	Iowa State University
Argonne National Laboratory	ANL	University of Chicago
Bettis Atomic Power Laboratory	BAPL	Westinghouse Electric Corp.
Brookhaven National Laboratory	BNL	Associated Universities of N.Y.
Energy Technology Engineering Center	ETEC	Rockwell International
Hanford Engineering Development Laboratory	HEDL	Westinghouse Electric Corp.
Idaho National Engineering Laboratory	INEL	Edgerton, Germeshausen and Grier, Inc.
Knolls Atomic Power Laboratory	KAPL	General Electric Co.
Lawrence Berkeley Laboratory	LBL	University of California
Lawrence Livermore National Laboratory	LLNL	University of California
Los Alamos National Laboratory	LANL	University of California
Mound Laboratory	Mound	Monsanto Research Corp.
Oak Ridge National Laboratory	ORNL	Union Carbide Corp.
Pacific Northwest Laboratory	PNL	Battelle Memorial Institute
Sandia National Laboratories	SNL	Western Electric Co.
Savannah River Laboratory	SRNL	E. I. du Pont de Nemours & Co.



**Figure A-1. Locations of DOE national and engineering laboratories.**

**Table A-4. Civilian Reactor Development Program Distribution by State**

FY 1983 participation in program (see chapter), \$-thousand

State	LWR Technology	LMFBR	WCB	Space & Terrestrial Applications	Total
California	250	33,900			34,150
Connecticut	20				20
District of Columbia	1,600	4,900			6,500
Florida		6,600			6,600
Georgia	500				500
Idaho	19,250	34,800	3,000		57,050
Illinois	250	41,100			41,350
Maryland				500	500
Nebraska	430				430
New Mexico	550	9,900		4,300	14,750
Ohio				3,477	3,477
Pennsylvania		4,700	38,800	11,100	54,600
South Carolina				6,898	6,898
Tennessee		262,200		1,225	263,425
Virginia	800	4,300			5,100
Washington	150	84,500			84,650
UNKNOWN	1,200				1,200
<b>TOTAL</b>	<b>25,000</b>	<b>486,900</b>	<b>41,800</b>	<b>27,500</b>	<b>581,200</b>

**Table A-5. Civilian Reactor Development Program Participation by National Laboratories and Other Government Installations**

FY 1983 participation in program, \$-thousand

Government installation, location (Field Office)	LWR Technology	LMFBR	WCB	Space & Terrestrial Applications	Total
<b>CALIFORNIA</b>					
Energy Tech. Eng. Center, Canoga Park	(SF)		23,500		23,500
Lawrence Livermore Lab., Livermore	(SF)	100			100
<b>DISTRICT OF COLUMBIA</b>					
Headquarters (HQ)		1,600			1,600
Undesignated (HQ)			4,900		4,900
<b>IDAHO</b>					
Argonne Natl. Lab.-West, Idaho Falls	(CH)		31,900		31,900
Idaho Natl. Eng. Lab., Idaho Falls	(ID)	19,250	2,900	3,000	25,150
<b>ILLINOIS</b>					
Argonne Natl. Lab.-East, Argonne	(CH)		41,100		41,100
<b>MARYLAND</b>					
Applied Physics Laboratory, Silver Spring				300	300
<b>NEW MEXICO</b>					
Los Alamos Natl. Lab., Los Alamos	(AL)	100	9,900		14,300
Sandia Laboratories Albuquerque	(AL)	450			450
<b>OHIO</b>					
Mound Laboratory, Miamisburg	(AL)			3,377	3,377
Battelle Memorial Inst. Columbus	(CH)			100	100
<b>PENNSYLVANIA</b>					
Bettis Atomic Power Lab., West Mifflin	(PNR)		28,200		28,200
<b>SCOTIA CAROLINA</b>					
Savannah River Laboratory, Aiken	(SR)			500	500
<b>TENNESSEE</b>					
Oak Ridge Natl. Lab., Oak Ridge	(OR)		9,700		1,225
<b>WASHINGTON</b>					
Hanford Eng. Devel. Lab., Richland	(FFTFPO)				84,500
Pacific Northwest Lab., Richland	(RL)		84,500		150
	(RL)	150			
<b>Total</b>		<b>21,650</b>	<b>208,400</b>	<b>31,200</b>	<b>9,802</b>
					<b>271,052</b>

**Table A-6. Major Industry and Utility Contractors\* in Civilian Reactor Development Program**

<i>Major contractor, location (Field Office)</i>	<i>LWR Technology</i>	<i>FY 1983 participation in program, \$-thousand</i>			<i>Space &amp; Terrestrial Applications</i>	<i>Total</i>
		<i>LMFBR</i>	<i>WCB</i>			
CALIFORNIA						
Atomics International, Canoga Park	(SF)		2,000			2,000
General Electric Co., Sunnyvale	(SF)		8,400			8,400
Sacramento Municipal Utility Dist.	(CH)	80				80
Science Applications Inc.	(CH)	70				70
CONNECTICUT						
Combustion Engineering, Windsor	(CH)	20				20
FLORIDA						
Westinghouse Tampa	(CH)		6,600			6,600
ILLINOIS						
Commonwealth Research Corp.	(CH)	250				250
MARYLAND						
Nuclear Utility Services, Rockville	(CH)			200		200
NEBRASKA						
Omaha Public Power District	(CH)	430				430
PENNSYLVANIA						
Duquesne Light Co., Pittsburgh	(PNR)		10,600			10,600
General Electric, Valley Forge					11,100	11,100
Westinghouse Elec. Corp., Pittsburgh	(CH)		4,700			4,700
SOUTH CAROLINA						
Savannah Power Plant, Aiken					6,398	6,398
TENNESSEE						
CRBR		252,500				252,500
VIRGINIA						
Babcock & Wilcox Co., Lynchburg	(CH)		4,300			4,300
Virginia Power & Light	(CH)	800				800
Total		1,650	278,500	10,600	17,698	308,448

\*Excluding contract operation of Government-owned installations.

**Table D-7. University\* Participation in Civilian Reactor Development Programs**

<i>University, location (Field Office)</i>	<i>LWR Tech.</i>	<i>FY 1983 participation in program, \$-thousand</i>			<i>Space &amp; Terr. Appl.</i>	<i>Total</i>
		<i>LMFBR</i>	<i>WCB</i>			
GEORGIA						
Georgia Institute of Technology		500				500
Total		500				500

\*Excluding contract operation of Government-owned installations.

## APPENDIX B

### Program Definitions

#### 1.0 FISSION ENERGY SYSTEM FUNDAMENTALS

In a nuclear fission energy system, energy is produced by a nuclear reaction in which an atomic nucleus captures a neutron and fissions (splits) into two approximately equal parts liberating a large amount of energy and, generally, one or more neutrons. The atomic nuclei that fission most easily are certain isotopes of uranium and plutonium. These isotopes constitute the fissile fuel of a nuclear powerplant. The fuel may also contain a fertile material that, although not in itself fissionable, can be converted into fissile material in a nuclear reactor. The neutrons released by the fission of a nucleus may also initiate fissions in other fissile nuclei. Under conditions provided in a nuclear reactor plant, the fission process becomes self-sustaining and controllable.

Uranium, as found in nature, contains 0.7 percent of U-235, 99.3 percent of U-238, and a trace of U-234. The fuel loaded into an LWR reactor is enriched in its U-235 content to about 3.2 percent at one of the Government-owned gaseous diffusion enrichment facilities. Enrichment removes almost 82 percent of the fertile U-238 originally mined before it ever reaches the reactor. These tailings of the enrichment process are stockpiled (still containing about 0.2 percent U-235) at the enrichment plant sites. These enrichment facilities will be augmented in the late 1980s by a gaseous centrifuge enrichment plant. Other more advanced separation processes are under investigation.

The conversion ratio of a reactor is the ratio of the rate at which fissile material is bred to the rate at which it is consumed. A reactor may be classified either as a converter, in which more fissile material is consumed than is generated (conversion ratio less than one), or as a breeder, in which more fissile material is generated than is consumed (conversion ratio greater than one). Converters that

are more efficient in fuel utilization than the standard, present day LWR on a once-through fuel cycle are termed **improved** or **advanced** converters.

Reactors may also be classified according to the predominant energy of the neutrons that induce fission. Fission neutrons are produced with a wide spectrum of energies; the average energy of freshly born neutrons is about one million electron volts. Before they are absorbed, the neutrons may collide with the nuclei of the reactor's coolant and structural materials, which reduces the neutron energies. The lightest-weight nuclei, such as the hydrogen in ordinary water, are most effective in reducing neutron energy. This process of slowing-down continues until the neutrons are captured or they reach thermal equilibrium with surrounding materials (about 0.025 electron volts at room temperature). Reactors such as LWRs, that operate with neutrons in this energy range, are termed thermal reactors. Those reactors that operate with relatively little slowing-down of neutrons are termed fast reactors, since the average energy of neutrons that are captured is high. The inherent nuclear properties of fertile materials make breeding more readily achievable in fast reactors.

In fission power systems, fuel utilization is defined as the amount of usable energy obtained per unit of uranium mined. Generally, the higher the conversion ratio, the higher the fuel utilization. In the LWR once-through fuel cycle, only about 1 percent of the energy content of the mined uranium is utilized.

There are many fuel cycles that can be employed. In the once-through fuel cycle, fuel is loaded into the reactor, used until full-power operation is no longer practical and then discharged and disposed of safely. Unused fissile material, either that remaining from the original charge or that generated in the reactor, is not recovered from the discharged fuel. This cycle is shown schematically in Figure B-1.

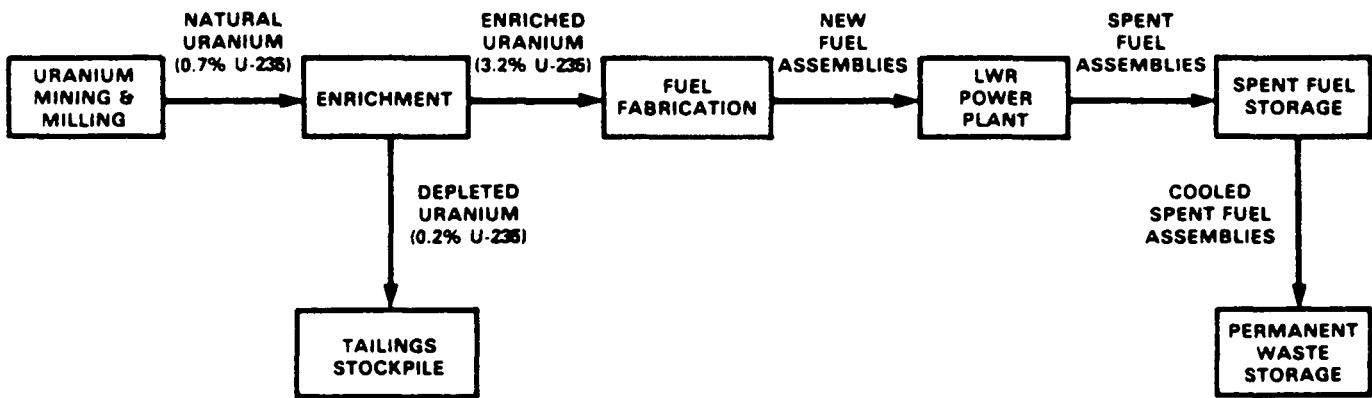


Figure B-1. LWR once-through fuel cycle

In the LWR system, the nuclear fission energy system is predominant use around the world today and, therefore, the reference system for comparative purposes, the fissile material is uranium-235 (U-235), and the fertile material is uranium-238 (U-238). Fuel that has been fabricated into large assemblies weighing several tons each is loaded into the reactor in an arrangement called a core, which enhances the fission reaction and permits its control. During reactor operation, fissile material is consumed. As operation proceeds, waste products of the fission process tend to poison or retard the process. The amount of fissile material decreases and the poisons build up until a point is reached at which the reaction can no longer be maintained. Then, even though the fuel still contains a significant amount of fissile material, it must be removed and replaced by new fuel assemblies. The spent fuel assemblies are removed to storage in large tanks of water awaiting permanent storage or disposal (for the once-through cycle), or reprocessing (see below).

There are several processes that can be employed to improve fuel utilization in converter reactors. One of these is uranium recycle, illustrated in Figure B-2. Here, the spent fuel assemblies, after an initial cooling period, are dissolved and the residual uranium, plutonium, and fission products are chemically separated in a reprocessing plant. The recovered uranium, containing about 0.8 percent U-235, is then passed to a fuel refabrication plant where it is mixed with new enriched uranium to bring its U-235 content up to the powerplant requirement of about 3.2 percent, refabricated into new assemblies, and returned to a reactor. The refabrication processes are about the same as those for new fuel except that the operations may be conducted using remote handling techniques because of the additional induced radioactivity accompanying the recovered uranium. Uranium recycle has the potential of improving fuel utilization by about 20 percent. However, no commercial reactors have yet been operated using recycled fuel.

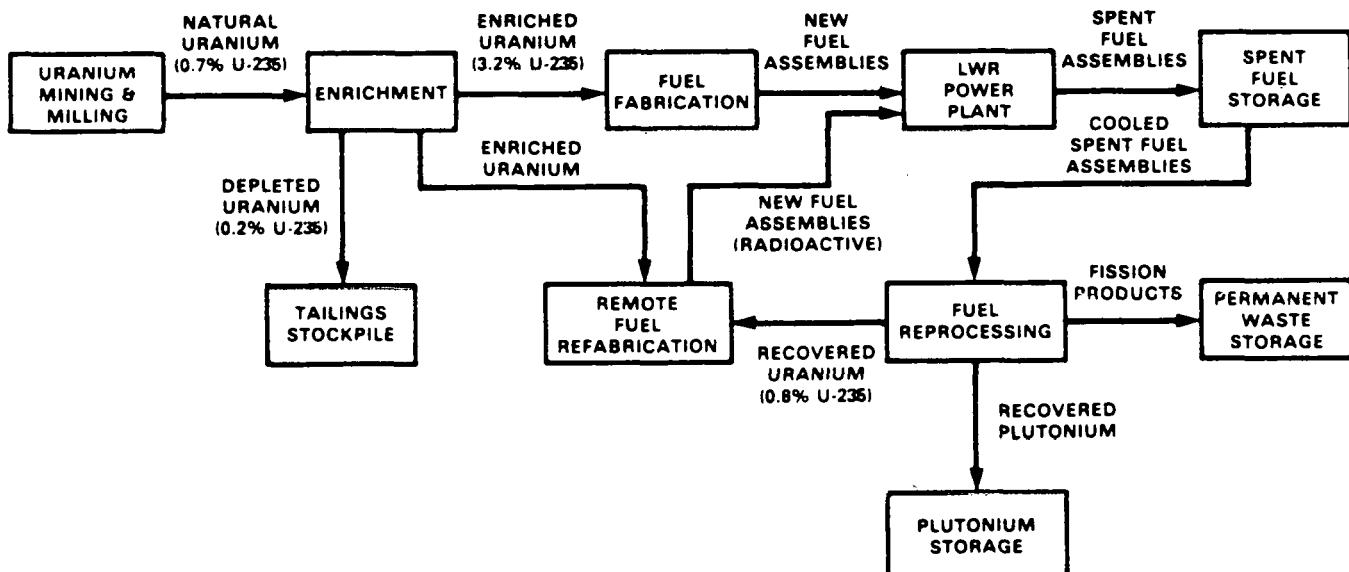


Figure B-2. LWR fuel cycle using uranium recycle.

The plutonium, a fissile material that has been generated during reactor operation from U-238 and separated during reprocessing, could also be recycled along with the uranium. However, because plutonium is more valuable as a fuel in fast breeder reactors and will be required for the initial fuel loadings in such reactors, prudent planning favors storing the plutonium for later breeder use rather than recycling it in converters. Thermal recycle, recycling both uranium and plutonium, has the potential for improving fuel utilization by about 35 percent. However, our commercial reactors have not yet operated using thermal recycle.

A thorium/uranium fuel cycle, such as might be used in an advanced converter, is shown in Figure B-3. Except for the addition of the thorium supply, it is generally similar to the LWR using recycle because reprocessing is required to recover and utilize the U-233 generated from the fertile thorium. Since the conversion ratio is usually not greater than one, and since U-233 does not occur naturally in uranium ores, the recovered U-233 is supplemented with U-235 to obtain the proper fissile material fraction in the new fuel assemblies. This can be done by making some

fuel assemblies with new U-235 and some with recovered U-233, or the U-233 and supplemental U-235 can be mixed. Plutonium storage is indicated because some plutonium will always be formed from the U-238 fed to the reactor in conjunction with the U-235 makeup.

The uranium/plutonium fuel cycle for a fast breeder is illustrated in Figure B-4. In this case, since all fissile material requirements of the reactor are fulfilled by bred and recycled plutonium, no U-235 input is required. The fertile U-238 requirements can be met from the existing stockpiles of depleted uranium tailings from enrichment plants.

In a breeder reactor, the fuel discharged from the reactor contains more fissile material than the fuel initially charged. This fuel must be reprocessed to extract the fissile material for further use as reactor fuel. Fissile material in excess of that required to fuel the reactor in which it was produced can be withdrawn from the cycle and used in other reactors.

Table B-1 summarizes the characteristics of LWRs and other major types of power reactors.

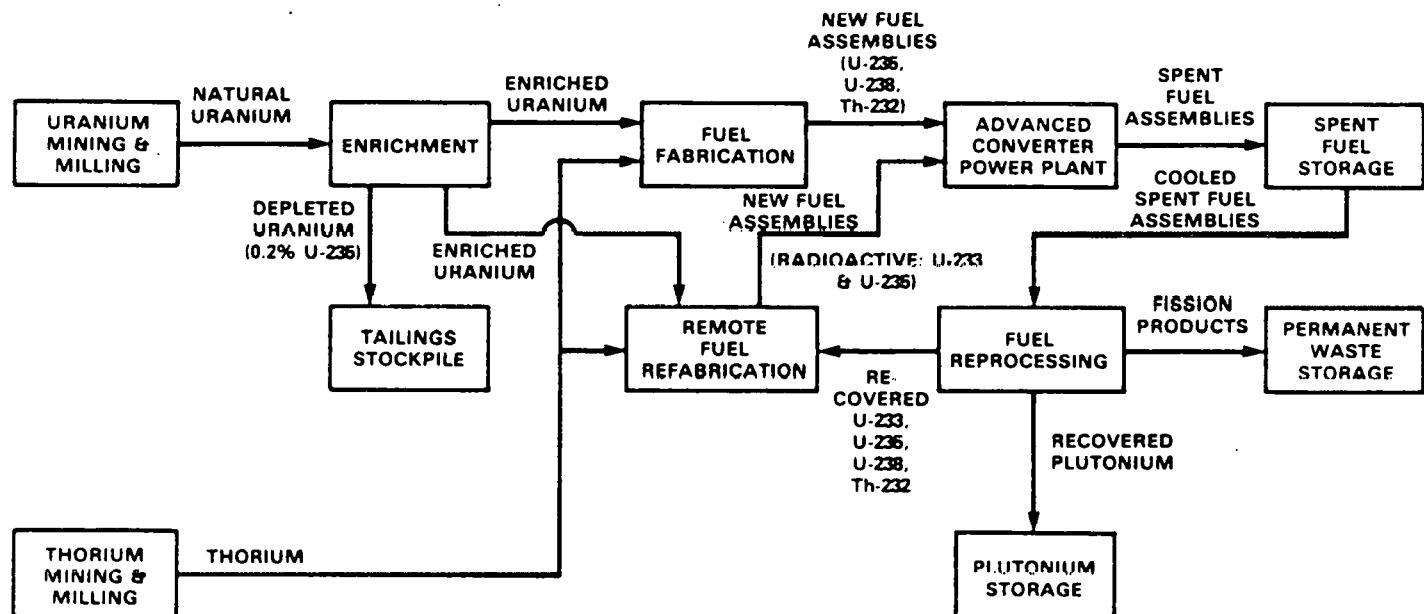


Figure B-3. Advanced converter using thorium/uranium fuel cycle

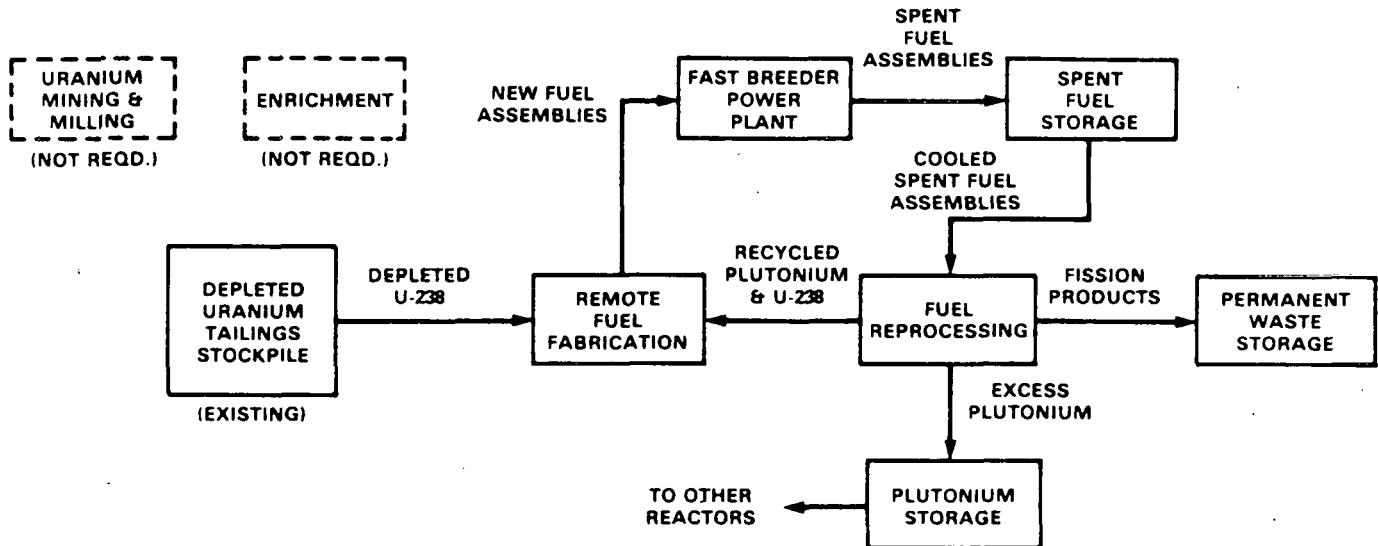


Figure B-4. Fast breeder plutonium/uranium fuel cycle

Table B-1. Characteristics of Fission Reactor Systems

Reactor technology	Reactor type	Neutron	State of development	Existing U.S. reactors	Coolant	Fuel cycle		
						Reactor loading	Fissile material generated	
Fissile		Fertile	Pu					
LIGHT WATER REACTOR	Converter	Thermal	Commercial	More than 70 commercial reactors in operation	Water	U-235	U-238	Pu
HIGH TEMPERATURE GAS COOLED REACTOR	Advanced converter	Thermal	Developmental	Fort St. Vrain	Helium	U-235 or U-233	Th	U-233
LIGHT WATER BREEDER REACTOR	Breeder	Thermal	Developmental	Shippingport	Water	U-233	Th	U-233
LIQUID METAL FAST BREEDER REACTOR	Breeder	Fast	Developmental	EBR-II & FFTF	Sodium	Pu	U-238	Pu

## 2.0 POWERPLANT FUNDAMENTALS

The fundamental difference between types of steam-electric powerplants is the source of the heat. The mode of operation of each of these plants is also slightly different. In a nuclear plant, heat is produced by the fission process (see Section 1.0). In a fossil plant, heat is produced by a chemical reaction (combustion) of carbon and hydrogen (in oil, coal, or natural gas fuels) with oxygen (in air); fuel and air are continuously supplied to a firebox. In a geothermal plant, the source of heat is that stored in the earth's interior; heat is continuously extracted from water, steam or hot rock deep within the earth. In all of these types of steam-electric plants, the basic elements other than the source of heat are the same.

All steam-electric powerplants have at least the following basic elements:

- a boiler and source of heat
- a turbine
- an electric generator
- a condenser
- pumps and piping

In addition, depending upon the specific design details of a particular plant, there are numerous auxiliary and support systems that are necessary to monitor and control the basic elements or to provide essential services for operating and maintaining the plant.

The fundamentals of steam-electric powerplant operation are as follows: A source of heat causes water in a boiler to be changed into steam. The steam flows to a turbine where the energy of the steam causes the turbine to spin. An electric generator, connected to the turbine, produces electric power, which is delivered to consumers via transmission lines. A steam-water mixture is exhausted from the turbine to a condenser which condenses it to water. A pump feeds the water back to the boiler. The boiler, turbine, condenser and pump are connected by piping. The cycle (heat in, electricity and heat out) continues as the water/steam circulates through the loop.

There are two common designs of nuclear plants currently in use in the United States. In the simplest, the reactor vessel and the boiler are one and the same. Water enters the fuel region and steam leaves. This design is called the boiling water reactor (BWR). In the other design,

boiling occurs in a separate vessel called a steam generator. The heat is supplied, or transferred, to the steam generator by an entirely different and isolated water system called the primary system. The primary system consists of a reactor vessel, pump, and piping and is pressurized to prevent boiling in the system. This design is called the pressurized water reactor (PWR). This is the basic type also used to power our country's nuclear ships.

Fluids other than water may be used in the primary system of a nuclear powerplant. Helium is used in gas-cooled reactors and sodium is used in the liquid metal fast breeder reactor. Other countries have designed and built nuclear plants using heavy water (Canada) or carbon dioxide (United Kingdom) in the primary system. However, the fluid predominantly used in the primary systems of nuclear plants around the world is light (ordinary) water. The term "light water reactor" (LWR) is commonly applied to both the BWR and PWR designs.

### 3.0 DEFINITIONS

**Acquisition Strategy.** Part of DOE's Energy System Acquisition Project Plan (ESAPP), the Acquisition Strategy details the resource requirements, methods of solicitation and contractual arrangements, cost participation or sharing, business risk, organizations involved by type and number, and identification of performers' responsibilities.

**Advanced Converter Reactor (ACR).** A reactor system that provides better uranium fuel utilization than that obtained in present commercial Light Water Reactors (LWRs), but not as good as a breeder reactor.

**Applied Research.** Systematic study directed toward fuller scientific knowledge or understanding for direct use in fulfilling specific energy requirements. More generally, applied research is defined as work to solve problems in the physical, biological, behavioral, social, and engineering sciences that have no clear-cut applicability to specific projects—it includes the technical means of obtaining the knowledge, understanding, and solution.

**Basic Research.** Systematic, fundamental study directed toward fuller scientific knowledge or understanding of subjects bearing on national energy needs. More generally, basic research is defined as work to increase knowledge and the quantitative understanding of natural phenomena and the environment.

**Blanket.** A layer of fertile material surrounding the driver core of a breeder reactor. See also "Fertile Material" and "Seed and Blanket."

**Breeder Reactor.** A reactor that creates more fissile material than it consumes; the process by which this occurs is known as breeding. The new fissile material is created by capture of fission-generated neutrons in fertile material.

**Commercial Demonstration Plants.** The purposes of commercial demonstration plants are: (1) to resolve commercial investment uncertainties by establishing the actual economic factors, environmental feasibility, socio-economic impact, capital and resource requirements, and constraints, and (2) to encourage creation of a viable industry using these technologies. They have an output of

about three to five times that of Demonstration Plants, and they demonstrate the viability of a facility or process to compete commercially.

**Commercialization.** The process of bringing a system or technology to commercial reality rather than demonstrating technical feasibility. The commercialization phase is characterized by the fact that: (1) "scale-up" problems have already been overcome; (2) economics of fabrication and operation are understood; (3) public acceptance, institutional, and environmental issues have been resolved; and (4) commercial interest arises. The path to commercialization proceeds from basic research through applied research, exploratory development, technology development, engineering development, and finally demonstration within the environment of production operations.

**Conversion Ratio.** The ratio of the atoms of fissile isotopes produced to those consumed in a reactor. In a converter reactor this ratio is less than 1; in a breeder reactor it is greater than 1.

**Demonstration.** Verification of economic and environmental viability for commercial application, through design, construction, test, and evaluation of large-scale energy systems in operational circumstances. The final engineering design, assembly, test and evaluation of full-scale energy systems aims to provide directly applicable experience in an operational environment. Demonstration projects are intended to (a) overcome "scale-up" problems; (b) contribute to the understanding of the economics of fabrication and operation; and (c) resolve other questions such as public acceptance, institutional and environmental issues. Preparation of suitable environmental impact statements is included in this category.

**Demonstration Plants.** Plants intended to demonstrate and validate economic, environmental, and productive capacity of a reactor technology. Demonstration plants are still developmental in the sense that technological scale-up problems could occur and require engineering modifications, but the risk is much lower because the plant production process was developed and tested at the pilot stage.

**Depleted Uranium.** Uranium having a lower concentration of the uranium-235 isotope than that found in natural uranium, i.e., uranium containing less than 0.71 percent U-235.

**Development Phases.** These are considered to be: (1) basic research, (2) applied research, (3) exploratory development, (4) technology development, (5) engineering development, (6) demonstration, and (7) commercialization, production, and operation.

**Engineering Development.** Systematic use of the knowledge and understanding gained from research and technology development to achieve the detailed design and construction of energy-system prototypes and pilot plants, and their testing for performance, producibility and reliability. Engineering development may concern itself with processes, preproduction components, equipment, subsystems, or systems. This category also includes major

system test facilities directed toward specific project development and the preparation of appropriate environmental impact statements.

**Enriched Uranium.** Uranium having a higher concentration of the uranium-235 isotope than found in natural uranium, i.e., uranium containing more than 0.71 percent U-235.

**Exploratory Development.** The assessment of technological options that have gone through the stages of basic and applied research. The work focuses the energy system options to identify technological potential, risks, resource requirements, environmental issues, and requirements for accelerated funding. The work is guided by the principle that it should lead ultimately to a particular application or product. Exploratory development can cut across several scientific disciplines and is intended to explore possible innovation in a particular area of one or more energy technologies.

**Fertile Material.** Normally nonfissile material that can, through the absorption of neutrons, be transmuted into fissile material. Examples are uranium-238 and thorium.

**Fissile Material.** Nuclear fuel that is capable of sustaining a nuclear chain reaction. Examples of fissile material are uranium-233, uranium-235, and plutonium-239.

**Heavy Water.** A compound chemically identical to water, composed of oxygen and the isotope of hydrogen of atomic weight 2; deuterium oxide, D<sup>2</sup>O.

**High-level Wastes.** By-products of the reprocessing of spent nuclear fuels, or in the case of the once-through fuel cycle, the spent fuels themselves. High-level waste from reprocessing contains most of the fission products and those actinides not carried with the uranium and plutonium.

**Life-cycle Cost.** The total of the direct, indirect, recurring, nonrecurring, and other related costs incurred, or estimated to be incurred, in the design, development, production, operation, maintenance, and support of a major system over its anticipated useful life span.

**Light Water.** Ordinary water (H<sub>2</sub>O), as distinguished from heavy water (D<sup>2</sup>O).

**Low-level Wastes.** Radioactive wastes containing less than 10 nanocuries of alpha-emitting transuranic elements and uranium-233 per gram. Their radioactivity can be concentrated and thus become dangerous, but it is usually barely above background levels. Low-level wastes are routinely buried in shallow repositories.

**Major System.** That combination of elements that will function together to produce the capabilities required to fulfill a mission need. The elements may include, for example, hardware, equipment, software, construction, other improvements, or real property. Major system acquisition projects are those projects that: (1) are directed at and are critical to fulfilling a DOE mission, (2) entail the allocation of relatively large resources, and (3) warrant special management attention.

**Natural Uranium.** The naturally occurring form of uranium—it contains 0.71 percent fissile uranium-235, a trace of uranium-234, and the remainder is uranium-238.

**Nuclear Wastes.** Wastes generated from nuclear processes. The four kinds of nuclear wastes are: high-level, transuranic (TRU), low-level, and uranium mine and mill tailings.

**Pilot Plant.** The purpose of a pilot plant is to establish the feasibility of an integrated process by combining commercial-type (not commercial-size) components into a small model plant to test and evaluate the critical scale-up parameters and to acquire engineering data needed to assess economic feasibility and design a nearer-commercial-size plant. Pilot plants are usually short lived and are the first scaleup facility to produce enough end product to permit product testing and refinement.

**Prebreeder Core.** A reactor core designed with a high conversion ratio (but less than 1.0) for the purpose of transmuting fertile material to fissile material for subsequent use in a breeder reactor.

**Proliferation.** The acquisition of nuclear weapons by a non-nuclear state.

**Reflector.** A layer of material that immediately surrounds a reactor core and scatters back (reflects), into the core, or into fertile material, neutrons that would otherwise escape. These neutrons can then cause additional fission or create fissile material, thus improving the neutron economy of the reactor. Common reflector materials are graphite, water, and beryllium.

**Seed and Blanket.** A reactor core that includes a relatively small volume of material with a high content of fissile material (the seed) surrounded by a much larger volume of material with a high content of fertile material (the blanket). As a result of fissions in the seed, neutrons are supplied to the blanket where new fissile fuel is produced and more fission takes place. In this way, the blanket is made to furnish a substantial fraction of the total power of the reactor.

**Technology Development.** Systematic use of the knowledge and understanding gained from research to achieve technical feasibility and to gauge the economic and environmental potential of energy concepts, processes, materials, devices, methods, and subsystems. More generally, technology development comprises development of engineering technologies, subsystems, planning and analysis studies, energy system concept formulation, comparison of alternative concepts, and development and test of laboratory-scale engineering feasibility models. This includes demonstration by experiment of alternative system concepts as well as preliminary studies encompassing system analysis, trade-offs, preliminary cost-benefit studies, planning, and the programming of environmental studies.

**Thoria.** Thorium oxide (ThO<sub>2</sub>).

**Transuranic (TRU) Wastes.** Materials containing more than 10 nanocuries of transuranic activity per gram. These come predominantly from spent fuel reprocessing activities and from the fabrication or processing of plutonium in the production of either nuclear weapons or fuel rods for reactors.

**Urania.** Uranium oxide (UO<sub>2</sub>).

**Uranium Mill Tailings.** Wastes resulting from extrac-

tion of uranium from ore at uranium mills. The radioactivity is of low concentration, but concern arises because many

piles of tailings are unstabilized and unprotected from spreading to adjacent property.

## **APPENDIX C**

### **Program Acronyms and Letter Designations**

ABS	Absorber
ACDA	Arms Control and Disarmament Agency
ACR	Advanced Converter Reactor
ACRP	Advisory Committee on Reactor Physics
ACRS	Advisory Committee on Reactor Safeguards (NRC)
A-E	Architect-Engineer
AEA	Atomic Energy Authority (UK)
AEC	United States Atomic Energy Commission (subsequently ERDA and NRC, now DOE and NRC)
AECL	Atomic Energy of Canada Ltd.
AEM	Acoustic Emission Monitoring
AETL	Approved Engineering Test Laboratories
AETR	Advanced Epithermal Thorium Reactor
AFCT	Alternative Fuel Cycle Technologies
AFR	Away From Reactor (Spent Fuel Storage Facilities)
AFSR	Argonne Fast Source Reactor (ANL-W/INEL)
AGC	Aerojet General Corp.
AGHCF	Alpha Gamma Hot Cell Facility (ANL)
AGNS	Allied General Nuclear Services
AGR	Advanced Gas-cooled Reactor
AI	Atomics International Div., Rockwell International Corp.
AIF	Atomic Industrial Forum, Inc.
AIPA	Accident Initiation and Progression Analysis
AIS	Advanced Isotope Separation (Program)
AL	Albuquerque Operations Office (DOE)
AMCF	Alkali Metal Cleaning Facility (HEDL)
ANL	Argonne National Laboratory
ANL-E	Argonne National Laboratory, East (Illinois)
ANL-W	Argonne National Laboratory, West (Idaho)
ANS	American Nuclear Society
APDA	Atomic Power Development Associates, Inc.
ARD	Advanced Reactors Div., Westinghouse Electric Corp.
ARCO	Atlantic Richfield Co.
ARS	Advanced Reactor Systems
ASDP/OSS	Assistant Secretary for Defense Programs/Office of Safeguards and Security
ASLB	Atomic Safety and Licensing Board
ASME	American Society of Mechanical Engineers
ASNE	Assistant Secretary for Nuclear Energy (DOE)
ASTM	American Society for Testing and Materials
ATL	Advanced Test Loop
ATR	Advanced Test Reactor (INEL/EG&G)
ATSR	Argonne Thermal Source Reactor (ANL-E)
AVR	Arbeitsgemeinschaft Versuchsreaktor
AWBA	Advanced Water Breeder Applications
AWF	Office of Science and Research (Switzerland)
BA	Budget Authority
BAPL	Bettis Atomic Power Laboratory
BIPS	Brayton Isotope Power System
BJ	Byron Jackson Pump Div. of Borg Warner Corp.
BL	Blanket

BLTC	Bottom Loading Transfer Cask
BMFT	Federal Ministry for Research & Technology (FRG)
BMI	Battelle Memorial Institute
BN-350, 600	Russian LMFBRs
BNAF	Breeding Non-Destructive Assay Facility
BNFP	Barnwell Nuclear Fuel Plant
BNFS	Barnwell Nuclear Fuel Services
BNL	Brookhaven National Laboratory
BO	Budget Outlay
BOM	Bureau of Mines (U.S. Dept. of Interior)
BOP	Balance of Plant
BOR-60	Russian LMFBR
BPV	Boiler and Pressure Vessel (Codes developed by the ASME)
BR-1,-2,-5,-10	Russian LMFBRs
BR-2	Belgian test reactor
BR'C	Breeder Reactor Corp.
B&W	Babcock and Wilcox Co.
B&R	Burns & Roe, Inc.
BWR	Boiling Water Reactor
CACS	Core Auxiliary Cooling System
CANDU	Canadian-Deuterium-Uranium Reactor
CDA	Core Disruptive Accident
CDF	Component Development Facility
CDFR	Commercial Demonstration Fast Reactors (UKAEA)
CDFSAR	Conceptual Design Final Safety Analysis Report
CDS	Conceptual Design Study (for LMFBR developmental plant)
CDSAR	Conceptual Design Safety Analysis Report
CE	Combustion Engineering, Inc.
CE	Commonwealth Edison, Co.
CEA	Commissariat a l'Energie Atomique (France)
CEL	Carbon Equilibrium Loop (WARD)
CERN	European Organization for Nuclear Research
CESNEF	Centro Studi Nucleari 'Enrico Fermi' (Italy)
CFR	Commercial Fast Reactor (U.K.)
CFRP	Consolidated Fuel Reprocessing Program
CFTL	Core Flow Test Loop
CHCF	Component Handling and Cleaning Facility (ETEC)
CIP	Cascade Improvement Program
CIVEX	Civilian Purex Process
CLEM	Closed Loop Ex-Vessel Machine (FFTF)
CLIRA	Closed Loop In-Reactor Assembly (FFTF)
CMM	Core Mechanical Mockup (HEDL)
CNEN	Comitato Nazionale per l'Energia Nucleare (Italy)
CNWV	Commercial Nuclear Waste Vitrification (Demonstration)
CORO	Chicago Operations and Regional Office
CP-5	Chicago Pile No. 5 (ANL-E)
CRBR	Clinch River Breeder Reactor
CRBRP	Clinch River Breeder Reactor Plant
CRCTA	Composite Reactor Component Test Activity (HEDL)
CRDM	Control-Rod Drive Mechanism
CREDO	Centralized Reliability Data Bank
CRM	Core Restraint Mechanism
CRT	Cathode-ray Tube
CSDD	Conceptual System Design Description
Cs	Cesium
CSTF	Containment Systems Test Facility
CUP	Cascade Upgrading Program
CY	Calendar Year
DAP	Data Acquisition Program (TMI)

DARPA	Defense Advanced Research Projects Agency
DAS	Data Acquisition System (EBR-II)
DASS	Disturbance Analysis and Surveillance Systems
DBA	Design Basis Accident
DBDA	Design Basis Depressurization Accident
D/D	Decommissioning and Decontamination
DEH	Direct Electrical Heating
DFR	Dounreay Fast Reactor (U.K.)
DHRS	Decay Heat Removal Systems
DHX	Dump Heat Exchanger
DOD	United States Department of Defense
DOE	United States Department of Energy
DOE-HQ	United States Department of Energy - Headquarters
DOS	United States Department of State
DOT	United States Department of Transportation
DPA	Displacement per Atom
DPSAR	Developmental Plant Safety Analysis Report
DWST	Double Wall Straight Tube
D <sup>2</sup> O	Deuterium Oxide, Heavy Water
EACRP	European-American Committee on Reactor Physics
EANDC	European-American Nuclear Data Committee
EARL	Ex-reactor Accident Risk Limitation
EBR-I	Experimental Breeder Reactor No. 1 (ANL-W/INEL)
EBR-II	Experimental Breeder Reactor No. 2 (ANL-W/INEL)
EBR-II SRM	Experimental Breeder Reactor No. 2 Safety Research Modification
ECCS	Emergency Core Cooling System
ECF	Expendable Core Facility
EDF	Electricite de France
EDF	Engineering Demonstration Facility
EEDB	Energy Economic Data Base (DOE)
EEI	Edison Electric Institute
EGCR	Experimental Gas Cooled Reactor
EG&G	Edgerton, Germeshausen and Grier, Inc.
EIA	Energy Information Administration (DOE)
EIS	Environmental Impact Statement
EM	Electromagnetic
EMC	Engineering Mockup Critical
ENDF	Evaluated Nuclear Data File
ENCA	European Nuclear Energy Agency
EOL	End of Life
EPA	Environmental Protection Agency
EPRI	Electric Power Research Institute
ERDA	United States Energy Research and Development Administration (now DOE)
ESA	European Space Agency
ESAPP	Energy System Acquisition Project Plan
ETEC	Energy Technology Engineering Center (formerly LMEC)
ETR	Engineering Test Reactor (INEL/EG&G)
EURATOM	European Atomic Energy Community
EURFNR	United States - EURATOM Fast Reactor Exchange Program
EVHM	Ex-Vessel Handling Machine
FAB	Fabrication
FBR	Fast Breeder Reactor
FCF	Fuel Cycle Facility (at EBR-II; now called HFFEF/S)
FCI	Fuel Coolant Interaction
FEDAL	Failed-Element Detection and Location System
FEFPL	Fuel Element Failure Propagation Loop (now SLSF)
FERMI	Enrico Fermi Atomic Power Plant (LMFBR)
FFM	Fuel Failure Mockup (ORNL)
FFT	Fast Flux Test Facility (HEDL)

FIV	Flow-Induced Vibration
FMEF	Fuels and Materials Examination Facility (HEDL)
FMSR	Fast-Mixed Spectrum Reactor
FNAL	Fermi National Accelerator Laboratory (formerly National Accelerator Laboratory)
FNG	Fast Neutron Generator (ANL)
FNR	Ford Nuclear Reactor
FOTA	Fuels Open Test Assembly (FFTF)
FRAD	Fuel Refabrication and Development Program
FRG	Federal Republic of Germany (West Germany)
FSA	Fueled Sphere Assembly
FSAR	Final Safety Analysis Report
FSF	Fuel Storage Facility (HEDL)
FSS	Full-Scale Shear
FSV	Fort St. Vrain, United States 330-MWe HTGR plant
FTR	Fast Test Reactor (now FFTF) (HEDL)
FWC	Foster-Wheeler Corp.
FY	Fiscal Year
GA	General Atomic Co. (Gulf/Shell)
GATR	General Atomic Test Reactor
GBRA	Gas-Cooled Brodor Roactor Association (Europcan)
GCFR	Gas Cooled Fast Reactor
GCHWR	Gas Cooled Heavy Water Reactor
GCR	Gas Cooled Reactor
GCRA	Gas Cooled Reactor Associates (HTGR utility group)
GCTR	Gas Cooled Thermal Reactor
GCUA	Gas Cooled Reactor Umbrella Agreement (international agreement on gas cooled reactors)
GDS	Ground Demonstration System (isotopic generator, Space Program)
GE	General Electric Co.
GEARSD	General Electric Advanced Reactor Systems Division
GEIS	Generic Environmental Impact Statement
GE-NED	General Electric Co. Nuclear Engineering Div.
GETR	General Electric Test Reactor (GE)
GPE	General Purpose Equipment
GPF	General Purpose Facility of the Integrated Equipment Test (IET) Facility
GPHS	General Purpose Heat Source (Solar Polar Mission, Space Program)
GPL	General Purpose Loop (WARD)
GPM	Gallons Per Minute
GPP	General Plant Projects
GPU	General Public Utilities
GRIST-2	Gas Reactor In-Pile Safety Test
GRT	Gulf Radiation Technology, Inc.
GT-HTGR	Gas Turbine High Temperature Gas Cooled Reactor
GWe	Gigawatts electric
HBA	Helium Breeder Associates (GCFR utility group)
HCDA	Hypothetical Core Disruptive Accident
HCM	Hydraulic Core Mockup (HEDL)
HCTF	Helium Component Test Facility
HEDL	Hanford Engineering Development Laboratory
HEF	Hot Experimental Facility (ORNL)
HEFA	Highly Enriched Fuel Assembly
HEPA	High-Efficiency Particulate Air (Filter)
HETF	Hot Engineering Test Facility
HEU	Highly Enriched Uranium
HFEF	Hot Fuel Examination Facility (ANL-W/INEL)
HFEF/N	HFEF-North (ANL-W/INEL)
HFEF/S	HFEF-South (formerly FCF) (ANL-W/INEL)
HFIR	High Flux Isotope Reactor (ORNL)
HFR	High Flux Reactor (Netherlands)
HHT	German direct-cycle HTGR program

HNPF	Hallam Nuclear Power Facility
HRI	Houston Research Institute
HRLEL	High-Radiation Level Examination Laboratory (ORNL)
HS	High Sulfur
HTF	Hydraulic Test Facility (ETEC)
HTGR	High Temperature Gas-cooled Reactor
HTGR-GT	HTGR with gas-turbine power conversion
HTGR-SC	HTGR with steam-cycle power conversion
HTL-1	Heat Transfer Loop No. 1 (HEDL)
HTR	High Temperature Reactor
HTR-R	Reformer System HTR
HTR-SC	Steam Cycle/Cogeneration HTR
HTS	Heat Transport System
HTSD	High Temperature Structural Design
HTSF	High Temperature Sodium Facility (HEDL)
HTTF	High Temperature Critical Test Facility (Naval Reactors Program)
HVEM	High Voltage Electron Microscope
HWOOCR	Heavy-Water-moderated Organic-Cooled Reactor
HWR	Heavy-Water Reactor
H <sup>2</sup> O	Ordinary (light) Water
I&C	Instrumentation and Control
IAEA	International Atomic Energy Agency
ID	Idaho Operations Office (DOE)
IEA	International Energy Agency
IEMTF	Interim Examination and Maintenance Training Facility (HEDL)
IET	Integrated Equipment Test (Facility) (ORNL)
IFAG	Irradiated Fuel Assay Gauge
IFSF	Irradiated Fuel Storage Facility (INEL)
IHX	Intermediate Heat Exchanger
ILW	Intermediate-Level Waste
IMGA	Irradiated Microsphere Gamma Analyzer System (ORNL)
INCOT	In-Core Instrument Test Facility (EBR-II)
INEL	Idaho National Engineering Laboratory (formerly NRTS)
INFCE	International Nuclear Fuel Cycle Evaluation
INPO	Institute for Nuclear Power Operations
INSAT	Instrumented Subassembly Test Facility (EBR-II)
INSRP	Interagency Nuclear Safety Review Panel
INTERATOM	Internationale Atomreaktorbau gmbH
IPD	Integrated Process Demonstration
IR	Infrared
ISI	In Service Inspection
ISPM	International Solar Polar Mission
ISSS	Inherently Safe Shutdown System
ITF	Interstitial Transfer Facility (WARD)
IVHM	In-Vessel Handling Machine
IVTM	In-Vessel Transfer Machine
IWGFR	International Working Group for Fast Reactors (IAEA)
JAERI	Japan Atomic Energy Research Institute
JAEC	Japanese Atomic Energy Commission
JOP	Jupiter Orbiter/Probe Mission (NASA)
JOYO	Japanese LMFBR
JAPFRX	U.S.-Japan Fast Reactor Exchange Program
JCAE	Joint Committee on Atomic Energy (United States Congress)
K\$	Thousands of dollars
KAPL	Knolls Atomic Power Laboratory
KFA	German Energy Research Center, Julich
KFK	Kernforschungscentrum Karlsruhe, Karlsruhe nuclear research center (Germany) (part of KFA)
KIPS	Kilowatt Isotope Power System

KNK	Kompaktes Natriumgekuhlte Kernreaktoranlage, compact sodium-cooled nuclear-reactor plant (Germany)
kW	Kilowatt
kWh	Kilowatt-hour
kW/kg	Kilowatts per kilogram
LANL	Los Alamos National Laboratory (formerly LASL)
LES	Lincoln Experimental Satellites
LEU	Low-Enriched Uranium
L.I.	Line Item
LINAC	Linear Accelerator
LLL	Lawrence Livermore Laboratory
LLTR	Large Leak Test Rig (ETEC)
LLTV	Large Leak Test Vessel
LLW	Low-Level Waste
LMFBR	Liquid Metal Fast Breeder Reactor
LOA	Line of Assurance
LOCA	Loss of Coolant Accident
LOF	Loss of Flow
LOFT	Loss-of-Flow Test (INEL/EG&G)
LOPI	Loss of Piping Integrity
LRL	Lawrence Radiation Laboratory
LS	Low Sulfur
LSBR	Large Seed Blanket Reactor
LTA	Lead Test Assembly
LWBR	Light Water Breeder Reactor
LWR	Light Water Reactor
M\$	Millions of dollars
MARF	Modifications and Additions to Reactor Facilities (Naval Reactors Program)
MASF	Maintenance and Storage Facility (HEDL)
M bbl/yr	Million barrels per year
METER	Meteorological Effects of Thermal Energy Release
MEU	Medium-Enriched Uranium
MHW	Multi-Hundred Watt (Heat Source, Space Program)
MJS	Mariner Jupiter/Saturn (Voyager Mission)
MLM	Mound Laboratory (Monsanto)
M lb/yr	Millions of pounds per year
Monju	Japanese prototype LMFBR
MOTA	Materials Open Test Assembly (FFTF)
MPS	Mechanical Properties Systems -1, -2, -3 (WARD)
MSAR	Mine Safety Appliances Research Corp.
MSBR	Molten Salt Breeder Reactor
MSG	Modular Steam Generator
MSRE	Molten Salt Reactor Experiment (ORNL)
MTHM	Metric Tons of Heavy Metal
MTI	Mechanical Technology, Inc.
MTL-1,-2	Materials Test Loops-1,-2 (WARD)
MTR	Materials Test Reactor (INEL/EG&G) (Decommissioned)
MTU	Metric tons of uranium
MWD/MT	Megawatt days per metric ton of reactor fuel
MWe	Megawatts, electrical
MWt	Megawatts, thermal
NACF	Sodium Cleaning Facility (WARD)
NAL	National Accelerator Laboratory (now Fermi National Accelerator Laboratory)
NASA	National Aeronautics and Space Administration
NASAP	Nonproliferation Alternative Systems Assessment Program
NATO	North Atlantic Treaty Organization
NBS	United States National Bureau of Standards
NDA	Non-Destructive Assay
NE	Office of Nuclear Energy (DOE)

NEA	Nuclear Energy Agency (OECD)
NEN	Deputy Assistant Secretary for Nuclear Reactor Programs (DOE)
NEP	National Energy Plan
NERVA	Nuclear Engine for Rocket Vehicle Application
NFS	Nuclear Fuel Services, Inc.
NOAA	National Oceanic and Atmospheric Administration
NPD	Division of Nuclear Power Development (DOE)
NPSH	Net Positive Suction Head
NRC	United States Nuclear Regulatory Commission
NRF	Neutron Radiography Facility (HEDL)
NRL	Naval Research Laboratory
NRTS	National Reactor Testing Station (now INEL)
NSAC	Nuclear Safety Analysis Center
NSMH	Nuclear Systems Materials Handbook
NSSS	Nuclear Steam Supply System
NURE	National Uranium Resources Evaluation
NYSERDA	New York Energy Research and Development Authority (formerly NYARDRA)
OECD	Organization for Economic Cooperation and Development
OER	Office of Energy Research (DOE)
OPERA	Out-of-Pile Expulsion and Reentry Apparatus (ANL-E)
ORELA	Oak Ridge Electron Linear Accelerator (ORNL)
ORNL	Oak Ridge National Laboratory
OR	Oak Ridge Operations Office (DOE)
ORR	Oak Ridge Research Reactor (ORNL)
ORRDACS	Oak Ridge Reactor Data Acquisition System
OSHA	Occupational Safety and Health Agency
OTA	Open-Loop Test Assemblies (FFTF)
PAHR	Post-Accident Heat Removal
PAL	Prototype Applications Loop (HEDL)
PBF	Power Burst Facility (INEL/EG&G)
PCI	Pellet-Clad Interaction
PCL	Partial Core Loading
PCML	Plutonium Critical Mass Laboratory (PNL)
PCR	Primary Control Rod
PCRS	Primary Control Rod System
PCHV	Prestressed Concrete Reactor Vessel
PCTF	Plant Component Test Facility
PDLP	Program Definition and Licensing Phase
PDU	Process Development Unit
PEC	Prova Elementi di Combustibile, fuel-element test reactor (Italy)
PEF	Plutonium Experimental Facility (SRL)
PFR	Prototype Fast Reactor (U.K.)
Phenix	French LMFBR demonstration plant
PHWR	Pressurized Heavy Water Reactor
PICS	Post-Impact Containment Shell
PLFFF	Pilot-Line Fuel Fabrication Facility
PISA	Post-Impact Shell Assembly
PLBR	Prototype Large Breeder Reactor
PMC	Project Management Corp.
PNC	Power Reactor and Nuclear Fuel Development Corp. (Japan)
PNL	Pacific Northwest Laboratory (Battelle)
PNP	German process heat program
PNR	Pittsburgh Naval Reactors Office (DOE)
PO	Project Office
POB	Proof of Breeding
PNL	Pacific Northwest Laboratory (Battelle)
PNP	German process heat program
PNR	Pittsburgh Naval Reactors Office (DOE)
PO	Project Office

POB	Proof of Breeding
PPBS	Planning, Programming and Budget System
PPS	Plant Protection System
PRCCS	Program Reporting and Change Control System
PRDC	Power Reactor Development Co.
PSAR	Preliminary Safety Analysis Report
Pu	Plutonium
PuFF	Plutonium Fuel Fabrication Facility (SRL)
PWR	Pressurized-Water-cooled Reactor
QA	Quality Assurance
R&D	Research and Development
RAPSODIE	French experimental LMFBR
RBCB	Run Beyond Clad Breach
RCB	Reactor Containment Building
RD&D	Research, Development and Demonstration
RDT	Reactor Development and Technology (Former AEC Division and name used for standards developed by that Division.)
RERTR	Reduced-Enrichment Research and Test Reactor (Program)
REU	Reduced Enrichment Uranium
RFP	Request for proposal
RFREPP	Remote Fuels Refabrication Engineering Pilot Plant
RINSC	Rhode Island Nuclear Science Center
RL	Richland (Washington) Operations Office (DOE)
RM	Reactor Manufacturer
RMEF	Remote Maintenance Evaluation Facility (HEDL)
RML	Radiometallurgy Laboratory (HEDL)
ROMD	Remote Operating and Maintenance Demonstration (ORNL)
RPD	Reactor Program Division
RRT	Division of Reactor Research and Technology (DOE)
RSCL	Radioactive Sodium Chemistry Loop (EBR-II)
RSS	Reactor Shutdown System
RTG	Radioisotope Thermoelectric Generator
RV	Reactor Vessel
S&W	Stone & Webster, Inc.
S/A	Subassembly
SACRD	Safety Analysis Computerized Reactor Data Bank
SAEA	Southwest Atomic Energy Associates
SAF	Secure Automated Fabrication (formerly ZRFF)
SAI	Science Applications, Inc.
SAN	San Francisco Operations Office (DOE)
SAPS	Shippingport Atomic Power Station
SAR	Safety Analysis Report
SAREF	Safety Research Experiment Facilities (formerly STF)
SASS	Self-Activated Shutdown System
SASS-ACA	Self-Activated Shutdown System - Articulated Control Assembly
SASS-FC	Self-Activated Shutdown System - Fluidic Control
SASS-HAB	Self-Activated Shutdown System - Hydraulic-Supported Absorber Balls
SCAE	State Committee for the Utilization of Atomic Energy (USSR)
SCEL	Small Components Evaluation Loop (HEDL)
SCRS	Secondary Control Rod System
SCTI	Sodium Components Test Installation (ETEC)
SCTL	Small Components Test Loop (ETEC)
SDD	System Design Description
SEFOR	Southwest Experimental Fast Oxide Reactor
SELNI	Societe Elettronucleare Italiana
SER	Safety Evaluation Report
SERF	Special Environment Radiometallurgy Facility (HEDL)
SF	Support Facilities
SG	Steam Generator

SGR	Sodium Graphite Reactor
SGTF	Steam Generator Test Facility (ANL-E)
SGTR	Steam Generator Test Rig (GE)
SHRS	Shutdown Heat Removal System
SIG	Selenide Isotope Generator
SIPS	Sterling Isotope Power System
SIR	Submarine Intermediate Reactor
SLSF	Sodium Loop Safety Facility (formerly FEFPL) (EG&G/INEL)
SMIS	Special Materials Information System
SNAP	Space Nuclear Auxiliary Power
SNL	Sandia National Laboratories
SNM	Special Nuclear Materials
SNR	Schnell Natriumgekuhlt Reaktor, fast sodium-cooled reactor (Germany)
SNR	Schenectady Naval Reactors Office
SOWAT	Small-Leak Sodium-Water Reaction Test Rig (GE)
SPAR	Space Power Auxiliary Reactor
SPDS	Safety Parameter Display System
SPL	Sodium Purification Loop (HEDL)
SPM	Solar Polar Mission
SPTF	Sodium Pump Test Facility (ETEC)
Sr	Strontium
SR	Savannah River (South Carolina) Operations Office (DOE)
SRDA	Sodium Removal Development Apparatus (HEDL)
SRE	Sodium Reactor Experiment
SRI	Stanford Research Institute
SRL	Savannah River Laboratory
SRP	Savannah River Plant
SS	Stainless Steel
S/S	Safeguards and Security
SSCR	Spectral Shift Controlled Reactor
SSS	Small Sodium System (HEDL)
SSST	Site Suitability Source Term
SSTF	Static Sodium Test Facility (ETEC)
STCL	Source Term Control Loop (HEDL)
STF	Safety Test Facility (now SAREF)
STL	Sodium Test Loop (GE)
STM	Steam
STP	Space Test Program (DOD)
SWHC	Single Wall Helical Coil
SWR	Sodium Water Reaction
SWRI	Southwest Research Institute
SWEATER	Sodium Friction and Wear Test Rig (WARD)
SWU	Separative Work Units
TBD	To Be Determined
TCC	Technical Coordinating Committee (INFCE)
TEC	Total Estimated Cost
TFCT	Thorium Fuel Cycle Technology (Program)
Th	Thorium
ThO <sup>2</sup>	Thorium, Thorium Dioxide
THORS	Thermal Hydraulic Out-of-Reactor Safety Facility
THTR	Thorium High-Temperature Reactor
TI	Texas Instruments
Title I	Preliminary Design Phase of Project
Title II	Final Design and Construction Phase of Project
TMC	Technology Management Center
TMI	Three Mile Island Reactor
TOP	Transient Over Power
TRA	Test Reactor Area (INEL)
TREAT	Transient Reactor Test Facility (ANL-W/INEL)

TRIGA	Training Reactor Isotopes, General Atomic
TRU	Transuranium
TSF	Tower Shielding Facility (ORNL)
TTF	Thermal Transient Facility (ETEC)
TTL	Transient Test Loop (HEDL)
TTTF	Thermal Transient Test Facility (ORNL)
TU	TREAT Upgrade (Part of SAREF)
T.U. ATL	TREAT Upgrade - Advanced TREAT Loop (ANL-W/INEL)
TURF	Thorium-Uranium Recycle Facility (ORNL)
TVA	Tennessee Valley Authority
U	Uranium
U-233	Uranium isotope with atomic weight 233
U-235	Uranium isotope with atomic weight 235
U-238	Uranium isotope with atomic weight 238
U <sup>3</sup> O <sup>8</sup>	Tri-uranium oct-oxide (yellowcake)
UCLA	University of California at Los Angeles
UC <sup>6</sup>	Uranium Oxycarbide
UE&C	United Engineers & Constructors, Inc.
UKAEA	United Kingdom Atomic Energy Authority
UNC	United Nuclear Corp
UO <sup>2</sup>	Urania, Uranium Oxide, Uranium Dioxide (the form suitable for reactor fuel)
UV	Ultraviolet
VHTR	Very High Temperature (gas-cooled) Reactor for high-temperature process applications
VTRZ	Variable Temperature Rodded Zone
W	Westinghouse Electric Corp.
WARD	Westinghouse Advanced Reactors Div.
WASH (#)	The serial numbering system for reports issued by the AEC
WBS	Work Breakdown Structure
WCA	Whole-Core Accident
WCB	Water Cooled Breeder
WCBR	Water Cooled Breeder Reactor
WCDA	Whole Core Disruption Accident
WEMD	Westinghouse Electro-Mechanical Division
WIRE	Waste Immobilization and Reactor Evaluation Program (TMI)
w%	Weight Percent
WPAD	Westinghouse Plant Apparatus Division
WSR	Waste Scrap Recycle
YAG	Yttrium Aluminum Garnet
ZPPR	Zero Power Plutonium Reactor (ANL-W/INEL) (now SAF)

## **APPENDIX D**

### **Program Supporting Legislation**

The following are the major pieces of legislation that provide the authorization and mandate for the current programs of the civilian reactor development program of the Department of Energy.

#### **Atomic Energy Act of 1954, as amended (Section 31, P.L. 83-703)**

Authorizes the Department (Atomic Energy Commission in original legislation) to make arrangements for the conduct of R&D activities relating to nuclear processes, the theory and production of nuclear energy, utilization of special nuclear material, atomic energy, and radioactive material for a number of purposes, including military, medical, industrial, and commercial, and the protection of health and the promotion of safety during research and production activities.

#### **Atomic Energy Commission. Appropriation Authorization, June 2, 1970, (Section 106, P.L. 91-273)**

Authorizes the Department (AEC in original legislation) to enter into a cooperative arrangement with a reactor

manufacturer and others for participation in the R&D, design, construction, and operation of CRBR powerplant, and authorizes the Department further to conduct the Project Definition Phase.

#### **Department of Energy Organization Act, as amended (Section 309(a), P.L. 95-91)**

Transfers the Division of Naval Reactors, established by section 25 of the Atomic Energy Act of 1954, to the Assistant Secretary for Nuclear Energy.

#### **Nuclear Safety Research, Development and Demonstration Act of 1980 (P.L. 96-567)**

Authorizes the Secretary to establish a research, development, and demonstration program to carry out the purpose of the Act, which is to develop practical improvements in the generic safety of nuclear powerplants during the 5 years beginning in FY 1981.

UNITED STATES  
DEPARTMENT OF ENERGY  
WASHINGTON, D.C. 20585

POSTAGE AND FEES PAID  
U.S. DEPARTMENT OF ENERGY  
DOE 350

OFFICIAL BUSINESS  
PENALTY FOR PRIVATE USE, \$300

