Nuclear Weapons Databook

Volume III
U.S. Nuclear Warhead Facility Profiles

Nuclear Weapons Databook

Volume III
U.S. Nuclear Warhead Facility Profiles

by

Thomas B. Cochran, William M. Arkin, Robert S. Norris,
and Milton M. Hoenig

A book by the
Natural Resources Defense Council, Inc.

BALLINGER PUBLISHING COMPANY
Cambridge, Massachusetts
A Subsidiary of Harper & Row, Publishers, Inc.

International Standard Book Number: 0-88730-126-6 (CL)
0-88730-146-0 (PB)

Library of Congress Catalog Card Number: 82-24376

Printed in the United States of America

Library of Congress Cataloging-in-Publication Data

U.S. nuclear warhead facility profiles.

(Nuclear weapons databook ; v. 3)
"A book by the Natural Resources Defense Council, Inc."
Includes bibliographical references and index.
1. Nuclear weapons—United States. 2. Munitions—United States.
I. Cochran, Thomas B. II. Natural Resources Defense Council.
III. Title: US nuclear warhead facility profiles. IV. Title: United States nuclear warhead facility profiles. V. Series: Cochran, Thomas B. Nuclear weapons databook ; v. 3.
U264.C6 1984 vol. 3 355.8'25119'0973 87-14552
[U264]
ISBN 0-88410-172-X (v. 1)
ISBN 0-88410-173-8 (pbk. : v. 1)
ISBN 0-88730-124-X (v. 2)
ISBN 0-88730-125-8 (pbk. : v. 2)
ISBN 0-88730-126-6 (v. 3)
ISBN 0-88730-146-0 (pbk. : v. 3)

About the Authors

Thomas B. Cochran is a Senior Staff Scientist and Director of the *Nuclear Weapons Databook* Project at the Natural Resources Defense Council, Inc. He has served as a consultant to numerous government agencies and non-government organizations on energy and nuclear non-proliferation matters, and was an Assistant Professor of Physics at the Naval Postgraduate School in Monterey, California, while on active duty in the Navy. He is the author of *The Liquid Metal Fast Breeder Reactor: An Environmental and Economic Critique* (Washington, D.C.: Resources for the Future, 1974). He has a Ph.D. in physics from Vanderbilt University.

William M. Arkin is Director of the Arms Race and Nuclear Weapons Research Project at the Institute for Policy Studies in Washington, D.C. He has been an intelligence analyst with the U.S. Army in Berlin and a Senior Staff Member of the Center for Defense Information. He is author of *Research Guide to Current Military and Strategic Affairs* (Washington, D.C.: IPS, 1981), *SIOP: The Secret U.S. Plan for Nuclear War* (with Peter Pringle) (New York: W.W. Norton, 1983), *Nuclear Battlefields: Global Links in the Arms Race* (with Richard W. Fieldhouse) (Cambridge, Massachusetts: Ballinger, 1985), and *Naked as a Jaybird: U.S. Military Strategy in the Pacific* (with David Chappell) (Washington, D.C.: IPS, 1986).

Robert S. Norris is a Senior Research Associate at the Natural Resources Defense Council, Inc. He has taught political science and international relations at several universities and has been a Senior Staff Member of the Center for Defense Information. He has a Ph.D. in political science from New York University.

Milton M. Hoenig is a consultant. In the past he has been at the U.S. Arms Control and Disarmament Agency. He has a Ph.D. in physics from Cornell University.

Table of Contents

List of Figures

Volume II

Volume III

List of Tables

Volume II

Volume III

Preface

The *Nuclear Weapons Databook* is meant to be a current and accurate encyclopedia of information about nuclear weapons. It should assist the many people who are actively working on the problems of the nuclear arms race. Today there is no greater threat to the human environment than a nuclear holocaust. Because of the obvious and terrifying consequences of the use of nuclear weapons, the Natural Resources Defense Council (NRDC) has followed every aspect of nuclear development for over a decade. NRDC has long believed that accurate information is critical in understanding the imperative for and implications of arms control. Information about nuclear weapons, policy, plans, and implications remains shrouded in secrecy. Informed public decisions on nuclear arms questions can occur if better and more information on the subject is available. The purpose of this *Databook* is to help overcome this barrier.

Since 1980, NRDC has sponsored the research required to produce three of several volumes on all aspects of the production, deployment and potential employment of nuclear weapons worldwide. As now planned the *Nuclear Weapons Databook* will consist of at least nine volumes:

I. U.S. Nuclear Forces and Capabilities
II. U.S. Nuclear Warhead Production
III. U.S. Nuclear Warhead Facility Profiles
IV. Soviet Nuclear Weapons
V. British, French and Chinese Nuclear Weapons and Nuclear Weapons Proliferation
VI. The History of Nuclear Weapons
VII. Command and Control of Nuclear Weapons and Nuclear Strategy
VIII. Arms Control
IX. Environment, Health and Safety

Volume II and its companion, Volume III, like Volume I are based as much as possible on original documentation, and the source of information is indicated in the extensive footnotes accompanying the text. The *Databook*, however, is only as useful as the accuracy of the information presented. We therefore strongly encourage the reader to contribute to this effort—to advise us of errors and new information. Please advise us also of other subject areas that should be included in future editions and any changes that could improve the format. We would like to hear from experts willing to serve as contributors or reviewers of the various sections of the *Databook*, particularly in subject areas not now covered.

Please address all correspondence to the authors at the Natural Resources Defense Council, 1350 New York Avenue, N.W. Suite 300, Washington, D.C., 20005 (202/783-7800).

Volumes II and III of the *Databook* series describe the research, testing, and manufacture of U.S. nuclear warheads, focusing on the complex of facilities and the activities they perform. Volume II is comprised of five chapters. Chapter One provides an historical overview of the forty-year evolution of the U.S. nuclear warhead stockpile, noting its size, cost, growth, and diversity. Chapter Two reviews the major laboratories, material production facilities, component production facilities, and test sites. Chapter Three discusses the production of nuclear materials, estimates their inventories, and surveys initiatives underway to increase them. Chapter Four describes the missions and functions of major civilian and military officials who decide upon the acqusition of nuclear warheads. Chapter Five reviews the major technologies and processes used to produce nuclear materials.

Volume III is comprised of profiles of thirty-four facilities where warhead research and development, testing, and production take place.

These volumes of the *Databook* are designed primarily for those who need basic facts about U.S. nuclear warhead production. It is meant for both layman and specialist. Chapters I, II, and IV of Volume II give a general introduction to warhead development and production. Chapters III and V, and the Appendices, entail more technical examinations of the nuclear fuel cycle, noting the types and quantities of material produced, and the technologies and processes involved. Each facility profile in Volume III provides details on the facility's history, weapon and non-weapon activites, management, budgets, and personnel. The Table of Contents, page headings, and index should enable any user to quickly find any information needed. A detailed glossary and list of abbreviations and acronyms is provided in Volume II. Numerous tables and figures are used throughout the books to help illustrate the difficult technical material.

Many gaps in data reflect the fact that we have been unable to get all the details about the history and activities of the warhead complex. We hope that what is provided will be useful.

Acknowledgments

Volumes II and III of the *Nuclear Weapons Databook* could not have been compiled without the invaluable assistance of many institutions and individuals. We are grateful to the U.S. Departments of Energy and Defense for their responsiveness to our numerous requests for information. The Department of Energy's Operations Offices at Albuquerque, Oak Ridge, and Savannah River were particularly helpful. The Arms Control Association, Federation of American Scientists, and the Center for Defense Information made available to us extensive data from their files.

Frank von Hippel contributed valuable information and insights. Robert Del Tredici also helped in making available a number of photographs. We want to thank reviewers David Albright of the Federation of American Scientists, Gerald Brubaker, and assistance provided by Chuck Hansen. Valuable research assistance was provided by Jeffrey I. Sands of the Natural Resources Defense Council, and Richard W. Fieldhouse of the Institute for Policy Studies. Nevertheless, responsibility for all facts and analyses in the *Databook* remains solely that of the authors.

The Natural Resources Defense Council and the authors wish to acknowledge gratefully the support and encouragement given to the *Nuclear Weapons Databook* by The Bydale Foundation, the Columbia Foundation, The Field Foundation, the George Gund Foundation, the W. Alton Jones Foundation, The New Hope Foundation, the Ploughshares Fund, the Charles H. Revson Foundation, the Rockefeller Family Fund, the Samuel Rubin Foundation, the Wallace Genetic Foundation, Mrs Philip S. Weld, and an anonymous donor.

We appreciate the continuing encouragement and support of the entire Board of Trustees and Staff of the Natural Resources Defense Council. Very special thanks goes to Adrian W. DeWind, Chairman of the Board, for his invaluable guidance and assistance. We also want to recognize James Marshall, a member of the Board until his death in August 1986, and Joan K. Davidson, NRDC Honorary Trustee, for their exceptional support and commitment. John H. Adams, Executive Director of NRDC, and S. Jacob Scherr, Senior Staff Attorney, have also been enormously helpful. We are deeply indebted to Barbara J. Pratt and Judy Funderburk for preparing numerous Freedom of Information Act requests. Wayne E. Nail designed the Databook series and coordinated production. Finally, we would like to thank Carol Franco, President of Ballinger Publishing Company, for her unfailing support of the *Databook* project.

Nuclear Weapons Databook

Volume III
U.S. Nuclear Warhead Facility Profiles

Argonne National Laboratory (ANL)

ADDRESS: Argonne National Laboratory
9700 South Cass Avenue
Argonne, IL 60439
312/972-2000

LOCATION: 27 miles southwest of Chicago; 1704–acre site; ANL also maintains second site, Argonne–West, at Idaho National Engineering Laboratory (INEL)

MISSION: Provides a broad range of research and development programs in the physical, biomedical, and environmental sciences with major emphasis in the development of energy technologies, particularly advanced nuclear reactor technology.

MANAGEMENT: GOCO facility operated for DOE by University of Chicago

ESTABLISHMENT: Established 1 July 1946 as first national laboratory created after World War II; purpose: mainly to carry on unclassified research.

BUDGET: $251.2 million total lab funding (FY 1986)

PERSONNEL: 2965, total lab (March 1985)

FACILITIES:

ANL-East:
- Alpha-Gamma Hot Cells
- Argonne Liquid Metal Engineering Experiment (ALEX)
- Biological Materials Growth Facility
- CP-5 Research Reactor
- Fast Neutron Generator Facility (FNG)
- Fossil Energy Users Laboratory (FEUL)
- Fusion Electromagnetic Induction Experiment (FELIX)
- Heat Exchange Test Facility
- Intense Pulsed Neutron Source (IPNS)
- JANUS Biomedical Research Neutron Reactor
- Liquid Metal/Water Components Testing Facilities
- National Battery Test Laboratory (NBTL)
- Pulsed Electron Linac (22 MeV)
- Salt Gradient Solar PondSolar Collector Test Facility
- 60–inch Cyclotron

Major User Facilities:
- Argonne Tandem Linac Accelerator Facility (ATLAF)
- Facility for High Resolution Atomic Spectroscopy
- High Voltage Electron Microscope/Ion–Beam Interface Facility
- Intense Pulsed Neutron Source I
- 4–MV Dynamitron Facility

ANL–West:
- Experimental Breeder Reactor (EBR-2)
- Hot Fuels Examination Facilities (HFEF)
- Sodium Loop Safety Facility (part of TREAT)
- Transient Reactor Test Facility (TREAT Reactors)
- Zero Power Plutonium Reactor (ZPPR)

History

The site of ANL was the Argonne Laboratory outside of Chicago. It had been constructed in 1943 as part of the war effort by the University of Chicago's Metallurgical Laboratory, which had been set up in late 1941, under Arthur Compton, by the Uranium Section (cryptically named S–1) of the Office of Scientific Research and Development (the forerunner of the Manhattan Engineer District) to determine the feasibility of a chain reaction and to produce plutonium and build an atomic bomb.[1]

The first chain reacting pile (the Chicago pile or Fermi pile) had been built by the Metallurgical Laboratory in a squash court at the University of Chicago (it achieved power on 2 December 1942 at 0.5 watt, later raised to 200 watts). The pile was reconstructed at the Argonne Laboratory and served as a prototype unit for studies of reactor control materials testing and nuclear physics. In the summer of 1943, construction of a 250–kilowatt heavy water moderated reactor was begun at Argonne, and operations commenced in May 1944.[2] The Argonne Laboratory was originally to be the site of the first plutonium production reactor pilot plant, but the

1 Richard G. Hewlett and Oscar E. Anderson, Jr., The New World, 1939/1946, A History of the United States Atomic Energy Commission, Vol. 1 (University Park, Pennsylvania: Pennsylvania State University Press, 1962), pp. 634, 65 ff.

2 Henry Smyth, Atomic Energy for Military Purposes (Princeton, New Jersey: Princeton University Press, 1945), p. 149.

facility was switched to the Metallurgical Laboratory's Clinton Laboratories (now Oak Ridge) in Tennessee and operated in 1943 as the Clinton pile (code named X–10).[3]

When the Atomic Energy Commission (AEC) came into being in 1947 its first duty was to channel atomic energy to satisfy military requirements. The scarcity of uranium ore for producing fissionable material for weapons, and the dependence on foreign supply, directed AEC's attention to new ideas for increasing the efficiency of materials production. One of these was the breeding of plutonium in a fast neutron reactor by conversion of the relatively abundant U–238 to Pu–239, making more fissionable material than was consumed as fuel.[4]

In this environment of scarcity, Walter Zinn, the first director of Argonne Laboratory, pushed research and development of a fast reactor for breeding plutonium and generating electricity. In November 1947 AEC approval was obtained by Argonne for construction of the Experimental Breeder Reactor I (EBR–I). In February 1949 a site was chosen at the National Reactor Test Station in Idaho (now INEL/ANL–West), and construction was completed in the spring of 1951.[5]

EBR–1 went critical in August 1951, and on 20 December 1951 it became the first nuclear reactor to generate electricity. A year and a half later, on 4 June 1953, the chairman of the AEC announced that the principle of breeding had been demonstrated.[6] Because of the value of Pu–239 as a fissionable material for weapons, the success of plutonium blending was then considered an important achievement in obtaining enough fissionable material.[7] From 1949 to 1953 the process became less important with the discovery of uranium ore deposits in Western United States and Canada.[8]

Nuclear Weapons Activities

For several years ANL has conducted research on heavy-ion beams to serve as the driver for inertial confinement fusion. ANL measures krypton–85 concentrations in the atmosphere as a means of estimating worldwide plutonium production. From this DOE is able to estimate Soviet plutonium production. ANL conducts research on international and domestic safeguards and defense waste management activities. ANL's isotopic correlation technique (ICT) program is developing measuring methods to improve material control and accountancy and safeguards applicable to plutonium production and naval and research reactor fuel cycle systems. ANL directs the Reduced Enrichment Research/Test Reactor (RERTR) Program to enhance the proliferation resistance of nuclear fuels used in research and test reactors by reducing the enrichment of the uranium fuel to substantially less than 90 to 93 percent. ANL is involved in nuclear waste related activities including studies of ceramic waste forms for high level wastes and monitoring instrumentation for low level and transuranic waste disposal. ANL has also supported Sandia Laboratories' work on nuclear waste management—the WIPP and SEABED programs. These efforts represent approximately 1 to 2 percent of the total ANL effort (FY 1985).

Nonweapon Activities

The major components of the research program are nuclear reactor research and development, physical sciences, and energy, biology, and environmental systems. ANL's advanced nuclear technology research and development is primarily in support of the Liquid Metal Reactor (LMR) and the breeding version of such a reactor, the Liquid Metal Fast Breeder Reactor (LMFBR). The laboratory also does work related to other fission reactor programs and maintains a substantial, diversified capability in physical and biological sciences in support of reactor efforts. ANL conducts some research on magnetic fusion, with emphasis on blanket technology and materials research. Research efforts in the area of fossil energy center on advanced process development, materials technology, and the engineering of instrumentation and controls systems. The laboratory conducts studies of health–related and environmental problems that are consequences of the use of particular energy technologies. In basic research, the principal effort is in the area of general materials studies, with work in high energy physics and nuclear physics also playing a significant role.

Management

ANL is a GOCO facility operated for DOE by the University of Chicago. A new five–year contract became effective on 1 October 1983. The ANL contract between DOE and the University of Chicago is administered through the Chicago Operations Office. Prior to October 1982, ANL was operated jointly by the University of Chicago and the Argonne Associated Universities (AAU), but all involvement of the AAU in establishing policy at the laboratory has since been terminated.

LABORATORY ACTIVITIES BY PROGRAM (FY 1985):[9]

Nuclear Energy	40%
Energy Research	34%
Conservation and Renewable Energy	5%
Fossil Energy	4%
Defense Programs	1%
Miscellaneous DOE Programs	3%
Other DOE Contractors	1%
Work for Others	
Nuclear Regulatory Commission	3%
Department of Defense	2%
Others	6%

3 Ibid., p. 143.

4 Lee Bowen, The United States Air Force Historical Division, *A History of the Air Force Atomic Energy Program, 1943–1953*, Vol. IV, The Development of Weapons, pp. 17–25.

5 William Lanouette, The Atlantic (April 1983): pp. 39–43.

6 Bowen, op. cit., p. 24.

7 Ibid., p. 24.

8 Ibid., p. 25–30.

9 Percentage of FTEs: ANL Institutional Plan FY 1986–FY 1991, pp. 6.6–6.9.

BUDGET[10]
($ million):

FY	Total Laboratory Funding:	DOE Defense Programs:
1978	226.0	2.0(1%)
1979	257.0	2.6(1%)
1980	286.3	4.3(2%)
1981	352.6	4.7(1%)
1982	288.7	3.6(1%)
1983	246.6	3.2(2%)
1984	249.3	3.4(2%)
1985	249.0	4.4(2%)
1986	251.2	5.0(2%)

ASSETS:

The laboratory occupies some 186 buildings covering 3.8 million square feet. Capital Investment (book value of plant and equipment) was estimated (FY 1983) at $545 million.[11]

PERSONNEL:[12]

Excludes University of Chicago employees at ANL–West.

End FY	ANL
1971	3850
1972	3720
1973	3392
1974	3440
1975 (Sep)	3879
1976	4018
1977	4153
1978	4301
1979	4230
1980	4186
1981	3696
1982	3413
1983	3293
1984	3107
1985 (Mar)	2965

10 DOE, Major National Laboratories Funding Table, March 1981; ANL Institutional Plans FY 1981-FY 1986; and FY 1982-FY 1987; DOE, FY 1986 Budget Request Estimates for Labs/Plants, Office of the Controller, 22 February 1985, pp. 7–12; ANL Institutional Plan FY 1985–FY 1990, p. 8.1; ANL Institutional Plan FY 1986–FY 1991, p. 8.1.

11 Includes ANL-West at INEL.

12 DOE, GOCO Employment, Computer printout for Office of Industrial Relations, R-552600B-012, 29 August 1985.

Ashtabula Extrusion Plant[1]

Figure 1 Aerial View of Ashtabula Plant

Source: DOE

ADDRESS: Ashtabula Extrusion Plant
P.O. Box 179
Ashtabula, OH 44004
216/997–5141

LOCATION: East 21st Street, Ashtabula, Ohio; 8.2 acres (see Figure 1)

MISSION: The extrusion of uranium ingots into tubes and billets, as a step in the fabrication of fuel and targets for the Hanford and Savannah River production reactors.

MANAGEMENT: Owned by Reactive Metals, Inc. (RMI), working under DOE contract

ESTABLISHMENT: Work for DOE and its predecessors at Ashtabula dates back to 1952

BUDGET: $7.251 million, total (1986)

PERSONNEL: 116 (March 1985)

FACILITIES: The DOE owns two extrusion presses at the plant, a 3300-ton horizontal extrusion press and a small 550-ton laboratory-size press, which can be combined to produce a maximum of 3850 tons.

Nuclear Weapons Activities

Ashtabula plays a small but important role in the production of plutonium for nuclear weapons. Depleted

1 Sometimes referred to simply as the Ashtabula Plant or the Extrusion Plant.

Figure 2 Depleted Uranium Ingots Awaiting Extrusion Source: DOE.

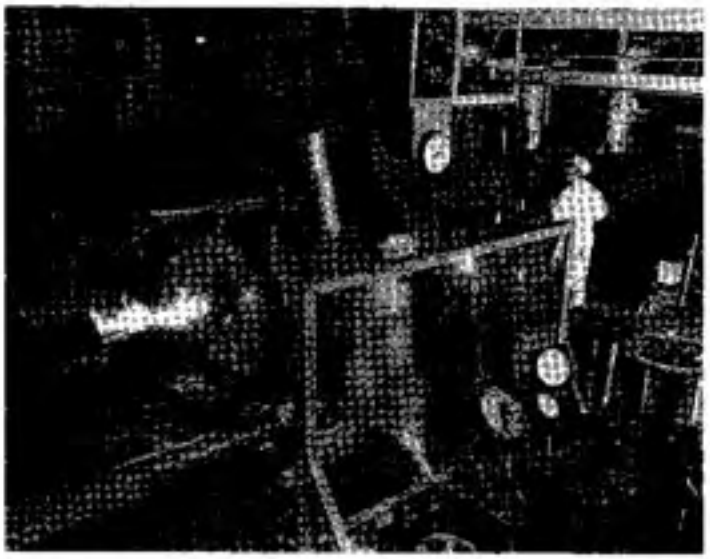


Figure 3 RMI Extrusion Press Source: DOE.

uranium and slightly enriched uranium (SEU) metal ingots (Figure 2) shipped from the Feed Materials Production Center (FMPC) at Fernald are extruded into tubes and billets at Ashtabula. The depleted uranium tubes are shipped back to FMPC where they are cut into pieces and machined to form hollow cores. These are then shipped to Savannah River where they are canned in aluminum and charged to the production reactors as target elements for the production of plutonium.

The SEU ingots are extruded into billets and shipped directly to Hanford where they are co-extruded and clad with a zirconium alloy to form N-reactor fuel elements.

Nonweapon Activities

Depleted uranium and other metals are processed on a commercial basis for non-DOE programs. The commercial uranium work is performed under a license granted by the Nuclear Regulatory Commission.

Management

The Ashtabula Plant is owned by Reactive Metals, Inc. (RMI) and works under DOE contract. Reactive Metals, Inc. is owned by National Distillers and Chemical Corporation and the United States Steel Corporation (50 percent by each). The DOE work at RMI is performed through a contract/job order arrangement under the Office of Nuclear Materials Production under the ASDP. The Reactive Metals contract will continue through FY 1988, and is administered by the Oak Ridge Operations Office.

In the past (1963) the Ashtabula Plant was operated by the Bridgeport Brass Company.[2]

Capacity: Recent scheduled produciton at the Ashtabula and FMPC plants:

FY	Depleted U target cores for SR reactors (MT)	SEU billets for Hanford N-Reactor (MT)
1980[3]	900	400
1982	1800	700
1983[4]	3000	870

BUDGET[5,6] (\$ million):

FY	Total
1971	1.117
1972	1.177
1973	1.302
1974	1.463
1975	1.327
1976	1.673
1977	1.484
1978	1.674
1979	1.620
1980	1.864
1981	2.300
1982	3.000
1983	5.233
1984	5.546
1985	5.652
1986	7.251

2 AEC, Report to Congress, January 1964, p. 43.
3 DOE, "Congressional Budget Request FY 1980," Vol. 1, (January 1979), p. 278.
4 HAC, FY 1983 EWDA, Part 4, p. 253.
5 Letter from Wayne Range, DOE, Oak Ridge Operations, to Thomas B. Cochran, 25 February 1982.
6 Outlays; Estimated costs from DOE, FY 1986 *Budget Request Estimates for Lab/Plants*, Office of the Controller, 22 February 1985, p. 23.

Ashtabula Extrusion Plant

ASSETS

Two government owned buildings with a 32,000 square foot floor space. Four buildings owned by RMI have a floor space of 27,500 square feet. Capital investment (plant and equipment) $653,000: FY 1982.

PERSONNEL:[7]

End FY	Employment
1971	52
1972	58
1973	59
1974	62
1975 (Sep)	50
1976	57
1977	55
1978	65
1979	80
1980	84
1981	88
1982	100
1983	118
1984	115
1985 (Mar)	116

7 DOE, GOCO Employment, Computer printout for Office of Industrial Relations, S-552303-012, 29 August 1985.

Feed Materials Production Center (FMPC)[1]

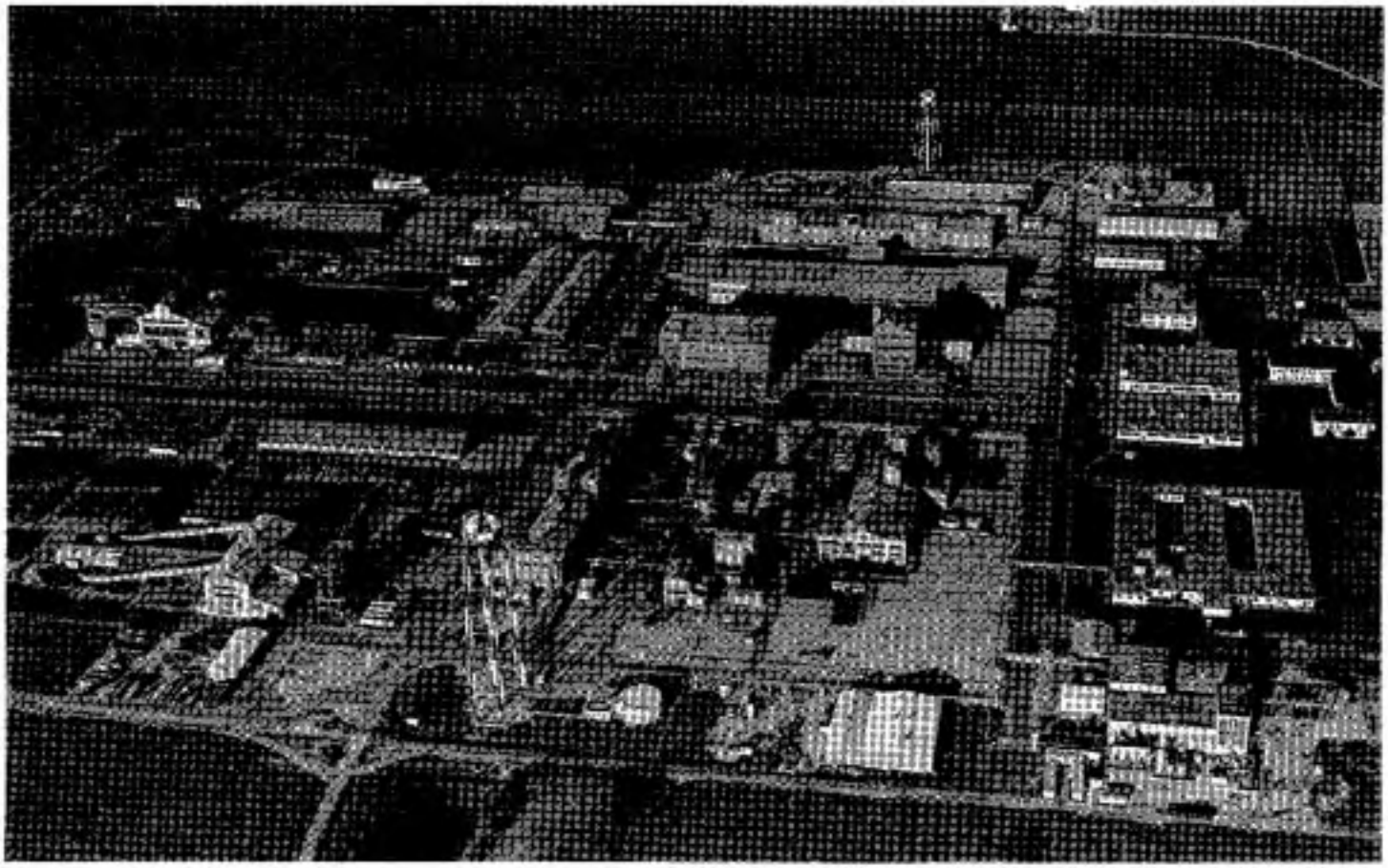


Figure 4 Aerial View of Feed Materials Production Center

Source: DOE.

ADDRESS: Westinghouse Materials Company of Ohio[2]
P.O. Box 398704
Cincinnati, OH 45239
513/738-6200

LOCATION: Near Fernald, Ohio, 20 miles northwest of Cincinnati; 1050-acre site (136 acres occupied by plant)(see Figure 4)

MISSION: The conversion of a variety of uranium feed materials into uranium metal, primarily for finished target and fuel elements of DOE production reactors.

MANAGEMENT: GOCO facility operated for DOE by Westinghouse Materials Company of Ohio

ESTABLISHMENT: Construction began in 1951 and was completed in May 1954; operations began in 1953

BUDGET: $119.4 million, total DOE (1986)

PERSONNEL: 1083 (March 1985)

FACILITIES: Extensive variety of facilities for handling and processing uranium feed materials

1 Also referred to as the Fernald Plant
2 Formerly National Lead of Ohio, Inc. and NLO, Inc.

Nuclear Weapons Activities

This large-scale integrated plant is utilized for the conversion of a variety of uranium feed materials containing depleted or slightly enriched uranium into (1) finished uranium metal used in the fuel and target elements of the DOE reactors, for (2) depleted uranium derby metal for fabrication into nuclear weapon components at Y-12 and Rocky Flats, and (3) refined uranium trioxide (UO_3) for eventual use (after conversion to uranium hexafluoride (UF_6)) in the DOE gaseous diffusion enrichment plants.

The uranium metal supplied for reactors is used in the fabrication of fuel cores for the Hanford N-reactor, target elements for the Savannah River production reactors, and fuel cores for other reactors operated by DOE.

Capabilities

FMPC has an extensive variety of facilities for handling and processing uranium feed materials. Capabilities include:[3]

- The conversion of uranium ore concentrates and recycle materials into refined uranium trioxide (UO_3 or "orange oxide")
- The recovery of slightly enriched uranyl nitrate (UNH) from nitrate solutions by solvent extraction techniques, and the conversion of the uranyl nitrate to U_3O_8 for feed to the uranium enrichment plants
- The reduction of UO_3 to uranium dioxide (UO_2) and conversion of the UO_2 to uranium tetrafluoride (UF_4 or "green salt") and further reduction into uranium metal
- Working with uranium metal by vacuum induction casting of uranium ingots, rolling of ingots into rods,[4] and machining of ingots, rods, and tubes.

Process Description

FMPC processing operations (see Figure 5) actually begin with refinery operations for conversion of feed materials—that is, ore concentrate and recycle materials—into refined UO_3 (see Table 1). The ore concentrate (and some scrap materials) are dissolved in nitric acid to produce uranyl nitrate (UNH) feed solution for solvent extraction purification and subsequent conversion to UO_3. (These refinery operations, with a nominal capability of 14,000 tons per year, were placed on standby in June 1977, except for occasional small batched operations, when the ERDA, now DOE, stockpile of uranium ore concentrates was consumed.) The FMPC still operates processes to convert slightly enriched (2 to 3 percent U-235) uranyl nitrate (UNH) solution, received from the Savannah River Plant, to U_3O_8, which is shipped in turn to Paducah for conversion into UF_6 feed. (This process can handle enrichments up to 10 percent U-235.)

Table 1
Recycled Uranium Received by FMPC

Source	Kg Uranium
Paducah Feed Plant[a]	313,271
Hanford Recycle[b]	5,589,591
West Valley	617,877
Savannah River Plant	669,026
Other Sources	284,570
TOTAL	7,474,335

Source: DOE, Oak Ridge Operations, "The Report of the Joint Task Force on Uranium Recycle Materials Processing," DOE/OR-858, 1985, p. 11

a Based on FMPC data.

b A part of this material was UO_3 received from Hanford after intermediate storage at Paducah.

A variety of scrap uranium materials from other facilities are processed at FMPC (See Table 7). Scrap metal materials (up to 10 percent U-235) generated in FMPC operations and those received from offsite—that is, scrap generated at Hanford from N-reactor fuel fabrication operations and the Ashtabula Plant—are upgraded to chemical requirements for processing at FMPC. Most of the slightly enriched uranium feed for subsequent manufacture of Hanford N-reactor fuel was in 1981 obtained from existing UO_3 stocks at FMPC. Uranium oxide of higher enrichment (less than 10 percent U-235) processed at FMPC is shipped to the Portsmouth gaseous diffusion plant at Piketon, Ohio.

Metal processing steps at FMPC begin with the conversion of green salt (UF_4) to elemental uranium derby metal by reducing the UF_4 with magnesium metal. Metallic scrap and briquettes recycled from subsequent fabrication operations are combined with derby metal, melted in a crucible, and poured to form ingots, varying in weight, size, and shape according to their ultimate use. Cast ingots may be rolled to rod at the FMPC or machined for extrusion into tubes at the Ashtabula Plant. Since the late 1960s, all ingots have been cut into billets, bored, and machined for extrusion. Some tubes are returned to the FMPC for heat treating, cutting, and final machining operations to produce target element cores for SRP. These are shipped to Savannah River where they are canned in aluminum and charged to the production reactors. The slightly enriched uranium billets that are extruded and processed at Ashtabula are shipped from Ashtabula to Hanford fuel fabrication facilities where they are further extruded and clad with a zirconium alloy to form N-reactor fuel elements.

3 ERDA, "The ERDA Facilities," ERDA 77-80, UC-13, August 1977, pp. 311-13.

4 The FMPC rolling mill is the only high tonnage production mill in the United States that is fully dedicated to uranium work. It has a capacity of about 30,000 tons per year. Ibid.

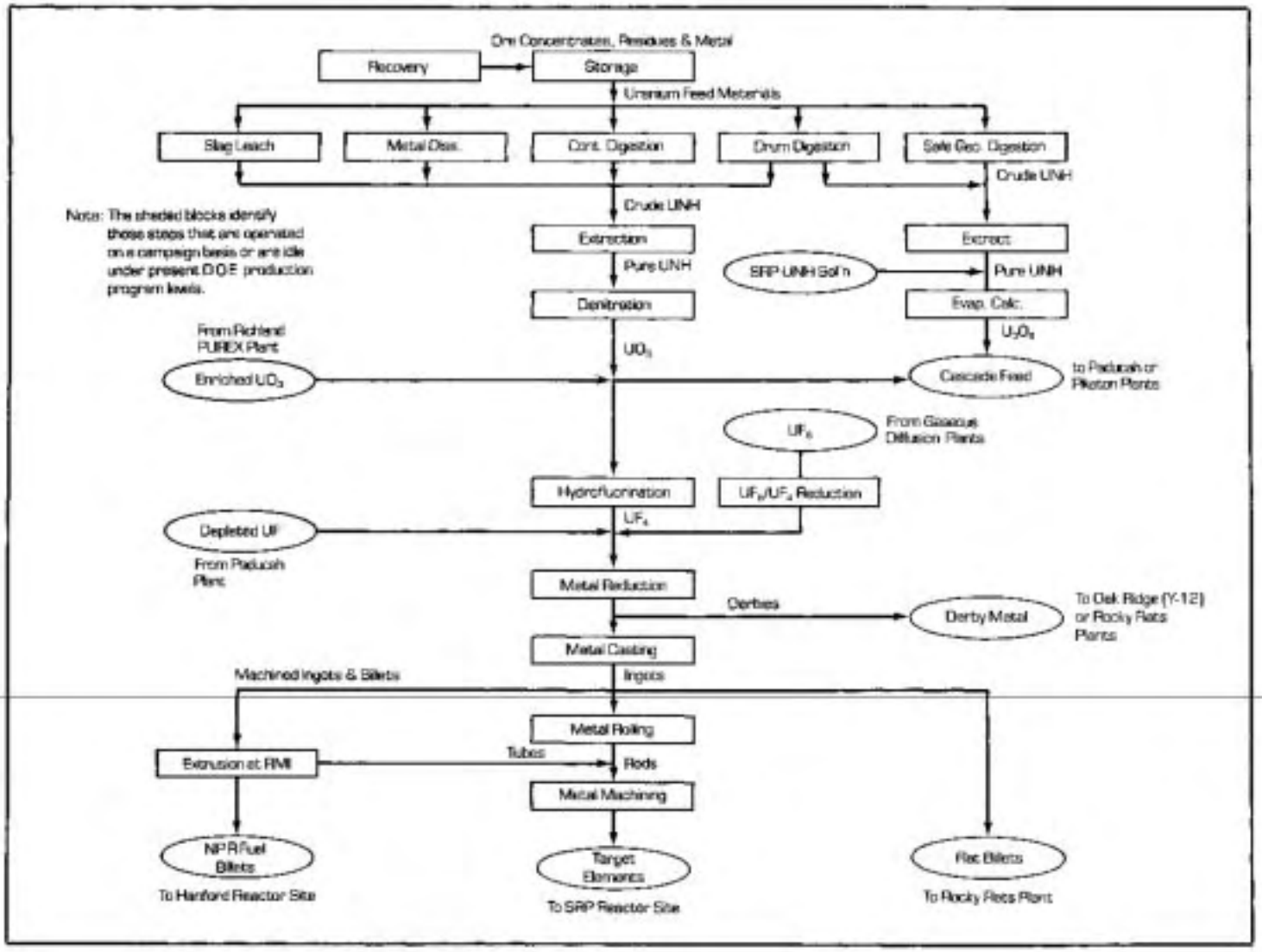


Figure 5 Schematic Diagram of the FMPC Process

Facilities

Production operations are handled in Plants 1 through 9 and the Pilot Plant. Each plant has specified functions and integrated production relationships for satisfying the overall mission. Principal capabilities of each plant are outlined below.

Sampling Plant (Plant 1)

- Ship, receive, sample, and store large amounts of depleted, normal, and enriched uranium materials in open and covered storage areas
- Dry crush, mill, and classify feed materials for subsequent processing
- Digest enriched feeds assaying up to 20% U–235 in geometrically safe equipment
- Open unirradiated fuel pins, containing enriched uranium dioxide pellets
- Recondition steel drums for reuse onsite and bale deteriorated drums for salvage

Refinery UO_3Plant (Plants 2 and 3)

- Digest residue materials in nitric acid using stainless steel tanks and conveying equipment
- Perform liquid–liquid countercurrent solvent extraction in stainless–steel, perforated–plate pulse columns for purification
- Concentrate purified uranium solution in stainless steel, thermo–syphon, and tank evaporators
- Calcine the concentrated purified uranium solution to uranium trioxide in denitration pots

Green Salt Plant (Plant 4)

- Convert UO_3 to UO_2 for hydrofluorination to uranium tetrafluoride (UF_4), or green salt, in continuous–flow reactor banks designed and staged for gas–solids reactions
- Blend and package depleted green salt for the metal reduction
- Operate the Tank Farm to supply all production

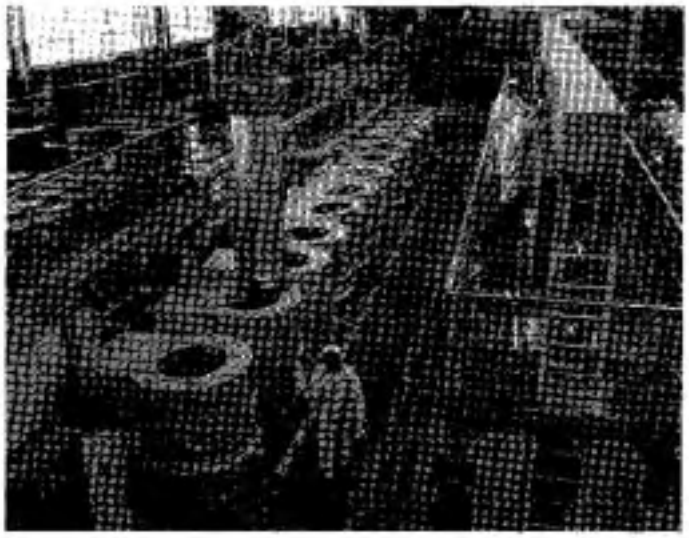


Figure 6 Rockwell Electrical–Resistance Furnaces in Plant 5

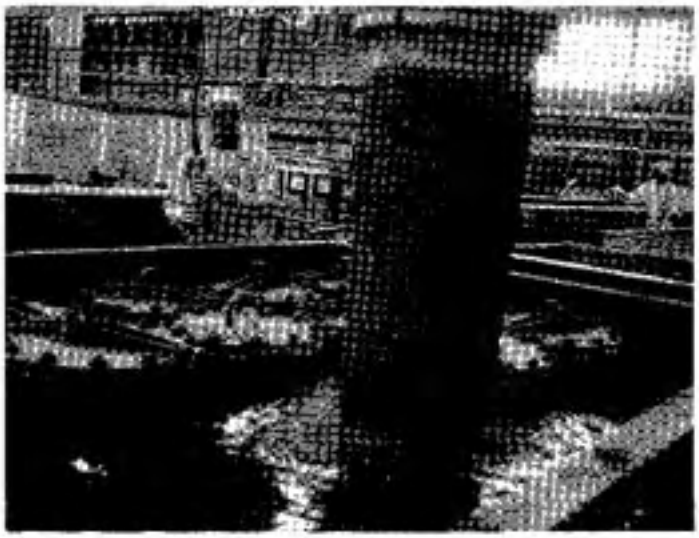


Figure 7 Water Cooling Cylinder Containing Reduction Pot and a Freshly Made Derby

plants with bulk quantities of required chemical raw materials

Metals Production Plant (Plant 5)

- Produce tonnage levels of high purity depleted and enriched uranium derby metal in electrical–resistance furnaces (see Figures 6 and 7)
- Remelt derby and recycle metals for casting into ingot or billet shapes in vacuum induction furnaces
- Crop and saw ingots into billets and saw sharpening
- Machine graphit into almost any shape using saws, lathes, milling machines, routers, and grinders
- Mill magnesium fluoride (MgF_2) slag byproduct for reuse in lining reduction pots

Metals Fabrication Plant (Plant 6)

- Salt–water heat treat enriched and depleted machined ingots and billets
- Cut depleted extruded tubes received from RMI Company into core blanks
- Salt–oil heat treat core blanks
- Final machine heat–treated depleted target element cores
- Metal pickling and chip briquetting
- Final inspection for production quality assurance and control
- Standby capability for rolling as–cast ingots into rod having close dimensional tolerances

Storage (Plant 7)

Scrap Recovery Plant (Plant 8)

- Furnace various residue recycle materials from onsite generation and offsite receipt to remove moisture, oils, graphite, and metallic impurities
- Crush, mill, and screen recycle materials
- Filter large volumes using rotary vacuum, precoat filters
- Wash used drums for reconditioning operations

Special Products Plant (Plant 9)

- Cast enriched derby and high–grade recycle metals into large diameter ingots
- Machine as–cast ingots and billets for extrusion at RMI Company
- Declad unirradiated fuel elements for remelt by chemical treatment
- Clean depleted derby metal using molten carbonate salt and acid pickling (see Figures 8 and 9)

Pilot Plant

- Convert uranium hexafluoride (UF_6) to uranium tetrafluoride (UF_4), assaying up to 2.5 percent U235
- Purify and convert thorium nitrate solution to various thorium compounds
- Furnace 1.25 to 20 percent U–235 residue recycle materials
- Declad aluminum jackets from unirradiated fuel cores by caustic treatment
- Shot blast uranium derby metal and plasma spray coat casting crucibles

Management

FMPC is a GOCO facility. Beginning in 1986 Westinghouse Electric Corporation, has operated FMPC under a prime contract with DOE. NLO, Inc. (formerly National Lead of Ohio, Inc.), a subsidiary of NL Industries (formerly National Lead Industries, New York), was the contract operator of FMPC for AEC, ERDA, and DOE from the time construction began in 1951 until the end of 1985. Operating missions and program direction are the

Figure 8 Collecting Filings to Determine Precise Enrichment of Each Specific Derby

responsibility of the Office of Materials Production under the ASDP. The Westinghouse contract is administered by the Oak Ridge Operations Office and will continue until 30 September 1991.

FMPC was designed by the Catalytic Construction Company and built by the George A. Fuller Company of New York.[5]

Capacity: Recent scheduled production at the FMPC and Ashtabula:

FY	Depleted U target cores for SR reactors [MT]	SEU billets for Hanford N-Reactor [MT]
1980[6]	900	400
1982	1800	700
1983[7]	3000	870

Product deliveries[8] (MTU/yr)

Shipments to:	1983	1984	1985–1990
Y–12			
depleted derbies	767	1127	1500
Rocky FLats			
2–inch billets	–	12	?
4–inch billets	230	189	?
derbies	?	?	?
N–Reactor			
ingots	?	?	1000
Savannah River			
target element cores	?	?	2500

5 AEC, Report to Congress, July 1951, p. 13.
6 DOE, "Congressional Budget Request FY 1980," Vol. 1, January 1979), p. 276.
7 HAC, FY 1983 EWDA, Part 4, p. 253.
8 N.J. Rixner, NLO, FY 1985 Issue—Environmental, Safety and Health Plan, 1 October 1984, p. 2–8. Letter from Pete Kelley, Westinghouse Materials Company of Ohio, to Thomas B. Cochran, 6 January 1986.

Figure 9 Finishing Depleted Uranium Cores at FMPC

BUDGET[9] ($ million):

FY	Total DOE
1971	13.864
1972	11.493
1973	12.617
1974	15.233
1975	17.115
1976*	21.646
1977	17.751
1978	18.149
1979	20.010
1980	24.516
1981	30.141
1982	33.000
1983	50.990
1984	76.132
1985	93.225
1986	119.392

* 1976 data for 15–month fiscal year.

9 Outlays: Letter from Wayne Riaga, DOE, Oak Ridge Operations Office, to Thomas B. Cochran, 25 February 1982; Estimated costs from DOE, FY 1986 Budget Request Estimates for Labs/Plants, Office of the Controller, 22 February 1985, p. 28.

Feed Materials Production Center

ASSETS

Cost of buildings and equipment (with additions through May 1980): $118 million.

PERSONNEL:[10]

FY	Employment
1952	1181
1953	1724
1954	2482
1955	2708
1956	2891
1957	2605
1958	2469
1959	2484
1960	2564
1961	2225
1962	2012
1963	2061
1964	1719
1965	1523
1966	1559
1967	1612
1968	1413
1969	1109
1970	907
1971	620
1972	662
1973	679
1974	677
1975	670
1976	633
1977	612
1978	573
1979	538
1980	566
1981	624
1982	757
1983	837
1984	1004
1985 (Mar)	1083

10 Rixner, p. 2–7; "Uranium Dust Leaks Worry Ohioans," New York Times, 3 January 1985, p. B–11; DOE, GOCO Employment, Computer Printout for Office of Industrial Relations, R–5529309–012, 29 August 1985.

Hanford Reservation[1]

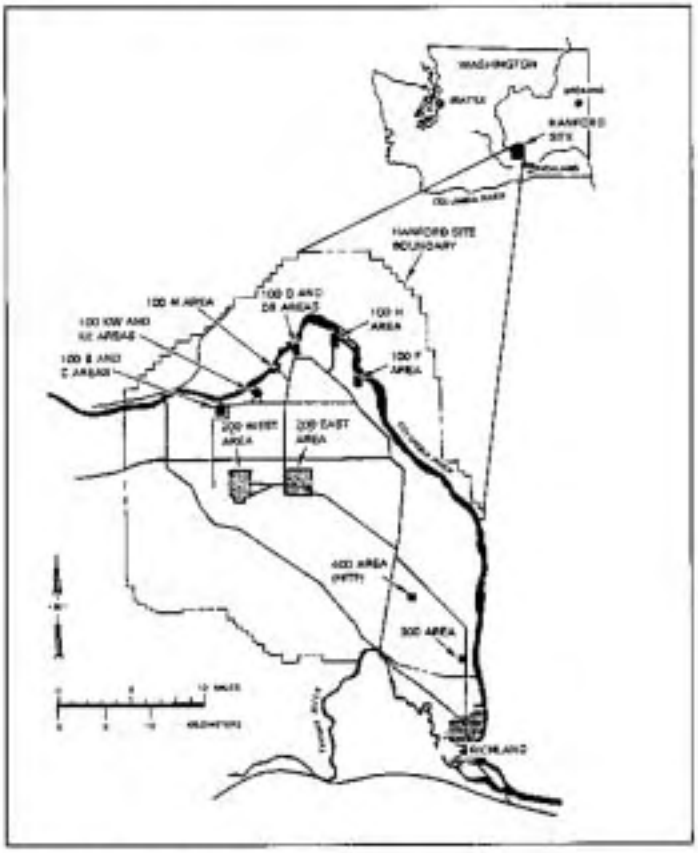


Figure 10 Map of Hanford Reservation Source: DOE

ADDRESS: U.S. Department of Energy
Richland Operations Office
P.O. Box 550
Richland, Washington 99352
509/376-7395

LOCATION: Southeastern Washington near Richland, just north of Yakima and Snake River junctions with Columbia River, which forms part of reservation's eastern boundary; 365,000 acres (570 square miles)

MISSION: The original Manhattan Project mission of the Hanford Works was the production of plutonium. While this still remains a key program responsibility, Hanford's mission has been considerably broadened, and today Hanford also plays a principal role in research and development of advanced nuclear power concepts.

MANAGEMENT: GOCO site (see text for list of contractors)

ESTABLISHMENT: Early 1943. Site selected in World War II by U.S. Army Corps of Engineers' Manhattan Engineer District to build first full-size reactors to produce plutonium for nuclear warheads.

BUDGET: $986.0 million, total (1986 est)

PERSONNEL: 13650 (Sep 1986 est)

FACILITIES:
- PUREX Plant and support facilities
- N-Reactor and support facilities
- Hanford Engineering Development Laboratory
- Fast Flux Test Facility
- Pacific Northwest Laboratory

History

In early 1943, the Hanford site was selected by the U.S. Army Corps of Engineers' Manhattan Engineer District to build larger versions of the Fermi (Chicago) and Clinton (Oak Ridge) piles to produce plutonium. A 200-square-mile tract was acquired by the government, and construction of the Hanford Engineer Works—which included three production reactors, three chemical separation plants, and 64 underground waste storage tanks—was begun in March 1943. Work on the first production reactor, the B-Reactor, was begun on 7 June 1943. The reactor began operation in September 1944,[2] and the first irradiated slugs were discharged on 25 December 1944. It was followed within a few months by the D and F reactors. In March 1945, two years from inception, construction of the Hanford works was completed at a total cost of about $350 million.

Between 1943 and early 1945, three production reactors (B, D, F) and three reprocessing plants (T, B, U) were constructed to produce and separate plutonium for the first nuclear explosive devices. Five more production reactors (H, DR, C, KE, KW), two replacement reprocessing plants (REDOX, PUREX), and 81 additional underground waste storage tanks were constructed between 1947 and 1955. From 1949 to 1965 Hanford fabricated nuclear warhead components from plutonium metal.

1 Formerly Hanford Engineering Works, then Hanford Works.

2 Henry DeWolf Smyth, Atomic Energy for Military Purposes, (Princeton, New Jersey: Princeton University Press, 1945). Section 6.51.

Between 1959 and 1963 the N-Reactor was built at a cost of $195 million. By 1971 the last of the original eight graphite-moderated water-cooled production reactors were shut down (placed on standby) and all have since been officially retired and partially dismantled.[3] Decommissioning of the eight reactors was scheduled to begin in FY 1986, starting with the F-Reactor. The preferred procedure is in-place stabilization and entombment with soil.[4] The REDOX plant was shut down in July 1967, leaving only an adjacent analytical laboratory at the site to support current B-Plant activities, which involve the recovery of cesium and strontium from high level waste. Of the five chemical separations plants originally built, only the PUREX plant remains available for fuel processing at Hanford.

Nuclear Weapons Activities

Plutonium Production (N-Reactor). The N-Reactor is a dual purpose reactor, producing plutonium and byproduct steam that is sold for commercial electricity generation. It began operating on 31 December 1963, and prior to FY 1983 it was used almost solely to produce fuel-grade plutonium. Electricity generation began in 1966 in an 860-megawatt (electrical) generating facility built adjacent to the N-Reactor.

In FY 1981, DOE began blending separated fuel-grade plutonium, some of which had been produced by the N-Reactor, with high-purity (super-grade) plutonium produced at the Savannah River Plant to obtain weapon-grade plutonium. By October 1982 the N-reactor itself had been fully converted to the steady-state production of weapon-grade plutonium. (See N-Reactor following the Hanford Reservation Summary Description for further details.)

Fuel Cycle Activities

Fuel Fabrication. In support of N-Reactor operations, low-enriched (about 1 percent U-235) cylindrical billets are simultaneously extruded and clad with zirconium to provide finished fuel elements. The fuel fabrication facility's schedule called for production of the following amounts of finished fuel annually:

FY	Finished Fuel (MT)
1980	280[5]
1982	600[6]
1983	690;[7] 900[8]
1984	950[8]

Chemical Separations. Capabilities exist to chemically process irradiated production reactor (namely, N-Reactor) fuel and plutonium-containing scrap. These include recovery and conversion of plutonium for the weapons program and reactor research programs, recovery and purification of neptunium-237 and americium-241 and other radioactive isotopes, and recovery and conversion of irradiated uranium for reuse as reactor fuel.

The PUREX Plant, the Hanford facility for chemical processing of spent fuel, was on standby from 1972 to November 1983. Following reactivation, it has been recovering 6 percent Pu-240 plutonium from irradiated N-reactor fuel to be followed by the recovery of higher assay plutonium.

Four additional facilities at Hanford are used in support of PUREX operations. At the UO_3 Plant, uranyl nitrate from PUREX is converted into UO_3 for shipment offsite to the Fernald Plant, where the depleted uranium is reused in the fabrication of new N-Reactor fuel elements. Some of the PuO_2 and Pu nitrate from PUREX is sent to the Plutonium Finishing Plant (Z Plant) for storage. Beginning in late FY 1985 the Z Plant was also used for conversion of PuO_2 to Pu metal. The B Plant has recently been serving as a waste fractionization plant where strontium and cesium are removed from high-level waste from the PUREX plant. The T Plant is now used on an irregular basis for PUREX equipment decontamination and repair. (For further discussion see PUREX, UO_3, Z, and B Plants following Hanford Reservation and Table 2.)

Waste Management. Activities at Hanford involve the evaporation and solidification of liquid high level radioactive waste from chemical separation (PUREX) operations into salt cake and storage in steel tanks. Hanford has a tank farm of single and double shell underground waste storage tanks with capacities up to 1 million gallons, including 149 old single shell tanks and 28 double shell tanks, 8 of which are new and began operation in 1986. A program to pump liquid from the aging single shell tanks into double shell tanks will be completed in 1989. Plans call for the construction beginning about 1989 of the Hanford Waste Vitrification Plant (HWVP) with operation beginning about 1993.

At the B Plant, cesium-137 and strontium-90 are removed, solidified, enclosed in double-walled metal capsules, and stored in water-cooled vaults.

Research is conducted on various modes of interim storage and geological disposal of high level waste, including conversion of salt cake to other waste forms, principally borosilicate glass. The Basalt Waste Isolation Project (BWIP) is studying the feasibility of locating a high level waste repository deep in the basalt layers underlying the Hanford site.

Plutonium Storage and Scrap Recovery. Recovery of plutonium from scrap material at the Plutonium Finishing Plant (Z Plant) was restarted in FY 1984 in the Plutonium Recovery Facility and Oxide Line.[9] Fuel-grade

3 Environmental Consequences of Alternatives to L-Reactor Restart, DPST-83-689, Savannah River Laboratory, 18 August 1983, p. 16.

4 HASC, FY 1986 DOE, p. 289.

5 Congressional Budget Request FY 1980, Vol. 1, p. 278 (January 1979).

6 HAC, FY 1982 EWDA, Part 5, p. 229.

7 HAC, FY 1983 EWDA, Part 4, p. 253.

8 HAC, FY 1984 EWDA, Part 4, p. 302.

9 *Ibid.*, p. 305.

Table 2
Operating Histories of Hanford Chemical Separation Facilities

Plant	Construction Began	Operation Startup	Operation Shutdown	Process
T	06/1943	10/1944	1956	Bismuth-phosphate (no uranium recovery). Floor space and facilities are
			–Present	currently used on an irregular basis for decontamination projects and equipment repair.
B	08/1943	02/1945	1952	Bismuth-phosphate (no uranium recovery)
		1968-Present		Waste fractionization.
U	1943	1945		Bismuth-phosphate (no uranium recovery)
		1952	1958	Recovery of uranium from stored radioactive waste.
			–Present	Adjacent UO_3 Plant is currently used to produce powdered UO_3 by calcining (UNH) solution from PUREX Plant.
REDOX	05/1950	08/1951	06/26/1967	REDuction-OXidation.
			–Present	222-S analytical laboratory still in operation in support of B Plant and other waste research activities.
PUREX	04/1953	10/1955	1972	PUREX
		11/1983	–Present	PUREX

plutonium in storage at the Z Plant is being shipped to the Savannah River Plant (F separations area) for blending with SRP high-purity (3 percent Pu-240) plutonium into weapon-grade plutonium. Additional plutonium for blending is provided by scrap recovery.[10]

Nonweapon Activities

In the early 1950s, nonweapons work began at Hanford with the construction of the Hanford Laboratories, now Hanford Engineering Development Laboratory (HEDL). The mission of HEDL now includes advanced reactor research, primarily liquid metal fast breeder reactor (LMFBR) research and development and testing.

The Fast Flux Test Facility (FFTF), a 400-Mw_t sodium-cooled fast reactor for testing fuels and materials for the breeder reactor program, is the major test facility operated at Hanford by HEDL.

Pacific Northwest Laboratory (PNL), also located at Hanford, is a multiprogram laboratory that does nondefense research on nuclear technology and nuclear waste management, and research in the life sciences on the environmental and health effects of nuclear and other energy sources (see Pacific Northwest Laboratory).

Steam produced by the N-Reactor is sold to the Washington Public Power Supply System to generate electricity in the 860-Mw_t on-site facility for sale to the Bonneville Power Administration.

Facilities

As shown in Figure 10, the Hanford Reservation is divided into several operating areas, namely:

100 Areas (6 total):	8 graphite reactors (retired) and the N-reactor
200 Areas (2 total):	fuel and waste processing and waste storage
300 Area:	R&D labs and fuel fabrication for N-reactor
400 Area:	Fast Flux Test Facility
600+ Areas:	balance of reservation

The principal facilities on the Hanford Reservation are:

N-Reactor, PUREX Plant, and Support Facilities

- N-reactor (100 Area) and adjacent, privately owned electricity generating station of the Washington Public Power Supply System
- Fuel fabrication facilities (300 Area)
- PUREX processing plant (200 East Area)
- UO_3 Plant (200 West Area) for conversion of uranyl nitrate from the PUREX plant to uranium oxide (UO_3) powder
- B-Plant (200 West Area), an early processing plant converted in 1968 to a waste fractionization plant for separating cesium and strontium from high level waste and their encapsulation and storage at the Waste Encapsulation and Storage Facility; to be used in the future for separating fractions of PUREX processing wastes identified for vitrification and possible geologic storage.
- Z Plant (Plutonium Finishing Plant) (200 West Area) for plutonium scrap recovery, conversion to metal, and storage
- T Plant (200 West Area), one of the original three fuel processing plant at Hanford, currently used on an irregular basis for equipment repair and decontamination projects

Hanford Engineering Development Laboratory (300 Area)

10 Ibid.

Fast Flux Test Facility
(400 Area) and the supporting Fuel Materials Examination Facility (FMEF); part of HEDL.
Pacific Northwest Laboratory

Management

The Hanford Reservation is a GOCO site managed for DOE under supervision of the Richland Operations Office by the following contractors:

1943-46: E.I. DuPont de Nemours and Company
1946-64: General Electric Company

In 1965 and 1966 five contractors were selected to replace GE: Batelle Memorial Institute (for the Hanford Laboratories, renamed Pacific Northwest Laboratory); Douglas United Nuclear, Inc. (for the production reactors); Isochem, Inc., a joint venture of U.S. Rubber Company and Martin Marietta Corporation (to operate the chemical separations facilities); ITT Federal Support Services, Inc.; Computer Sciences Corporation; and United States Test Company, Inc. (for radiation protection services).[11] Douglas United Nuclear assumed N-Reactor operation on 1 July 1967, completing the GE phase-out. Atlantic Richfield Hanford Co. replaced Isochem in late 1967.

The current principal operating contractors are:

Rockwell Hanford Operations (RHO). Subsidiary of Rockwell International—responsible for fuel processing (PUREX Plant, Z Plant, UO_3 Plant, T Plant); waste management (B Plant, Tank Farm Operations); Basalt Waste Isolation Project (BWIP); and site support services (bus and rail system, firefighting, central stores, etc.)[12]

Westinghouse Hanford Company (WHC). Operates the Hanford Engineering Development Laboratory (HEDL), the Fast Flux Test Facility (FFTF), and the Fuels and Materials Examination Facility (FMEF).

Battelle Memorial Institute (BMI). Operates the Pacific Northwest Laboratories (PNL).

UNC Nuclear Industries, Inc. Operates the N-Reactor and the N-Reactor fuel fabrication facility, maintains surveillance of the eight retired Hanford reactors, and leads a national program for the decontamination and decommissioning of retired government reactor facilities.

J.A. Jones Construction Services Company (JAJ). Owned by Philipp Holzman, AG, West Germany—responsible for construction and major maintenance services at all DOE Hanford facilities.

Kaiser Engineers Hanford Company (KEH). Provides onsite architectural engineering services to DOE and its contractors.[13]

BSC Richland, Inc. (BCSR). Subsidiary of Boeing Company—provides automatic data processing services to DOE and its contractors at Hanford.

Hanford Environmental Health Foundation (HEHF). Provides personnel protection services (occupational medicine, psychology, and environmental health services) to DOE and its contractors at Hanford.

Non-DOE Activities Located on the Hanford Site:

U.S. Ecology, Inc. Operates a commercial low level radioactive waste disposal site (licensed by the Nuclear Regulatory Commission and the State of Washington) on 100 acres of the Hanford site leased from DOE by the state of Washington.

Washington Public Power Supply System (WPPSS). Operates the 860 megawatt (electrical) Hanford Generating Project, which uses steam produced by the N-Reactor to generate electricity for the Bonneville Power Administration grid, and the 1100-megawatt (electrical) WPPS-2 boiling water reactor on land leased from DOE at Hanford.

BUDGET[14] (\$ million): Hanford Program Funding—All Hanford operations managed by Richland Operations Office:

FY	Total	Defense	Non-Defense
1977	437.0	167.0	270.0
1978	542.0	172.0	370.0
1979	557.0	199.0	358.0
1980	627.0	198.0	429.0
1981	669.7	257.6	412.1
1982	755.8	332.5	423.3
1983	828.5	438.6	389.9
1984	913.0	515.5	397.5
1985	973.3	552.8	420.5
1986 (est)	986.0	550.0	436.0

PERSONNEL:[15]

End FY	Rockwell Hanford	UNC	West Hanford	Pac North Lab	J. A. Jones	Kaiser Eng.	BCS	Hanford Health	Vitro Engineering	Total
1971	1870	960	1171	1240	—	—	154	60	200	5355
1972	2123	733	1367	1315	—	—	174	58	312	5972
1973	1943	686	1293	1467	—	—	227	60	210	5884
1974	2169	732	1589	1645	—	—	248	62	205	6700
1975 (Sept	2319	784	1839	1833	—	—	273[17]	65	361	7303
1976	2595[16]	811	2503	1980	—	—	313	67	509	8309
1977	2832	834	3542	2193	—	—	328	74	347	9140
1978	3243	988	2885	2470	—	—	395	86	396	10253
1979	3559	899	2952	2537	—	—	402	98	286	10723
1980	3847	965	3002	2673	—	—	373	101	266	11029
1981	3985	1199	2948	2622	—	—	398	102	249	11111
1982	4117	1361	2173	2216	631	253	279	102	—	10655
1983	4653	1815	2228	2300	793	397	248	108	—	12642
1984	5009	2079	1986	2392	755	395	342	108	—	13089
1985	5390	2222	1847	2532	797	435	405	110	—	13650
1986 (est)	5340	2220	1845	7536	775	435	405	110	—	13650

11 AEC, Report to Congress, January 1966, p. 28.
12 Prior to 1 October 1977 the contractor was Atlantic Richfield Hanford Co. (ARHCO).
13 Kaiser Engineers took over the A/E contract in December 1981. This contract was previously held by C.F. Braun and Co., a subsidiary of Santa Fe International Corp. In late 1981 Santa Fe was taken over by, and became a subsidiary of, the Kuwait Petroleum Corp., wholly owned by the government of Kuwait. The C.F. Braun Hanford contract was terminated at the request of Santa Fe shortly after the takeover. C.F. Braun has previously provided A/E services on plutonium processing and purification facilities at Rocky Flats and the Lawrence Livermore National Laboratory; and on equipment upgrading at the N-Reactor and the PUREX Plant at Hanford.
14 Letter to Milton Hoenig from O.L. Olson, DOE Richland Operations Office, 6 April 1982; Letter to Thomas B. Cochran from Mike Talbot, DOE Richland Operations Office, 18 March 1985.
15 DOE, GOCO Employment, Computer printout for Office of Industrial Relations, B-5520309-012, 29 August 1985; Letter to Thomas B. Cochran from Mike Talbot, DOE Richland Operations Office, 18 March 1986.
16 Prior years Atlantic Richfield Hanford Co.
17 Prior years Computer Sciences Co.

Hanford Engineering Development Laboratory (HEDL)

ADDRESS: Hanford Engineering Development Laboratory (Westinghouse)
P.O. Box 1970
Richland, Washington 99352
509/376-3915

LOCATION: Hanford Reservation 300 and 400 Areas

MISSION: Development of advanced nuclear power concepts, principally fission breeder and fusion reactors, with special emphasis on breeder reactor fuels and materials. HEDL has lead laboratory responsibility for the Fast Flux Test Facility (FFTF), which represents over one half of the HEDL effort.

MANAGEMENT: GOCO facility operated for DOE since early 1970 by Westinghouse Hanford Corp., a subsidiary of Westinghouse Electric Corp.

BUDGET: $104.0 million total lab (1986 est)

PERSONNEL: 1845 (1986 est)

FACILITIES:
- Fast Flux Test Facility
- Fuels and Materials Examination Facility
- Breeder Reprocessing Engineering Test
- Secure Automated Fabrication Line

Nuclear Weapons Activities

HEDL conducts research and development on nuclear waste processing technologies (e.g., conversion of combustible solid waste containing transuranic materials to a nonreactive solid) as part of the Defense Waste Program. This Defense Programs activity represents less than one percent of the HEDL effort.

HEDL has been chosen as the site for ground demonstration and testing of the compact space reactor under the SP-100 program. This reactor will provide up to 1000 kilowatts of electric power for a broad range of civilian and military applications, notably those under the Strategic Defense Initiative. The construction began in FY 1986 and will end in FY 1989. The test is scheduled to begin in FY 1990.

Nonweapon Activities

HEDL scientific and technical activities are directed primarily toward the development and testing of materials and fuels for the breeder reactor program. Included is the development of cladding and duct alloys; the design, fabrication, testing, and evaluation of fuel, blanket, and absorber assemblies; and the development of sodium coolant technology.

Major breeder program facilities are the Fast Flux Test Facility (FFTF), in full operation since 1982, and the Fuels and Materials Examination Facility (FMEF), scheduled for full operation in FY 1986. Currently laboratory and hot cell experiments on irradiated fuel are carried out at a reduced level.[1] Work also supports the DOE program of fast reactor safety assessment and licensing. A program is being undertaken for test irradiation of candidate fusion reactor materials.

Facilities[2]

Fast Flux Test Facility (FFTF). A 400-Mw_t loop-type, liquid sodium cooled, fast neutron reactor for irradiation testing of breeder fuels, materials and components and systems. Built at a cost of $647 million. Went critical on 9 February 1980, reached full power in early 1982, achieved (in October 1983) the design burnup of 80,000 Mw_d/MT in selected fuel assemblies after three full cycles of operation (100 days each) and a burnup of over 100,000 Mw_d/MT after four cycles (end of March 1984).[3]

FFTF core is 3 feet high and 4 feet in diameter with vertical array of 74 hexagonal driver assemblies, each with 217 fuel pins. (73,000 fuel pins fabricated in the 1970s by Kerr-MaGee and Babcock and Wilcox contain 2.9 MT of fuel-grade plutonium.) Core loading is 563 kg fissile plutonium (640 kg 12 percent Pu-240 plutonium) in mixed-oxide fuel with approximately 25 percent plutonium content. Discharge burnup of driver fuel is about 30,000 Mw_d/MT.

The FFTF does not generate electricity, but conversion to electricity generation was given consideration after cancellation of the Clinch River Breeder Reactor.

Fuels and Materials Examination Facility (FMEF). Facility for advanced fuel fabrication and reprocessing systems. Will house the Secure Automated Fabrication (SAF) process line for fabrication of reactor fuels and the Breeder Processing Engineering Test (BRET) for processing FFTF fuel to demonstrate closure of the fuel cycle. Construction of FMEF was completed in late FY 1984 at a total estimated cost of $174.9 million.[4]

Breeder Processing Engineering Test (BRET). Fuel processing facility located in the FMEF. BRET will have a

1 HAC, FY 1986 DWDA, Part 4, pp. 876-877.

2 HEDL Institutional Plan, FY 1982-87; HEDL Institutional Plan, FY 1981-86.

3 Defense program accomplishments since January 1981, Memorandum, 28 July 1982; HAC, FY 1985 DWDA, Part 4, p. 928; Nuclear News, May 1984, p. 59 ff; Energy Daily, 15 November 1983, p. 3; 2 April 1984, p. 2; 4 April 1984, p. 2; letter from Donald Paul Hodel to Richard L. Ottinger, 5 March 1984, Encl. 1.

4 HAC, FY 1985 DWDA, Part 6, pp. 860-861.

nominal capacity of 15 MT heavy metal per year for reprocessing FFTF and other breeder reactor fuels. Product is to be recycled into the breeder reactor development program. Completion scheduled in FY 1985.

BRET duplicates the capability of the planned Processing Facility Modifications (PFM) at PUREX plant to process FFTF fuel. The PFM is primarily to recover plutonium for weapons program (for SIS plant or blending); BRET is for breeder R&D, but functions are interchangeable, at least for burnups up to 30,000 Mw_d/MT.

Secure Automated Fabrication (SAF) Line. Remotely operated and automated mixed-oxide fuel fabrication line housed in FMEF. Will fabricate mixed-oxide fuel for the FFTF at throughput of 6 MT per year accommodating plutonium with up to 20 percent Pu-240, or higher with reduced batch size. Operational in 1987.

BUDGET[5] (\$ million):

FY	Total Laboratory Funding:
1980	250.7
1981	207.8
1982	218.8
1983	?
1984	145.3
1985	126.8
1986	104.0

ASSETS

Plant replacement value in FY 1982: \$750 million. Temporary and permanent office and laboratory space: 500 thousand square feet in FY 1982; planned growth to 640,000 square feet by FY 1986.

PERSONNEL:

End FY	Total
1971	1171
1972	1367
1973	1291
1974	1580
1975 (Sep)	1859
1976	2303
1977	2532
1978	2885
1979	2952
1980	3002
1981	2648
1982	2173
1983	2228
1984	1996
1985	1847
1986 (est)	1845

5 Letter to Thomas B. Cochran from Mike Talbot, Richland Operations Office.

N-Reactor[1]

Figure 11 Aerial View of N-Reactor

ADDRESS: See Hanford Reservation

LOCATION: Hanford Reservation 100-N area (see Figure 10)

MISSION: Designed as a dual purpose reactor for the production of plutonium and the production of by-product steam for the generation of electricity.

ESTABLISHMENT: N-Reactor, built between 1959 and 1963 at a cost of $195 million, went into operation as plutonium production reactor 31 December 1963.[2] Began dual purpose operation 8 April 1966, generating 860 Mw_e.[3]

BUDGET: $246.0 million (1986 est)

NOTE: See Table 3 for detailed specifications

History

The reactor and component systems within the reactor building (105-N) were designed by General Electric Company and built by Kaiser Engineers; the heat dissipation plant was designed by Burns and Roe. Construction occurred between 1959 and 1963 at a cost of $195 million. Plutonium production began in 1963. It first reached full design power of 4000 Mw_t in December 1965.[4] Subsequently the Washington Public Power Sup-

1 Formerly the "New Production Reactor."

2 Letter to Thomas B. Cochran from Robert W. Newlin, DOE Richland Operations Office, 26 February 1981.

3 The N-Reactor, like the production reactors at SRP, was designed with a capability to produce a variety of nuclear materials. Congress authorized dual purpose operation in 1965; Environmental Report on the Operation of the N-Reactor and Fuels Fabrication Facilities, United Nuclear Industries, Inc., UNI-1313, 9 May 1979, p. 1-1.

4 AEC, Report to Congress, January 1966, p. 75.

Table 3
Characteristics of the Hanford N-Reactor

DUAL PURPOSE:	Production of plutonium and electricity
DESIGN RATING:	4000 Mw_t[a] 862 Mw_e[b]
Operating Power:	3760 Mw_t (1975),[c] 3850 Mw_t (1982),[d] 4000 Mw_t (1983),[e] 4800 Mw_t (19 June 1987)[f]
CAPACITY FACTORS:	
Design:	0.60 (corresponds to 4.5 billion Kwh/yr)[g]
Actual:	See Volume II, Table 3.4.
Lifetime Average:	
Thermal:	1964-FY 1984): 0.442[h]
Electrical:	(1966-FY 1984): 0.428
1985:	0.429[i]
OPERATING HISTORY:	Began operation, 31 December 1963 Began dual purpose operation, 8 April 1966,[j] producing. Operated in plutonium/tritium coproduction mode, 1966-67.[k]
FUEL:	
Characteristics:	Elements of slightly enriched uranium metal in two concentric cylindrical zirconium clad fuel tubes (2.5 in. diameter): Mark IV elements (0.95 percent U-235, 26 in length) in 80 percent of core, Mark I-A "spike" elements (1.25 percent U-235 inner tube, 0.95 percent U-235 outer tube, 21-inch length) in 20 percent of core. Used to drive reactor and breed plutonium.
Requirements:	Production of fuel-grade (12 percent Pu-240) plutonium at design capacity factor: 325,[l] 315,[m] 316,[n] 328[o] MT uranium per year. Production of weapon-grade (6 percent Pu-240) plutonium at design capacity factor: 750-800 MT/yr.[p] One-fourth core discharged at each shutdown.[q]
Burnup:	2600-2800 Mw_d/MT (12 percent Pu-240); 1100-1200 Mw_d/MT (6 percent Pu-240).[r]
Refueling Interval:	Approximately 3 months (12 percent Pu-240); 5 weeks (6 percent Pu-240).[s]
ELECTRICITY PRODUCTION:	
Dual Purpose Operation:	Since 8 April 1966
Electrical Energy Production 1966-85 (19.73 years):	64.50 billion kwh[t]
Annual Output:	See Volume II, Table 3.4.
1985:	2.94 billion kwh[u]
DOE Contract:	DOE-Washington Public Power Supply System—renewed in 1978; DOE to provide WPPSS with steam availability equivalent to 4.5 billion kwh annually over five years ending June 1983.[v] A ten year extension effective June 1983 increases revenues by 68 percent.[w]
PLUTONIUM PRODUCTION:	
Production History:	
31 Dec 1963:	Began operation
1966-67:	Operated in plutonium/tritium coproduction mode
Prior to 1973:	Produced 9 percent (fuel-grade) and some 6 percent (weapon-grade) Pu-240 plutonium
1973-82:	Produced fuel-grade (nominal 12 percent Pu-240) plutonium
After Oct 1982:	Converted to production of weapon-grade (6 percent Pu-240) plutonium.[x]
Production Rates:	600 to 630 kg/yr fuel-grade (12 percent Pu-240) plutonium at design capacity factor.[y] 700 to 750 kg/yr weapon-grade (6 percent Pu-240) plutonium at design capacity factor.[z]
Cumulative Fuel-Grade Production	
1964-80:	7.6 MT fuel-grade plutonium,[aa] see Table 3.4. Includes 4.2 MT unseparated.[bb]
1964-1982:	8.3 MT (estimated)
Spent Fuel:	In storage basin, 31 December 1981: 2440 MT uranium.[cc]
BUDGET COSTS ($ million):	**UNC Nuclear Industries, Inc.**[dd] **FY** **Total** 1964 197.1 1985 233.7 1986 est 246.0

a Environmental Report on the Operation of N-Reactor and Fuels Fabrication Facilities, United Nuclear Industries, Inc., 9 May 1979, UNI-1313, p. II-36. The N-Reactor has operated at 4800 Mw_t during a plutonium/tritium coproduction run in 1966-67.

b *Nucleonics Week*, 25 December 1980.

c Environmental Report on the Operation of the N-Reactor, UNI-1313, p. II-38.

d HASC, FY 1983 DOE, p. 843.

e FEIS, L-Reactor Operation, Savannah River Plant, DOE/EIS-0108, May 1984, Vol. 1, p. 2-4.

f For one day during the plutonium/tritium coproduction mode demonstration. Afterwards the reactor returned to normal 4000 Mw_t operation; AEC, *Report to Congress*, January 1968, p. 38. See also FEIS, L-Reactor, May 1984, Vol. 1, p. 2-4.

g Environmental Report on the Operation of the N-Reactor, UNI-1313, p. II-15.

h *Nucleonics Week*, 28 January 1982. During this period the reactor was frequently down for maintenance, inspection and repair.

i *Nucleonics Week*, 2 January 1986, p. 19.

j Letter to Thomas B. Cochran from Robert W. Newlin, DOE Richland Operations Office, 26 February 1981.

k HASC, FY 1983 DOE, p. 843.

l HASC, FY 1981 DOE, p. 585. In FY 1980, "[in] support of N-reactor operations, the Richland fuel fabrication facility was scheduled to produce about 280 metric tons of finished fuel." HASC, FY 1980 DOE, p. 450. 280 MT/yr is assumed to be requirements for a capacity factor of 0.52; ibid., p. 587.

m Approximate discharge; Environmental Report on the Operation of the N-Reactor, UNI-1313, p. II-14.

n Projected requirement, FY 1979; ibid., p. II-102.

o Projected requirement, FY 1980; ibid.

p HASC, FY 1981 DOE, p. 587.

q FEIS, L-Reactor, Vol. 1, p. 1-4.

r See Gene I. Rochlin, *et al.*, "West Valley: Remnant of the AEC," *Bulletin of the Atomic Scientists*, January 1978.

s *Health Physics Society Newsletter*, June 1981, p. 6.

t *Nucleonics Week*, 2 January 1986, p. 18.

u *Ibid.*

v For an analysis of N-reactor steam payments, see HASC, FY 1980 DOE, p. 267.

w Defense Program Accomplishments Since January 1981, Memorandum of Herman E. Roser to the Secretary of Energy, 29 July 1982.

x *Ibid.*

y The lower value is from HASC, FY 1980 DOE, p. 23. The upper value is derived from the lower value by scaling the N-Reactor power to 4000 Mw_t from 3800 Mw_t.

z The upper value is from HAC, FY 1980 EWDA, p. 2635.

aa As of 30 September 1980. Letter from F.C. Gilbert, Acting Deputy Assistant Secretary for Nuclear Materials, DOE, to Thomas B. Cochran, 24 March 1981.

bb *Ibid.*

cc HASC, FY 1981 DOE, p. 587; Draft Environmental Impact Statement, Operation of PUREX and Uranium Oxide Plant Facilities, DOE/EIS-0089D, May 1982, p. 3.1.

dd Letter to Thomas B. Cochran from Mike Talbot, Richland Operations Office, 19 March 1986.

ply System (WPPSS) built an 860 Mwe generating station on-site, and dual purpose operation (plutonium production and electricity generation) began on 8 April 1966.

Nuclear Weapons Activities

From the beginning of operation in December 1963 until dual purpose operation in April 1966 the N-Reactor appears to have operated in the weapon-grade plutonium (6 percent Pu-240) production mode. From 1966 through 1972 it operated to produce fuel-grade plutonium (9 percent Pu-240).[5] From 1973 (after the PUREX plant went on standby in 1972) until 1982, the N-Reactor produced fuel-grade (nominal 12 percent Pu-240) plutonium,[6] although the actual Pu-240 content varied from about 5 percent to 19 percent, depending on the fuel position in the reactor and the degree of exposure.[7] In FY 1981 (late 1980), Congress approved the conversion of the N-Reactor from fuel-grade to weapon-grade plutonium production.[8] The conversion took the reactor from 12 percent to 9 percent to 6 percent Pu-240 over a period beginning in February 1982[9] on a scheduled basis.[10] It reached a steady-state weapon-grade (6 percent Pu-240) mode of production by October 1982, ahead of schedule.[11]

The production of tritium in the N-Reactor has been demonstrated,[12] but it is a far more effective producer of plutonium. 650 kg per year of weapon-grade plutonium and 3 kg per year of tritium can be coproduced.[13]

Several alternative plans to increase production of weapon-grade plutonium have been proposed but not funded. They are conversion of the N-Reactor to the production of 5 percent Pu-240 plutonium for blending[14] or operation of the N-Reactor at an increased power level of about 4400 Mw_t,[15] or both. With both of these initiatives in place, the fuel throughput would more than triple fuel requirements for fuel-grade plutonium production.[16]

General opinion has been that by the mid-1990s the N-Reactor will need to be shut down due to physical deterioration (swelling) of the graphite moderator, which is not correctable.[17] Nevertheless, DOE requested funding in FY 1985 for studies of ways to extend the operating life economically.[18] Extending the operating life will require disassembly and rebuilding of the core.

Nonweapon Activities

Prior to FY 1983, the N-Reactor was operated mainly to produce fuel-grade plutonium, some of which has been used in the breeder reactor research and development program, and byproduct steam. The steam is sold to the Washington Public Power System to generate electricity for the Bonneville Power Administration.

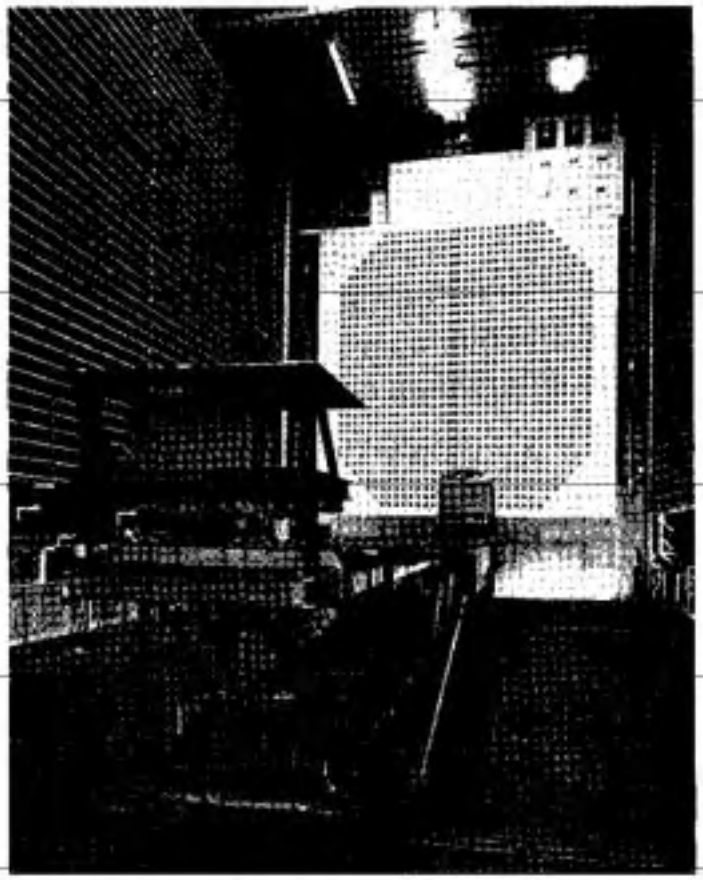


Figure 12 N-Reactor Front Face

Characteristics

Reactor. The N-Reactor is graphite-moderated and is cooled with pressurized light water. It has a rated capacity of 4000 Mw_t.[19]

The reactor core is constructed of interlocking high-density graphite blocks that support pressure tubes made of zirconium into which the fuel elements are inserted. There are 1003 horizontal process blanket gas pressure

5 14.9 kg of weapon-grade plutonium was recovered in 3 batches of N-Reactor spent fuel processed by Nuclear Fuel Services at West Valley, NY between April and July 1966; Cass I. Bochlin, Margery Hield, Barbara G. Kaplan and Louis Kruger, "West Valley: Remnant of the AEC," Bulletin of the Atomic Scientists, January 1978, p. 23; FEIS, *L-Reactor Operation, Savannah River Plant*, DOE/EIS-0108, May 1984, Vol. 1, p. 1-4.

6 FEIS, *L-Reactor*, Vol. 1, p. 1-4.

7 *Ibid.*, p. 1-6.

8 At that time authorization was also given to start up the PUREX facility at Hanford for processing N-Reactor fuel and to upgrade the L-Reactor at SRP to bring it to a condition where it could be restarted on short notice.

9 "Defense Program Accomplishments Since January 1981," Memorandum from Herman E. Roser to the Secretary of Energy, 28 July 1982, Enclosure: "Hanford Accomplishments Jan. 1 1981-Present," 25 August 1982.

10 HAC, FY 1982 EWDA, Part 7, p. 627; and "Hanford News," reprinted in Health Physics Society Newsletter, June 1981, p. 6.

11 HAC, FY 1984 EWDA, Part 4, p. 301.

12 During 1966-67 the N-Reactor operated in a plutonium/tritium coproduction mode at a power level of 4000 Mw_t except for one day, 18 June 1967, when it operated at 4800 Mw_t; AEC, Report to Congress, January 1968, p. 38, and FEIS, *L-Reactor*, Vol. 1, p. 2-4.

13 HASC, FY 1982 DOE, p. 171.

14 HASC, FY 1983 DOE, p. 418.

15 Ibid., p. 243.

16 Ibid.

17 HASC, FY 1982 DOE, p. 38; Extended Service Live of Savannah River Plant Reactors, DPST-80-510, Savannah River Laboratory, October 1980, p. 7; HASC, FY 1984 DOE, p. 177.

18 HAC, FY 1985 EWDA, Part 4, p. 426.

19 Environmental Report on the Operation of the N-Reactor and Fuels Fabrication Facilities, UNI-1313, p. II-27.

tubes running from front to rear through the graphite core. Helium is the blanket gas.[20]

High-purity water is recirculated under pressure through the process tubes to remove heat from the fuel. The heat is transferred into secondary loop steam generators, located in an adjacent heat dissipation building (109-N). The steam produced is used to drive the reactor primary coolant pumps, generate electricity for N-reactor use, and supply the adjacent Hanford Generating Plant, built and operated by the Washington Public Power Supply System. The Hanford Generating Plant is capable of generating 862 Mw of electrical power for the DOE Bonneville Power Administration.

The graphite core is 39 feet 5 inches long, 33 feet wide, and 33 feet 6 inches high. It is surrounded by a graphite reflector, 20 inches thick in the front and rear and 48 inches thick on the other sides. Gas plenums between the core and the reflectors are filled with helium. A thermal shield (to absorb radiation and heat energy), consisting of 8-inch thick cast iron blocks in the front and rear and 1-inch thick boron steel plate on the other sides, surrounds the graphite stock.[21] Outside this is a concrete biological shield of high density concrete that supports the thermal shield, the fuel tubes, the control rods, and the ball hoppers, and acts as the reactor gas atmosphere container. In the 105-N building the reactor core and primary coolant system piping are contained within a secondary concrete enclosure that provides isolation from the rest of the building during reactor operation.[22]

Eighty-four horizontal boron carbide control rods enter side-to-side channels in the graphite core, approximately half from each side. These can be operated individually for reactor control or scrammed for rapid shutdown. One hundred and seven vertical channels that pass through the core for the ball safety system provide gravity feed for samarium oxide ceramic balls coming from hoppers in the top biological shield to shut down the reactor.[23]

The pressurized primary coolant enters the reactor through sixteen lines, each connected to fifty-four to sixty-six pressure tubes. The heated coolant is transported to the adjacent heat dissipation building (109-N) where the primary coolant system consists of six cells in parallel (one in standby), each with two heat exchangers and a circulatory pump. Normal operating levels are approximately 390°F inlet and 535°F outlet temperatures and a pressure of 1600 psig.[24] The secondary coolant system (steam supply) boils water to remove heat from the primary system.

Some steam is used in-plant with the excess exported to drive turbine generators of the WPPS Hanford Generating Project. Steam not exported can be routed to sixteen dump condensers; this is the current operating mode.[25]

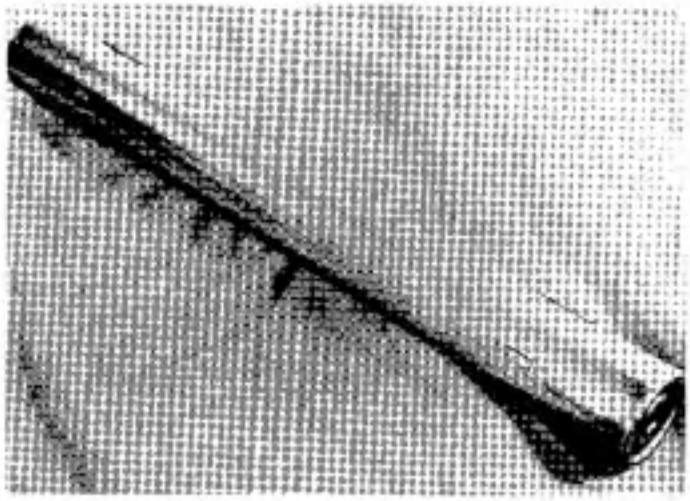


Figure 13 Zirconium Clad Fuel Element

The Columbia River is the source of raw water for the reactor cooling systems, supplying 315,000 gpm at full power operation. Demineralized water is used in the primary, secondary, control rod, and graphite coolant systems with a normal flow of 1300 gpm and a maximum of 2300 gpm.[26] The graphite core is maintained at a temperature below 1325°F by coolant passing through 640 side-to-side tubes.[27]

Fuel. The N-Reactor uses slightly enriched uranium fuel (0.947 percent and 1.25 percent U-235). Unlike the production reactors at SRP, the same fuel elements are used for both driving the reactor and breeding plutonium. The fuel elements consist of cylinders arranged in a tube-in-a-tube configuration that provides for three channels of coolant around the fuel.[28] The elements are clad in zircalloy (zirconium-tin alloy).

Two types of fuel are used. The Mark I-A assembly—called the "spike"—is 21 inches long and has a total uranium weight of 36.6 pounds. The outer tube has an enrichment of 1.25 percent U-235; the inner tube is 0.947 percent U-235; and the average for the total element is 1.15 percent U-235. This type of element is used to obtain the desired reactivity pattern in the N-Reactor and represents approximately 20 percent of the total reactor charge. The Mark IV element, representing approximately 80 percent of the reactor core load, is 26 inches long and has a uranium weight of 51.7 pounds. Both the inner and outer tubes are enriched to 0.947 percent U-

20 Ibid.
21 Ibid., p. II-33.
22 Ibid., p. II-34.
23 Ibid., p. II-30.
24 Ibid., pp. II-32, 33.
25 Ibid., p. II-34.
26 Ibid., p. II-41.
27 Ibid., p. II-30.
28 Ibid., p. II-31.

235.[29] Sixteen of these rods fill one N-Reactor process tube[30], so that the length of the fuel charge in a process tube is about 35 feet.[31] The tubes have a 2.7-inch inside diameter and a 0.250-inch thickness.[32]

After irradiation, the average concentrations of U-235 in the Mark IV fuel range from 0.83 percent (when the reactor is operated to produce plutonium containing 6 percent Pu-240) to 0.75 percent U-235 (when the reactor is producing 12 percent Pu-240 plutonium). For the Mark I-A fuel, the corresponding U-235 average values are 1 percent and 0.85 percent.[33] (The weights and dimensions are typical; there are several minor deviations in common use for basically similar fuel elements.)[34]

Operation. Prior to 1983, the N-Reactor operated at a power of about 3800 Mw_t.[35] The current power level is 4000 Mw_t.[36]

For production of fuel-grade (12 percent Pu-240) plutonium (the chief mode of operation from 1973 to FY 1983) the annual fuel discharge is about 315 MT uranium containing approximately 615 kg plutonium (1950 g/MT), corresponding to electricity generation of 4.5 billion kilowatt-hours.[37] The equivalent fuel burnup is 2600 to 2800 Mw_d/MT. The comparable fuel discharge for current weapon-grade (6 percent Pu-240) production mode is estimated at about 750 to 800 MT uranium annually, yielding approximately 700 to 750 kg[38] plutonium at a 60 percent capacity factor.

In the fuel-grade plutonium (12 percent Pu-240) production mode, the N-Reactor is refueled every three months; in the weapons-grade (6 percent Pu-240) mode, about every five weeks.[39] At each refueling, one fourth of the core is discharged.[40]

During the period of PUREX standby (1972-83), irradiated fuel was discharged for cooling into the N-Reactor spent fuel pool followed by storage in the 105-K spent fuel pool.[41] Following PUREX restart in November 1983 both N-Reactor spent fuel in storage and more recently discharged spent fuel are being processed. N-Reactor spent fuel in storage has been sorted so that spent fuel with lower Pu-240 content (as low as 6 percent) is being processed first—that is, in FY 1984 and FY 1985. The plutonium recovered is shipped to Los Alamos and the Savannah River Plant either for use in weapons or for blending.[42]

Prior to 1972, irradiated N-Reactor fuel was processed in the PUREX plant, except for 380 MT processed at West Valley, New York, between 1966 and 1971.[43]

29 Rockwell International, "Environmental Report of PUREX Plant and Uranium Oxide Plant—Hanford Reservation," RHO-DC-742, April 1979, pp. II-24 and II-26.

30 HASC, FY 1982 DOE, p. 130.

31 Environmental Report on the Operation of the N-Reactor, UNI-1313, p. II-31.

32 Ibid., p. II-31.

33 HASC, FY 1982 DOE, p. 130.

34 Ibid.

35 Environmental Report on the Operation of the N-Reactor, UNI-1313, p. II-31; HASC 97-41, April 1982, p. 243.

36 FEIS, L-Reactor, Vol. 1, p. 2-3.

37 Environmental Report on the Operation of the N-Reactor, UNI-1313, p. II-14.

38 Upper value from HAC, FY 1980 EWDA, Part 7, p. 2630.

39 "Hanford News," reprinted in Health Physics Society Newsletter, June 1981, p. 6.

40 FEIS, L-Reactor, Vol. 1, p. 1-4.

41 Environmental Report on the Operation of the N-Reactor, UNI-1313, p. I-1.

42 HAC, FY 1985 EWDA, Part 4, p. 429; FEIS, L-Reactor, Vol. 1, p. 1-4.

43 553 kg of mainly weapon-grade plutonium was recovered. Gene I. Rochlin, et al., "West Valley: Remnant of the AEC," Bulletin of the Atomic Scientists (January 1978): 17.

PUREX, Uranium Oxide (UO_3), B and Z Plants

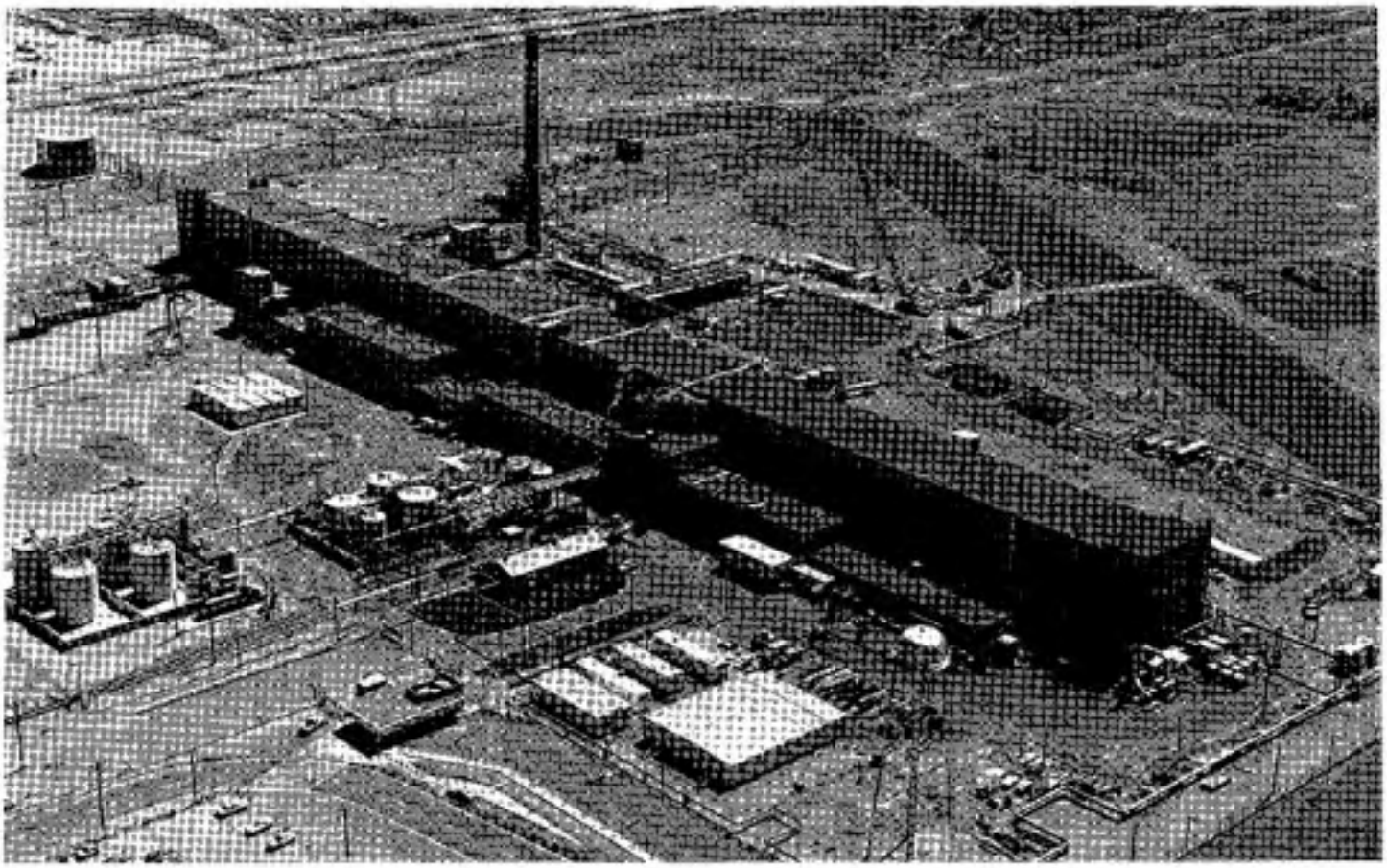


Figure 14 Aerial View of PUREX Plant

ADDRESS:	See Hanford Reservation
LOCATION:	Hanford Reservation 200 East Area (PUREX and B Plants), and 200 West Area (UO_3 and Z Plants)
MISSION (PUREX):	Processing of irradiated fuels from Hanford production reactors (the N-Reactor) to recover plutonium, neptunium, and uranium, as well as byproduct cesium and strontium.
ESTABLISHMENT (PUREX):	
Construction:	April 1953 to October 1955
Operation:	1956 to September 1972
Standby:	September 1972 to November 1983[1]
Restart:	November 1983[2]
BUDGET:	$405.0 million (1986 est)

History

In their first periods of operation, from 1956 to 1972, the PUREX (Plutonium-Uranium Extraction Process) and UO_3 Plants processed irradiated fuels discharged from all nine plutonium production reactors at the Hanford site—the original eight graphite reactors and the N-reactor—to recover plutonium and uranium. During the late 1960s, irradiated thorium targets were also processed at the PUREX plant to separate uranium-233 for the weapons program.[3]

PUREX is the most recently constructed of the fuel processing plants at Hanford, and it took over fuel processing operations from the REDOX Plant, which was placed on standby on 26 June 1967.[4] The REDOX Plant, located in 200 West Area, used a reduction-oxidation process for fuel separation that, for the first time, allowed recovery of uranium as well as plutonium. It succeeded

1 HAC, FY 1985 EWDA, Part 4, p. 423.
2 HAC, FY 1984 EWDA, Part 4, p. 388.
3 Seattle Post-Intelligencer, 28 August 1963, p. A1.
4 AEC, Annual Report to Congress, January 1967, p. 99. Dissolution of irradiated fuels at REDOX terminated on 31 December 1966.

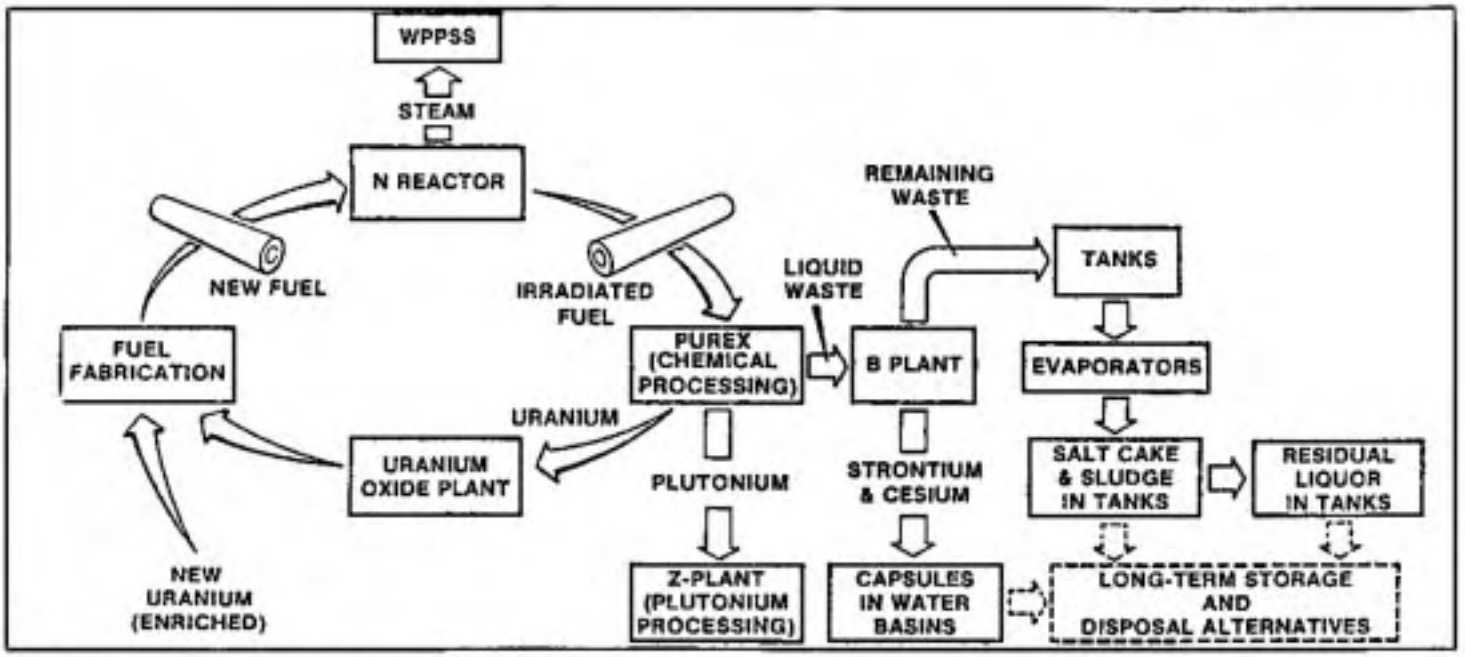


Figure 15 Hanford Production of Nuclear Materials

1985, conversion of PuO2 to metal will be transferred to the Z Plant.

Uranium Oxide (UO_3) Plant. The UO_3 Plant converts uranyl nitrate hexahydrate (UNH) from the PUREX plant to solid UO_3. From the PUREX plant an aqueous solution of approximately 60 weight percent UNH is received for storage in 100,000-gallon tanks and concentrated in evaporators to 100 weight percent UNH. Calciners then convert the UNH solution into UO_3 by application of heat. Oxides of nitrogen and water are driven off, collected, and converted to nitric acid and are then returned to the PUREX Plant for reuse, and the UO_3 powder is collected from the calciners and loaded into drums.

The UO_3 Plant is scheduled to operate in one or two short campaigns each year. The product UO_3 will be shipped either to the Paducah Gaseous Diffusion Plant for reenrichment in the isotope U-235 or to the Feed Materials Production Center (Fernald) for conversion to uranium metal.

B Plant. As part of the program to develop methods for the solidification of high-level waste, the B Plant was converted in 1968 to a waste fractionization plant. The plant's mission has been to remove Cs-137 and Sr-90 from current PUREX acid waste and from high-level supernatant liquids in stored waste. The Waste Encapsulation and Storage Facility was constructed on the west end of the B Plant building. Here the strontium and cesium are converted to solid strontium fluoride and cesium chloride, doubly encapsulated, and placed in retrievable water-cooled storage. These activities are coming to a close. Solidification and encapsulation of the backlog of cesium was completed in FY 1983 (1575 capsules); encapsulation of strontium is to be finished in FY 1985 (630 to 660 capsules). Starting in FY 1985 and 1986, the B Plant was converted to treat newly generated high level waste (HLW) and transuranic (TRU) waste from the PUREX plant. To save storage space in the HLW tank farm, the decontaminated salt fraction of the high level waste will be separated and disposed of as low level waste (LLW). In the future, the remaining high level waste will be converted to glass (for permanent disposal) in the planned Hanford Waste Vitrification Plant.[17]

Z Plant. The Plutonium Finishing Plant (Z Plant) is a complex of buildings with the capability for converting plutonium to oxide or metal, recovering plutonium from scrap, and plutonium storage. Conversion of plutonium to metal (in the 234-5-Z building) was terminated in 1972 but was restarted in late FY 1985 to process weapon-grade plutonium oxide being separated at PUREX from N-Reactor fuel and to prepare feed for the Hanford SIS plant. The conversion of plutonium nitrate to oxide, originally carried out at the Z Plant for PUREX, is now done at the PUREX Plant. The Z Plant has a plutonium storage vault, and fuel-grade plutonium oxide is shipped from there to Savannah River for blending (see Table 4).

Scrap recovery (in the 236-Z building) reclaims plutonium for the weapons program from scrap inventory and from scrap generated during terminal cleanout.[18] (400 kg of recovered scrap were to be blended in FY 1984).[19] The Z Plant was temporarily deactivated in FY 1980-83, leaving Hanford without capability to recover plutonium scrap, and operation of the Plutonium Recov-

17 SASC, FY 1985 DOE, p. 148.
18 HAC, FY 1984 EWDA, Part 4, p. 306.
19 Ibid.

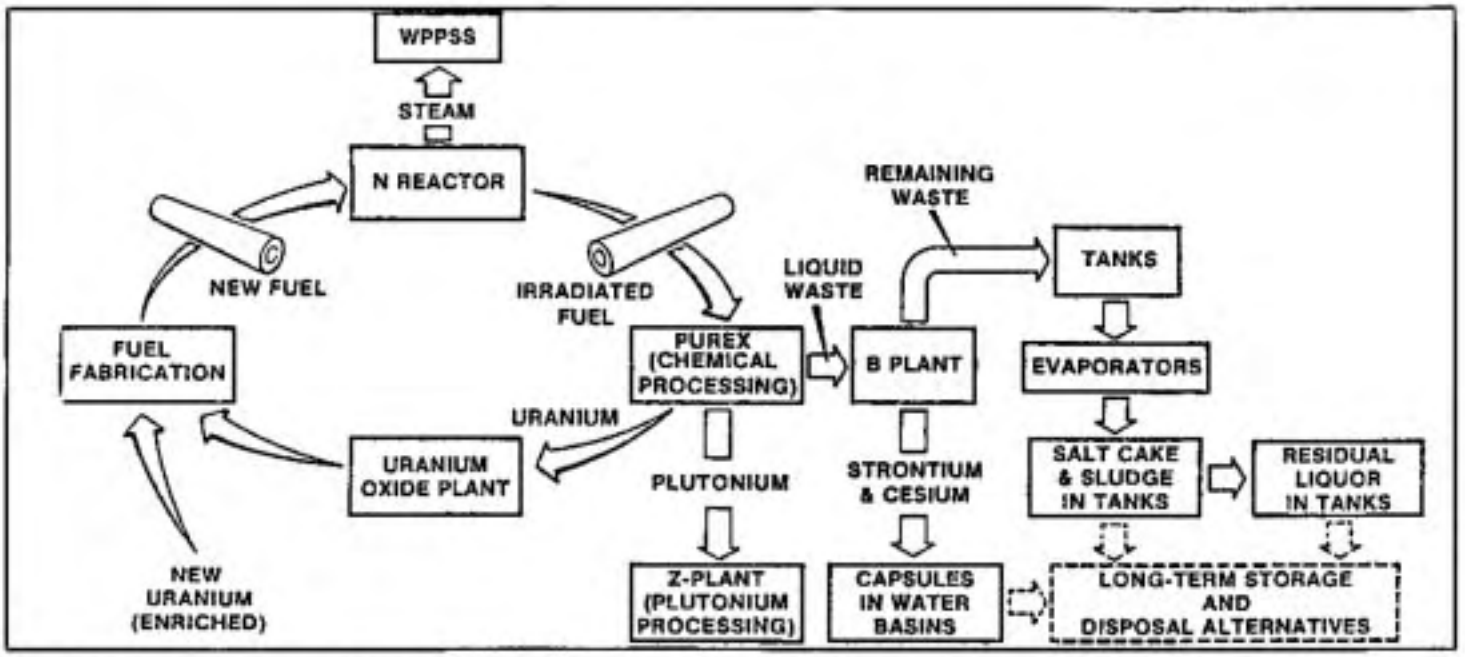


Figure 15 Hanford Production of Nuclear Materials

1985, conversion of PuO2 to metal will be transferred to the Z Plant.

Uranium Oxide (UO_3) Plant. The UO_3 Plant converts uranyl nitrate hexahydrate (UNH) from the PUREX plant to solid UO_3. From the PUREX plant an aqueous solution of approximately 60 weight percent UNH is received for storage in 100,000-gallon tanks and concentrated in evaporators to 100 weight percent UNH. Calciners then convert the UNH solution into UO_3 by application of heat. Oxides of nitrogen and water are driven off, collected, and converted to nitric acid and are then returned to the PUREX Plant for reuse, and the UO_3 powder is collected from the calciners and loaded into drums.

The UO_3 Plant is scheduled to operate in one or two short campaigns each year. The product UO_3 will be shipped either to the Paducah Gaseous Diffusion Plant for reenrichment in the isotope U-235 or to the Feed Materials Production Center (Fernald) for conversion to uranium metal.

B Plant. As part of the program to develop methods for the solidification of high-level waste, the B Plant was converted in 1968 to a waste fractionization plant. The plant's mission has been to remove Cs-137 and Sr-90 from current PUREX acid waste and from high-level supernatant liquids in stored waste. The Waste Encapsulation and Storage Facility was constructed on the west end of the B Plant building. Here the strontium and cesium are converted to solid strontium fluoride and cesium chloride, doubly encapsulated, and placed in retrievable water-cooled storage. These activities are coming to a close. Solidification and encapsulation of the backlog of cesium was completed in FY 1983 (1575 capsules); encapsulation of strontium is to be finished in FY 1985 (630 to 660 capsules). Starting in FY 1985 and 1986, the B Plant was converted to treat newly generated high level waste (HLW) and transuranic (TRU) waste from the PUREX plant. To save storage space in the HLW tank farm, the decontaminated salt fraction of the high level waste will be separated and disposed of as low level waste (LLW). In the future, the remaining high level waste will be converted to glass (for permanent disposal) in the planned Hanford Waste Vitrification Plant.[17]

Z Plant. The Plutonium Finishing Plant (Z Plant) is a complex of buildings with the capability for converting plutonium to oxide or metal, recovering plutonium from scrap, and plutonium storage. Conversion of plutonium to metal (in the 234-5-Z building) was terminated in 1972 but was restarted in late FY 1985 to process weapon-grade plutonium oxide being separated at PUREX from N-Reactor fuel and to prepare feed for the Hanford SIS plant. The conversion of plutonium nitrate to oxide, originally carried out at the Z Plant for PUREX, is now done at the PUREX Plant. The Z Plant has a plutonium storage vault, and fuel-grade plutonium oxide is shipped from there to Savannah River for blending (see Table 4).

Scrap recovery (in the 236-Z building) reclaims plutonium for the weapons program from scrap inventory and from scrap generated during terminal cleanout.[18] (400 kg of recovered scrap were to be blended in FY 1984).[19] The Z Plant was temporarily deactivated in FY 1980-83, leaving Hanford without capability to recover plutonium scrap, and operation of the Plutonium Recov-

17 SASC, FY 1985 DOE, p. 148.
18 HAC, FY 1984 EWDA, Part 4, p. 306.
19 Ibid.

Table 4
Highlights of Z Plant Operation

231-Z Building	
1944-49:	Plutonium Nitrate Concentration.
1955-75:	Plutonium R&D for weapons. Weapon part fabrication for LLNL (1969-75).
1975-early 1990s:	Material engineering test laboratory. Possible site of plutonium SIS plant.
234-5-Z Building	
1949-72:	Metal production. Oxide production. Scrap recovery (Plutonium Reclamation Facility in 236-Z Building began operation in 1964).
1973-85:	Oxide production. Scrap recovery. (Temporarily shutdown FY 1980-83).
1985- :	Metal production. Oxide production. Scrap recovery.

Source: Hanford SIS Deployment Program Preaour Briefing, Rockwell Hanford Operations, January 1983, p. 8.

ery Facility and Oxide Line for scrap recovery began in FY 1984.

Future Projects

PUREX Modification. Currently the PUREX plant processes only low burnup, metal (N-Reactor) fuel, and processing is begun by chemical dissolution of the fuel cladding. DOE's new Process Facility Modification (PFM) project will alter the first (head-end) step of PUREX operation by mechanically chopping fuel elements into short segments and dissolving only the contained fuel material (oxide or metal) by acid leaching (shear-leach process), leaving a solid cladding (zircalloy, stainless steel, or aluminum) waste. Also, the modification will enable the PUREX plant to process high burnup fuel containing high concentrations of fission products.

The PFM facility will consist of a building adjacent to the PUREX plant, connected by piping to allow transfer of a variety of process streams. Completion is scheduled for early FY 1992 at an estimated cost of $235 million (FY 1984) with construction starting in FY 1987.[20]

For high burnup fuels the dissolver solution must be diluted (blended) with recycle uranyl nitrate solution from PUREX to lower the plutonium concentration to 2000 grams per MT uranium, feed suitable for processing in the PUREX plant.[21]

The PFM design has been upgraded to include processing N-Reactor fuel (at an added project cost of $50 million) to recover weapon-grade plutonium. It will also give DOE the capability for processing and recovery of plutonium from DOE-owned fuels not processable in the United States "due to cladding material, physical size or other technical or economical considerations."[22] This includes spent fuel from the Fast Flux Test Facility (FFTF) and other DOE owned fuels. "These fuels represent an available source of plutonium needed for use in meeting Defense Program requirements."[23] The facility will recover some 2 MT of fuel-grade plutonium in FFTF fuel,[24] and by 1990 a total of about 3.5 MT of fuel-grade plutonium will be available for processing.[25]

DOE's plans call for recovered fuel-grade plutonium to be converted to weapon-grade either by blending, or by lasers in a special isotopic separation (SIS) plant. In the FY 1985 Budget Request DOE stated that the PFM Project "is not needed in the near-term unless an SIS production facility is built,"[26] but since then PFM has been separated from the contingencies of an SIS plant.

The PFM facility is being designed to allow expansion at some future date, to accommodate a variety of "fuel possibilities."[27] This may include a limited capacity to handle commercial light water reactor spent fuel.[28]

SIS Plant. Plans were announced by DOE in August 1983 for construction and full operation of a special isotope separation (SIS) production plant at Hanford by FY 1991 (costing $600 million) that would employ the atomic vapor laser isotope separation (AVLIS) process developed at Lawrence Livermore National Laboratory, to purify plutonium for weapons requirements. Included in the plans was a prototype SIS facility at Hanford by FY 1989, which was to be preceded by operation of a full-scale demonstration system at LLNL in FY 1987 (costing $150 million).[29]

One possible location of the SIS plant at Hanford is in the existing 231-Z building (adjacent to the main buildings 234-5-Z/236-Z), with the separation devices in the existing plutonium-qualified building and lasers and support equipment in a building annex to be constructed.

The status of the SIS production plant is uncertain. In early 1984, no commitment was being made beyond the fiscal year, except to review the option for the Hanford plant on an annual basis.[30] Criticism of the SIS plant project is that existing production alternatives "would adequately address currently projected plutonium requirements," that the "SIS process has the highest cost . . . of the various methods for increasing productivity," and that it "requires the most lead time, and is the most

20 DOE Construction Project Data Sheet, Project No. 84-D-135, 27 February 1984; Functional Design Criteria, Process Facility Modification Project, SD-414-PDC-001, Rockwell Hanford Operations, January 1983, pp. 1-1, 1-2.
21 Functional Design Criteria, p. 2-4.
22 Data Sheet, Project No. 84-D-135.
23 Ibid.
24 Ibid.
25 House Report 98-125, Part I, 13 May 1983, p. 20.
26 HAC, FY 1985 EWDA, Part 4, p. 431.
27 Letter from Donald Paul Hodel to Richard Ottinger, 5 March 1984, Enclosure 1.
28 Letter from J. Dexter Peach to Richard L. Ottinger, B-207484, 14 May 1982, p. 6; Letter from Hodel to Ottinger, 5 March 1984; Letter from Donald Paul Hodel to Richard Ottinger, 30 August 1983, Enclosure.
29 Nucleonics Week, 11 August 1983, p. 4; James Carreon, DOE, 15 August 1983 private communication; HAC, FY 1985 EWDA, Part 4, p. 430.
30 HAC, FY 1985 EWDA, Part 4, 431.

technologically uncertain."[31] By early 1985, work at LLNL on separator hardware continued but had been scaled back, definite plans for a prototype plant at Hanford had been dropped, and work at Hanford centered on the design of a production plant and support facilities.

Operating in the early 1990s as planned, the SIS plant would first separate weapon-grade plutonium from existing DOE stocks of fuel-grade plutonium. Subsequently, it would perform other defense related missions, including cleanup of the existing weapon-grade plutonium stockpile to reduce radiation exposure to workers in weapons production facilities and personnel on board submarines and ships.[32]

The estimated SIS plant capacity is approximately 2 MT of plutonium per year. Upgrading the plant to increase production goals would be achieved by increasing the laser repetition rate.[33]

BUDGET
($ million):

FY	Rockwell Hanford Operations[34] 1984
349.9	1985
355.4	1986 (est)
405.0	

31 Ibid.

32 HASC, FY 1984 DOE, p. 179; HAC, FY 1984 EWDA, Part 6, p. 365.

33 Hanford Special Isotope Separation (SIS) Deployment Project, Rockwell Hanford Operations, 4 August 1982; Hanford SIS Deployment Program Preteur Briefing, Rockwell Hanford Operations, January 1983; Hanford LIS Deployment Program, Rockwell Hanford Operations (undated).

34 Letter to Thomas B. Cochran from Mike Talbot, Richland Operations Office, 18 March 1986.

Pacific Northwest Laboratory (PNL)

ADDRESS: Pacific Northwest Laboratory
P.O. Box 999
Richland, Washington 99352
509/375-2201

LOCATION: The principal laboratory is in Richland, Washington. Additional research facilities are within the Reservation.

MISSION: To carry out basic and applied research and engineering in the areas of special nuclear materials, nuclear waste management, energy technology development, and environment and health. PNL is a multiprogram interdisciplinary R&D laboratory and has been assigned by DOE the role of Hanford's R&D laboratory.

MANAGEMENT: GOCO facility operated by Batelle Memorial Institute under management of Richland Operations Office

BUDGET: $218.0 million, total lab funding (FY 1986)

PERSONNEL: 2447 (March 1985)

FACILITIES:
- Two Life Science Laboratories
- Marine Research Laboratory
- Meteorological Center
- Critical Materials Laboratory
- Nuclear Waste Vitrification Laboratory
- Materials Reliability Center
- Steam Generator Examination Facility
- Biomass Experimental Unit
- Geophysical and Astronomical Observatory
- National Environmental Research Park

Nuclear Weapons Activities

A significant portion of PNL's work (about 9 percent in FY 1985) is for DOE's Defense Programs.[1] This effort focuses on fuel cycle activities at Hanford (the N-Reactor and PUREX) and defense waste management. Research on defense wastes includes pilot-scale testing of waste vitrification technology with applications at Hanford and the Savannah River Plant, the recovery and use of nuclear waste byproducts (e.g., Sr-90, Cs-137, and noble metals), and the evaluation of in-situ waste treatment technologies. Research funded by the DOE Defense Programs also includes engineering development work for inertial confinement fusion (ICF) as a commercial energy source, verification and control services for the weapons program, and coated optical components for high power optics.

Nonweapon Activities

PNL's nonweapon activities in the area of fission nuclear energy include nuclear fuel development and evaluation, spent fuel storage and reprocessing, decommissioning, decontamination, and inhalation toxicology. Work is also done in biology, ecology, atmospheric sciences, corrosion chemistry, biomass research, materials research and health physics technology, and in energy economics and policy analysis. Funding by various DOD organizations (about 6 percent of PNL's funding in FY 1985) includes research in automated measurement systems development, advanced materials fabrication technology development, radiological studies, health physics, and conventional ordnance.

LAB ACTIVITIES BY PROGRAM (FY 1985):[1]

DOE	
Defense Programs	9%
Nuclear Energy	8%
Energy Research	13%
Conservation and Renewable Energy	9%
Civilian Radioactive Waste Management	14%
Other DOE Programs	21%
NRC	13%
DOD	9%
EPA	2%
Other	1%

BUDGET[2] ($ million):

FY	Total Lab Funding	DOE Defense Programs
1983	134.5	14.9
1984	173.0	19.5
1985	195.6	16.5
1986	218.0	19.8

ASSETS Capital Investment (Plant and Equipment) FY 1982: $65 million. Laboratory and Office Space FY 1981: 440,000 square feet.

1 Pacific Northwest Laboratory Institutional Plan 1986-91, pp. 69-70. Percentages reflect direct staff (full-time equivalent).

2 PNL Institutional Plan 1985-90, p. 58; PNL Institutional Plan 1980-91, p. 69.

PERSONNEL:[3]

End FY	Personnel
1971	1240
1972	1315
1973	1467
1974	1645
1975 (Sep)	1833
1976	1980
1977	2193
1978	2470
1979	2537
1980	2673
1981	2622
1982	2216
1983	2274
1984	2374
1985 (Mar)	2447

3 DOE, COCO Employment, Computer printout for Office of Industrial Relations, E-5529309-012, 29 August 1985.

Idaho National Engineering Laboratory (INEL)[1]

ADDRESS: U.S. Department of Energy
Idaho Operations Office
785 Doe Place
Idaho Falls, ID 83402
208/526-1322

LOCATION: 17 miles southeast of Arco, Idaho, and 29 miles west of Idaho Falls, Idaho, on lava-and-sand plateau by the Snake River; 571,800-acre (893-square-mile) site

MISSION: Broad based multiprogram activities (see text for details)

MANAGEMENT: GOCO facility operated for DOE by EG&G Idaho, Inc., Westinghouse Idaho Nuclear Company, and Argonne National Laboratory-West. Contracts administered by the Idaho Operations Office.

BUDGET: $366.4 million, total lab funding (FY 1986)

PERSONNEL: 5064 total lab (March 1985)

FACILITIES:
- Idaho Chemical Processing Plant
- Radioactive Waste Management Complex
- Fluorinel Dissolution Process and Fuel Receiving Facility
- Rover Fuel Processing Facility
- New Waste Calcining Facility
- Power Burst Facility
- Semiscale Facility
- Loss-of-Fluid Test Facility
- Raft River Geothermal Loop Facility
- Experimental Breeder Reactor-2
- Naval Reactors Facility

ESTABLISHMENT: Established 1949 as National Reactor Testing Station (NRTS) at site of former artillery test range to provide isolated location for building and testing various types of nuclear reactors and support facilities; name changed to INEL in August 1974

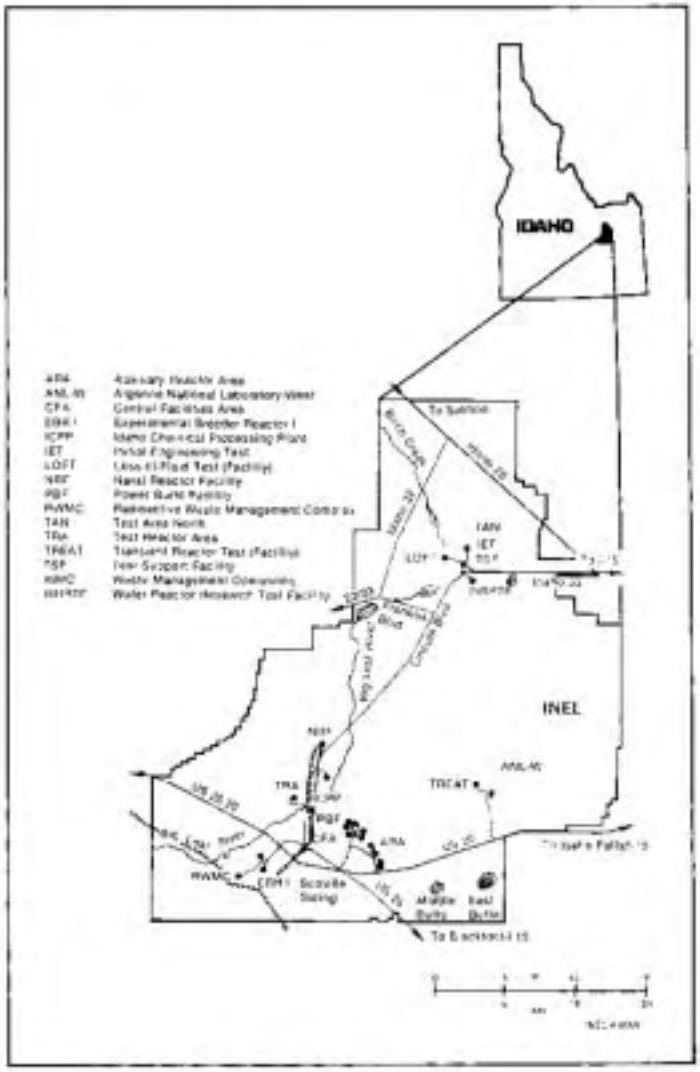


Figure 16 Idaho National Engineering Laboratory Vicinity Map

History

The first liquid metal fast breeder reactor, the Experimental Breeder Reactor 1 (EBR-1), was built at the site between 1949 and 1951 by Argonne Laboratory for the AEC. EBR-1 went critical in August 1951, and produced the first electrical power from a nuclear reactor on 20 December 1951. On 4 June 1953, the reactor demonstrated plutonium breeding for the first time (creating fissile material at a rate greater than consumed in operation). It was cooled with liquid sodium-potassium alloy and fueled with enriched uranium (52 kg U235 in its core). EBR-1 suffered a partial core meltdown during experiments with reduced coolant on 29 November 1955.[2] It was decommissioned in 1964 and was designated a national landmark in 1966.

1 Sources: INEL, DOE Idaho Operations Office; INEL, Institutional Plans, FY 1981-86, FY 1985-90; FY 1986-91.

2 William Lanouette, The Atlantic (April 1983): 39-42.

At INEL the first submarine prototype reactor, the *Nautilus* prototype, was developed and achieved an initial power run on 31 May 1953. Also early prototypes for commercial pressurized water reactors and light water reactors were developed there.

INEL's Test Area North (TAN) in the 1950s was the site of the Aircraft Nuclear Propulsion project for the development of three prototype Heat Transfer Reactor Experiments (HTRE-1, HTRE-2, and HTRE-3) for investigating the use of air-cooled reactors to operate an aircraft turbojet engine with nuclear heat. The project was terminated in 1961.

Mission

INEL operates as a broad-based multiprogram laboratory with the primary mission to furnish engineering services and products, principally in nuclear energy and associated technologies. INEL focuses on the following programs:

- Naval nuclear reactor propulsion plants—research, development, testing, and evaluation
- Receipt, storage, and processing of spent nuclear fuel from naval reactors, government-owned research and test reactors, and nongovernment research reactors
- Nuclear waste management
- Civil nuclear reactor safety research
- Breeder reactor research and development
- Reactor development and operation related to materials testing, isotope production, and irradiation services
- R&D on geothermal, small hydropower, and other advanced energy sources
- Industrial energy conservation
- Environment and safety

Nuclear Weapons Activities

DOE weapons related activities at INEL are mainly in two areas: (1) research, development, and testing of nuclear reactor propulsion plants for submarines and surface ships (which themselves are nuclear weapons delivery systems); and (2) the processing of spent fuel from naval and other reactors and nuclear waste management. INEL is also participating in the National Space Reactor Program to develop reactors for military space applications with a power of 100 kilowatts or greater.

Nuclear Material Production Activities

The Idaho Chemical Processing Plant (ICPP)[3] recovers enriched uranium from spent nuclear fuels, primarily from naval reactors but also from research and test reactors, both American and foreign. The enriched uranium is recycled into fuel for the Savannah River production reactors (see Idaho Chemical Processing Plant). High-level radioactive liquid wastes are calcined to granular solids in the New Waste Calcining Facility (NWCF).

Plutonium Production and Use

Plutonium is used as fuel in the Zero Power Plutonium Reactor (ZPPR) (about 3.8 MT) and is produced in the blankets of the Experimental Breeder Reactor-2 (EBR-2) (several kilograms per year) as a byproduct of electricity production. Both reactors are part of the DOE nondefense research and development program. High-purity plutonium recovered from EBR-2 blankets is used for weapons research.

Nonweapon Activities

INEL conducts research and development on civilian energy technologies and concepts mainly for DOE in the areas of reactor safety, breeder reactors, advanced energy sources (geothermal, hydropower, etc.), energy conservation, and nuclear waste management. It also conducts research in basic nuclear physics.

The Idaho Operations Office administers DOE sponsored work at the damaged Three Mile Island-2 reactor and at the shutdown nuclear fuels processing facility in West Valley, New York.

The Rare Gas Plant at the ICPP recovers Kr-85 for commercial sale (see Idaho Chemical Processing Plant). The Special Manufacturing Capability (SMC) project (so-called "Project X") is a secret military (nonweapons) activity under construction at the INEL TAN site.

Facilities

More nuclear reactors have been built at INEL than at any other site in the world. A list of INEL facilities is presented in Table 5. Of the fifty-two reactors and critical assembly facilities at INEL, fifteen were operable (as of August 1984). The others have been dismantled or placed in standby. With the exception of the naval reactors, the operable reactors are part of DOE's civilian nuclear energy program.

EBR-2 is a pool type sodium-cooled fast breeder reactor with a thermal power of 62.5 Mw and an output of 20 Mw of electrical power that is fed to the INEL grid. It began operation in 1963 and went to full power on 13 August 1964. It is used mainly for irradiating fuels and materials and for the development of instrumentation and sodium technology. ZPPR is a critical facility, the world's largest, used to construct fuel core mockups of large fast breeder reactors. Its fuel consists of clad blocks of plutonium. ZPPR began operation on 18 April 1969.

The 250-Mw_t Advanced Test Reactor (ATR) is used to test new fuels and materials in a high-flux environment. The ATR has nine test loop areas, allowing nine individual experiments to be conducted simultaneously. The ATR incorporates advances gained through experience with two inactive INEL materials test facilites, the Engineering Test Reactor (ETR), and the Materials Testing Reactor (MTR). ATR irradiation activities are mainly

3 Formerly called the Idaho Fuel Processing Facility (IFPF).

Table 5

Facilities at the Idaho National Engineering Laboratory

Reactors and Critical Assembly Facilities
Operating or Operable as of 1984

	Name	Startup	Abbreviation	Operating Contractor
1.	Advanced Reactivity Measurement Facility No. 1	1980	ARMF-1	EG&G
2.	Advanced Test Reactor	1968	ATR	EG&G
3.	Advanced Test Reactor Critical	1964	ATRC	EG&G
4.	Argonne Fast Source Reactor	1959	AFSR	ANL
5.	Coupled Fast Reactivity Measurement Facility	1968	CFRMF	EG&G
6.	Experimental Breeder Reactor-II	1963	EBR-II	ANL
7.	Large Ship Reactor Prototype (2 reactors, A & B)	1958	A1W-(A)	WEC
8.	Loss-of-Fluid Test Facility	1978	LOFT	EG&G
9.	Natural Circulation Reactor	1965	S5G	WEC
10.	Neutron Radiography Facility	1977	NRAD	ANL
11.	Power Burst Facility	1973	PBF	EG&G
12.	Submarine Thermal Reactor	1958	S1W(STR)	WEC
13.	Transient Reactor Test Facility	1959	TREAT	ANL
14.	Zero Power Plutonium Reactor	1969	ZPPR	ANL

Reactors and Critical Assembly Facilities
Dismantled, Transferred, or in Standby Status (1984)

	Name	Startup	Shutdown	Abbreviation	Operating Contractor
1.	Advanced Reactivity Measurement Facility No. 2	?	?	ARMF-II	PPCo., INC
2.	Boiling Water Reactor Experiment No. 1	1953	1954	BORAX-I	ANL
3.	Boiling Water Reactor Experiment No. 2, 3, 4	1954	1958	BORAX-II, III,IV	ANL
4.	Boiling Water Reactor Experiment No. 5	1962	1974	BORAX-V	ANL
5.	Cavity Reactor Critical Experiment	?	?	CRCE	GE,INC
6.	Critical Experiment Tank	?	?	CET	GE
7.	Engineering Test Reactor	1957	1981	ETR	INC,ANC,EG&G
8.	Engineering Test Reactor Critical	?	?	ETRC	INC,ANC,EG&G
9.	Experimental Beryllium Oxide Reactor	Terminated	EBOR	GA	
10.	Experimental Breeder Reactor-I	1951	1964	EBR-I	ANL
11.	Experimental Organic Cooled Reactor	Terminated	EOCR	PPCo.	
12.	Fast Spectrum Refractory Metals Reactor	?	?	710	GE
13.	Gas Cooled Reactor Experiment	1960	1962	GCRE	AGC
14.	Heat Transfer Reactor Experiment No. 1	1956	1957	HTRE-I	GE
15.	Heat Transfer Reactor Experiment No. 2	1957	1961	HTRE-II	GE
16.	Heat Transfer Reactor Experiment No. 3	1958	1961	HTRE-III	GE
17.	High Temperature Marine Propulsion Reactor	?	?	630-A	GE
18.	Hot Critical Experiment	?	?	HOTCE	GE
19.	Materials Testing Reactor	1952	1970	MTR	PPCo.,INC
20.	Mobile Low Power Reactor No. 1 (Army)	1961	1965	ML-1	AGC
21.	Nuclear Effects Reactor	1967	1970	FRAN	INC
22.	Organic Moderated Reactor Experiment	1957	1963	OMRE	AI
23.	Reactivity Measurement Facility	?	?	RMF	PPCo.
24.	Shield Test Pool Facility Reactor	?	?	SUSIE	GE

Table 5

Facilities at the Idaho National Engineering Laboratory

	Name	Startup	Shutdown	Abbreviation	Operating Contractor
25.	SNAP 10A Transient No. 1	1963	1965	SNAPTRAN-1	AI/PPCo.
26.	SNAP 10A Transient No. 2	1965	1966	SNAPTRAN-2	AI/PPCo.
27.	SNAP 10A Transient No. 3	1964	1964	SNAPTRAN-3	AI/PPCo.
28.	Special Power Excursion Reactor Test No. 1	1955	1964	SPERT-I	PPCo.
29.	Special Power Excursion Reactor Test No. 2	1960	1965	SPERT-II	PPCo.
30.	Special Power Excursion Reactor Test No. 3	1958	1968	SPERT-III	PPCo.
31.	Special Power Excursion Reactor Test No. 4	1962	1970	SPERT-IV	PPCo.
32.	Spherical Cavity Reactor Critical Experiment	?	?	SCRCE	ANC
33.	Split Table Reactor	?	?	STR	GE,INC,ANC
34.	Stationary Low Power Reactor No. 1	1958	1961	SL-1	CE
35.	Zero Power Reactor No. 3	?	?	ZPR-III	ANL

Other Facilities In Use (1984)

	Name	Abbreviation	Operating Contractor
1.	Argonne National Laboratory—West Area	ANL-W	ANL
2.	Auxiliary Reactor Area	ARA	EG&G
3.	Central Facilities Area	CFA	EG&G
4.	Chemical Engineering Laboratory	CEL	WINCO
5.	Computer Science Center (in Idaho Falls)	CSC	EG&G
6.	Expended Core Facility	ECF	WEC
7.	Experimental Field Station	EFS	DOE-ID
8.	Field Engineering Test Facility (formerly Flight Engine Test Facility)	FET	EG&G
9.	Fluorinel and Fuel Storage Facility	FAST	WINCO
10.	Fuel Element Storage Facility	FESF	WINCO
11.	Fuel Receiving and Storage Building	-	WINCO
12.	Hot Fuel Examination Facilities	HFEF	ANL
13.	Hot Pilot Plant	HPP	WINCO
14.	Idaho Chemical Processing Plant	ICPP	WINCO
15.	Idaho Laboratory Facility (in Idaho Falls)	ILF	WINCO
16.	Irradiated Fuel Storage Facility	IFSF	WINCO
17.	LOFT Test Support Facility	LTSF	EG&G
18.	Naval Reactors Facility	NRF	WEC
19.	New Waste Calcining Facility	NWCF	WINCO
20.	Radioactive Waste Management Complex	RWMC	EG&G
21.	Radiological and Environmental Sciences Laboratory	RESL	DOE-ID
22.	Reactor Training Facility	RTF	EG&G
23.	Semiscale Test Facility	STF	EG&G
24.	Small Hydroelectric Power Program	-	DOE-ID
25.	Standards Calibration Laboratory (CF-698)	SCL	EG&G
26.	Technical Services Center (CF-698;699)	TSC	EG&G
27.	Technical Services Facility	TSF	EG&G
28.	Test Area North	TAN	EG&G
29.	Test Reactor Area	TRA	EG&G
30.	Waste Experimental Reduction Facility	WERF	EG&G
31.	Willow Creek Building (in Idaho Falls)	WCB	EG&G/WINCO

Facilities Under Construction (1984)

1.	Coal Fired Steam Generating Facility	-	WINCO
2.	Fuel Processing Restoration Project	-	WINCO
3.	Special Manufacturing Capability Project	SMC	ENICO

Facilities Dismantled, Transferred, or in Standby Status (1984)

1.	Alcohol Fuels Plant	-	EG&G
2.	Raft River Geothermal Project	-	EG&G
3.	Waste Calcining Facility	WCF	PPCo.,AL,ENICO

Sources: DOE, "Idaho National Engineering Office," Idaho Operations Office, undated (circa 1984); DOE, "Nuclear Reactors Built, Being Built, or Planned," TIC-8200-R48, annual

in support of the naval nuclear program, and the majority of experiments are for the Bettis Atomic Power Laboratory.

The Naval Reactor Facility (NRF) comprises the Submarine Prototype (S1W), the Large Ship Reactor (A1W), the Natural Circulation Submarine Prototype (S5G), and the Expended Core Facility (ECF). The NRF is involved in the development of naval nuclear power systems and serves as a training station for nuclear Navy crews.

The principal nuclear materials production facility at INEL is the ICPP described below.

INEL is one of three sites (the other two are Hanford and Savannah River) being considered for the New Production Reactor (NPR). A heavy water moderated reactor to operate in the early 1990s would produce tritium and plutonium for the weapons program and possibly generate electricity as a byproduct.[4]

The Argonne National Laboratory-West (ANL-West) area located near the eastern boundary of INEL supports DOE's fast breeder program and includes three principal breeder reactor program facilties: the Experimental Breeder Reactor 2 (EBR-2), the Transient Reactor-2 Facility (TREAT), and the Zero Power Plutonium Reactor (ZPPR). In addition, the Hot Fuels Examination Facility (HFEF) provides hot cells for the examination of irradiated materials.

Management

INEL is a DOE GOCO facility. The two major operating contractors are EG&G, Idaho, Inc., and Westinghouse Idaho Nuclear Company (WINCO). EG&G is the operating and principal research and development contractor. It operates the Low-Level Waste Management Program, the Advanced Test Reactor, and some breeder program research facilities. WINCO operates the Idaho Chemical Processing Plant (ICPP), the New Waste Calcining Facility, the Fluorinel Dissolution Process and Fuel Receiving (FAST) Facility, the Rover Fuel Processing Facility, and the naval reactor training facility at NRF. (DOE selected WINCO to take over these activities from Exxon Nuclear Idaho Company (ENICO) as of 1 April 1984 on a five-and-one-half year contract worth $100 million annually;[5] Exxon Nuclear decided not to renew its contract, which expired on 30 September 1984).[6]

Exxon Nuclear Idaho Company operates the classified Special Manufacturing Capability project. Argonne National Laboratory-West operates a complex of five facilities supporting the fast breeder reactor research program. Westinghouse Electric Corporation (WEC) operates the Naval Reactor Facility for DOE and the U.S. Navy under jurisdiction of DOE's Pittsburgh Naval Reactors Office.

INEL is administered primarily by the Idaho Operations Office of DOE, which oversees the prime contractors, EG&G, WINCO and ENICO, and other operating and construction contractors including Morrison-Knudsen, Catalytic, and the Montana Energy and MHD Research and Development Institute, Inc. The Chicago Operations Office administers Argonne National Laboratory-West activities. The Pittsburgh Naval Reactor Office of DOE administers the Naval Reactors Program at INEL.

LAB ACTIVITIES BY PROGRAM (FY 1984):[7]

Defense Programs	46.1%
Nuclear Energy	
Naval Reactors	7.9%
Other	19.1%
Other DOE Programs	8.8%
Work for Others	
Nuclear Regulatory Commission	18.1%
DOD	0.1% (approx.)
Department of Interior	0.1% (approx.)

BUDGET[8]
($ million):

FY	Total Laboratory Funding	DOE Defense Programs	
		ICPP	INEL[9]
1983	298.8	136.0	208.8
1984	317.9	79.1	181.5
1985	357.4	111.7	228.6
1986	366.4	120.6	241.3

ASSETS

The INEL site is valued at more than $2.9 billion. The laboratory and office space (FY 1981) was 294 million square feet (EG&G and ENICO resources only).

4 Press Release, Senator James A. McClure, 10 August 1983.
5 Nucleonics Week, 23 June 1983, p. 4.
6 Nucleonics Week, 20 October 1983, p. 3.
7 Percent direct FTE's, INEL Institutional Plan, FY 1985-FY 1990, p. INEL-11.
8 Estimated costs from DOE, "FY 1985 Budget Request Estimates for Labs/Plants," January 1984, pp. 39, 144; DOE FY 1986 Budget Request Estimates for Labs/Plants, Office of the Controller, 22 February 1985, pp. 31, 97; INEL Institutional Plan, FY 1985-FY 1990, p. INEL-68; Does not include ANL-West and Westinghouse Electric Corporation at the NRF. Includes $41.0 million (FY 1984), $51.0 million (FY 1985), and $51.0 million (FY 1986) for the Special Manufacturing Capability project.
9 Including ICPP.

PERSONNEL:[10]

End FY	EG&G	Westinghouse Idaho Nuclear	Exxon Nuclear Idaho Co.	Total
1972	2131	228		2359
1973	2142	259		2401
1974	2285	325		2609
1975 (Sep)	2717[11]	377		3094
1976	2887	634		3521
1977	3547	712		4259
1978	3923	836[12]		4759
1979	3933	874		4807
1980	4151	949		5100
1981	3735	1014		4749
1982	3607	1084		4691
1983	3471	1200[13]		4671
1984	3681	1287	57	5025
1985 (Mar)	3657	1320	87[14]	5064

10 DOE, GOCO Employment, Computer printout for Office of Industrial Relations, S-9525909-012, 29 August 1985.
11 From FY 1971-75 the contractor was Aerojet Nuclear Co.
12 From FY 1971-76 the contractor was Allied Chemical Corp.
13 From FY 1979-82 the contractor was Exxon Nuclear Co.
14 Special Manufacturing Capability Project.

Idaho Chemical Processing Plant (ICPP)[1]

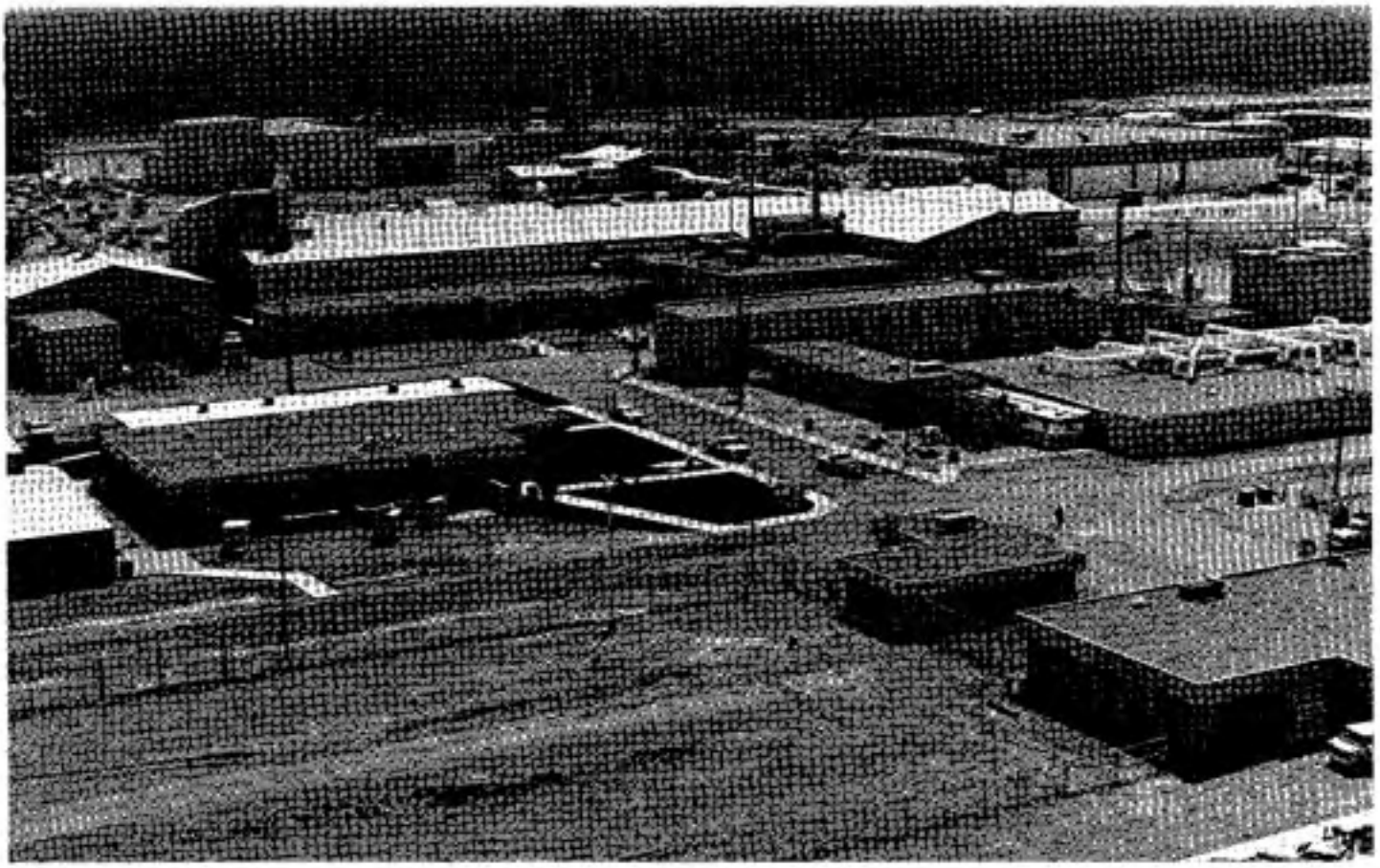


Figure 17 Idaho Chemical Processing Plant

Source: DOE

ADDRESS: See Idaho National Engineering Laboratory (INEL)

LOCATION: INEL site

MISSION: The recovery of highly enriched uranium and krypton-85 from spent nuclear fuels of Naval propulsion reactors. Also recovers uranium from the irradiated fuels of research and test reactors and other reactor fuels.

ESTABLISHMENT: Basic plant completed 1951 and first operated 1953.

BUDGET: See Idaho National Engineering Laboratory (INEL)

FACILITIES:
- Spent fuel receipt and storage facilities
- Fuel processing facilities
- Waste calcining facilities

Nuclear Weapons Activities

The ICPP is designed to process highly enriched uranium fuels. It has multiple processes to handle a variety of fuel and cladding types. ICPP also conducts research on fuel processing and waste management.

ICPP is the principal element in DOE Defense Program's recent and projected growth at INEL.

The amount of enriched uranium recovered at ICPP annually is given in Table 6. Through FY 1984 a total of 29 MT of uranium (23 MT of U-235) was recovered from naval and other reactor fuels. Also shown in the same table is the amount of spent fuel received from government and nongovernment research and test reactors since 1973. While the annual values for earlier years are

1 Formerly Idaho Fuels Processing Facility (IFPF).

Table 6

Summary of ICPP Spent Fuel Receipts and Reprocessing Quantities

FY	Reprocessing Quantities (Includes Naval Reactors) Total (kg)	U-235 (kg)	% U-235	Spent Fuel from Gov. and Non-Gov. Research and Test Reactors Total U (kg)	U-235 (kg)	% U-235
1953	161.0	146.0	91			
1954	165.0	149.0	90			
1955	930.0	819.0	88			
1956	914.0	816.0	89			
1957	746.0	656.0	88			
1958	1593.0	1390.0	87			
1959	2931.0	2534.0	86			
1960	941.0	828.0	88			
1961	45.0	35.0	78			
1962	690.0	614.0	89			
1963	191.0	166.0	87			
1964	677.0	589.0	87	aprx 7770*	aprx 6870*	aprx 88[b]
1965	685.0	588.0	86			
1966	625.0	527.0	84			
1967	102.0	82.0	80			
1968	737.0	623.0	85			
1969	.0	.0				
1970	1275.0	997.0	78			
1971	800.0	600.0	75			
1972	354.0	284.0	80			
1973	1543.6	802.2	52	913.8	598.6	66
1974	414.9	315.3	76	623.3	357.5	57
1975	2724.0	1812.8	67	1237.7	1031.1	83
1976	1825.9	1006.1	55	3024.9	2570.1	85
1976T				184.6	125.4	68
1977	1680.7	1316.7	78	535.4	414.9	77
1978	461.4	358.7	78	288.9	200.4	69
1979	34.6	24.8	72	317.1	201.0	63
1980	123.7	91.2	74	479.3	325.7	68
1981	1375.9	1000.5	73	254.5	177.6	70
1982	693.3	498.4	72	766.3	541.2	71
1983	882.7	793.2	90	141.8	91.3	64
1984	2464.1	2294.4	93	345.4	246.5	71
TOTALS	28,786.8	22,762.3	79	aprx 16,980*	13,750[a]	aprx 81*

a. From Volume II, Table 3.8.
b. Estimated.
* Calculated from other data in the table.

not readily available, it is estimated that by February 1985 13.75 MT of U-235 had been recovered from non-naval reactor fuels (see Volume II, Table 3.8). The recovery of HEU at ICPP is projected to be about 950 MT annually from FY 1988 to FY 1992, 1870 MT annually from FY 1993 to FY 1998, and 2860 MT annually in FY 1999 and FY 2000 (see Volume II, Table 3.6).

Enriched uranium recovered at ICPP (an average of about 1.1 MT per year from FY 1980-84) is used in driver fuel elements for the Savannah River production reactors. The uranium in oxide form is shipped from ICPP to the Y-12 Plant at Oak Ridge. There it is mixed with highly enriched uranium recovered at Savannah River Plant, and virgin HEU (93.5 percent enriched) from DOE stocks and the blended product (usually about 60 percent U-235) is converted to metal form before shipment to SRP (see Volume II, Chapter Three).[2]

2. HASC, FY 1980 DOE, p. 750.

Nonweapon Activities

The ICPP Rare Gas Plant recovers krypton-85 (Kr-85) gas from the processing of spent nuclear fuel. The Kr-85 is shipped to the Oak Ridge National Laboratory for commercial sale (including defense related electronics industries). The ICPP is the only source of Kr-85 in the West.[3] Recovery of 40,000 curies of Kr-85 was scheduled for FY 1983.[4] Krypton-85 is in short supply. The Soviet Union is the only other world supplier.[5]

Facilities

ICPP consists of (1) spent fuel receipt and storage facilities, (2) fuel processing facilities for chemical dissolution systems, solvent extraction, and product denitration, and (3) waste calcining facilities. New facilities at ICPP include the Fluorinel Dissolution Process and Fuel Storage (FAST) Facility, the ROVER Fuel Processing Facility, and the New Waste Calcining Facility (NWCF).

CPP Fuel Storage

Water-filled fuel storage basins are used for receipt and storage of spent nuclear fuels primarily from the Naval propulsion program, from INEL's Experimental Breeder Reactor (EBR-2), and from other research and test reactors. The ICPP has been designated as the interim storage facility for a variety of nuclear fuels considered nonreprocessable in existing facilities. The Graphite Fuels Storage Facility stored fuel from the ROVER nuclear rocket program (see below). Also, it will receive and store fuel from Fort St. Vrain, the commercial demonstration high temperature gas-cooled reactor (HTGR). FAST is a new facility for the storage of Navy and research reactor fuels (see below). ICPP has been designated the storage site for Shippingport light water breeder reactor (LWBR) spent fuel (17,000 fuel rods containing 505 kg U-235) classified as non-reprocessable at ICPP.[6]

ICPP Fuel Processing

The ICPP has multiple head-end processes to dissolve several fuel types with various claddings—aluminum, zirconium, stainless steel, graphite, and ceramic. Specific dissolution processes are followed by solvent extraction, decontamination, and purification operations common to all fuels.[7]

Reactor fuels clad with aluminum are dissolved in nitric acid, using mercuric nitrate as a catalyst to promote rapid dissolution.

Zirconium-uranium alloy fuels are dissolved in hydrofluoric acid to which aluminum nitrate is added to prevent corrosion of the stainless steel equipment.

Stainless steel clad fuels are dissolved in nitric acid using an electrolytic process. (Stainless steel does not normally dissolve in nitric acid.)

For naval and other graphite-based fuels, which consist of uranium particles in a graphite matrix, the graphite (carbon) is first burned off as carbon dioxide by heating the elements in a fluidized bed of aluminum oxide to a temperature of 840°C. The resulting fuel components convert to an oxide form, which is then dissolved in hydrofluoric acid and nitric acid and further processed in the extraction and purification system.

Fluorinel Dissolution Process. The Fluorinel Dissolution Process and Fuel Storage (FAST) Facility will cost some $200 million.[8] Fuel storage at FAST began in FY 1985. The facility is designed to receive, handle, store, and perform head-end chemical dissolution of a variety of irradiated fuels, including Navy fuels to recover uranium.[9] The fluorinel dissolution process is scheduled to begin operations in FY 1986. FAST will increase the efficiency of the spent fuel receiving activities at INEL. Fuel will be moved from water filled storage basins to processing without exposure to air. It will also process Light Water Breeder Reactor (LWBR) fuels irradiated in the Shippingport reactor. Operation will permit an additional 11 MT of U-235 to be recovered through FY 1992.[10]

ROVER Facility. The ROVER nuclear rocket program at LANL was terminated in the mid-1960s. The processing of ROVER graphite-based nuclear rocket fuel (pyro-carbon-coated uranium carbide particles in a graphite matrix) began at ICPP in the last quarter of FY 1983 and was completed by FY 1985.[11] Head-end operations include combustion of the graphite matrix and dissolution of uranium in the ash followed by solvent extraction and purification. A total of 2819 kg of U-235 was recovered from irradiated and unirradiated ROVER fuel (see Volume II, Appendix D).

ICPP Waste Storage—New Waste Calcining Facility. At ICPP high level and intermediate level radioactive liquid wastes from fuel processing after interim storage in underground stainless steel tanks are calcined into solid granules in the New Waste Calcining Facility (NWCF). The granules are stored in underground stainless steel bins inside concrete vaults. The waste is reduced to one eighth of its original volume. The original Waste Calcining Facility (WCF) operating since 1963 was shut down in FY 1981.[12] The NWCF began operation in September 1982.[13]

3 HAC, FY 1985 EWDA, Part 4, p. 423.
4 HAC, FY 1983 EWDA, Part 4, p. 255.
5 Press Release, DOE, Idaho Operations Office, 23 June 1983.
6 HAC, FY 1985 EWDA, Part 4, p. 455.
7 Idaho National Engineering Laboratory, DOE Idaho Operations Office, (undated) p. 28.
8 HAC, FY 1985 EWDA, Part 4, p. 382.
9 *Ibid.*, pp. 257, 263, 382-87.
10 *Ibid.*, p. 383.
11 *Ibid.*, pp. 255, 257.
12 Idaho National Engineering Laboratory Institutional Plan, FY 1982-FY 1987, November 1981, p. 22.
13 The New Waste Calcining Facility, Exxon Nuclear Idaho, EI241-0082-5M (undated).

Idaho Chemical Processing Plant

Waste calcining is a fluidized-bed process in which liquid waste is sprayed onto coarse granules in a heated chamber (500 C) where water evaporation converts the dissolved nitrates into oxide coating on the granules. The granules (0.5 to 0.6 millimeters in diameter) are called calcine. The calcine is routed by airstream through tubes to the underground storage bins. The NWCF has a throughput of 3000 gallons of liquid waste per day.[14] In total, about 5 to 6 million gallons of liquid waste have been generated at ICPP (1983), with 3 to 6 million gallons converted to calcine.[15]

The first NWCF campaign, twenty-two months in duration, was completed in June 1984 and included the calcining of all ROVER waste. The NWCF will be restarted in FY 1987 for the processing of waste generated by the fluorinel process.[16]

14 Idaho National Engineering Laboratory, Idaho Operations Office, [undated], pp. 29-30; The New Waste Calcining Facility, Exxon Nuclear Idaho, EI243-0882-5M [undated].
15 Idaho National Engineering Laboratory, Idaho National Laboratory, [undated], p. 14; The Idaho Sun 4: 1 (1983): 6.
16 INEL, Institutional Plan FY 1985-FY 1990, p. INEL-33.

Kansas City (Bendix) Plant[1]

Figure 18 Aerial View of Kansas City Plant

ADDRESS: Kansas City (Bendix) Plant
P.O. Box 1159
Kansas City, MO 64141
816/997-3212

LOCATION: Kansas City, Missouri; 113 acres within 300-acre site

MISSION: Production or procurement of electrical, electronic, electromechanical, plastic, and non-fissionable metal components for nuclear warheads

MANAGEMENT: GOCO facility operated for DOE by the Bendix Kansas City Division of the Allied Corporation, which has been operating contractor since plant's beginning. Contract administered by Albuquerque Operations Office

ESTABLISHMENT: 1949

BUDGET: $531.8 million (FY 1986)

PERSONNEL: 7853 DOE Defense Programs (March 1985)

FACILITIES:
- Miniature Radar Assembly Facility
- Electrical and Special Firing Assembly Facility
- Microcircuit assembly area

1 DOE Research and Development and Field Facilities, DOE/ER-0020, June 1979, pp. V-36, 37.

Nuclear Weapons Activities

As the most diversified of the seven weapons production plants, the Kansas City Plant's technically oriented operation embraces the full spectrum of work on nonnuclear products—from research on new materials to the production of complex and reliable weapons components. Production concentrates on relatively small quantitities, fabricated to meet the high quality, high reliability, and close tolerance requirements characteristic of weapons programs.

Among the plants and laboratories of the weapons production complex, the Kansas City Plant has the largest employment (7853 employees in 1985 or 31 percent) and the largest operating budget ($531.8 million in FY 1986 or 30 percent).

Production activities are directed to three basic areas:

1. Electrical and electronics work, with applications in warhead electrical systems, arming, fusing, and firing systems. Included are components such as radars, timers, high energy power supplies, hybrid microcircuits, fiber optics, printed circuit boards, and telemetry and fight instrumentation units used in simulated weapons performance analysis. Many of these systems rely heavily on an in-house capability for fabrication of advanced technology microcircuits. Electrical and electronic products required 30 percent of the productive (manpower) effort in 1978.

2. Mechanical products for weapon structural components and precision mechanical devices, such as command and control elements including precision valves, coded locking devices, environmental sensing components, and machined support structures. Mechanical products required 50 percent of the productive effort in 1978.

3. Rubber and plastic products including injection and compression molded polymers, filled elastomers, and molded- and machined-to-size syntactic, polyurethane, and polystyrene foam and polyurethane foam encapsulation. Rubber and plastic products represented 20 percent of total production in 1978. The Bendix Plant has been the prime plastics fabricator within the weapons complex for many years.[2]

Nonweapon Activities

The Kansas City Plant provides developmental hardware for research programs conducted at the DOE laboratories. This includes targets for laser-fusion and electron beam fusion, laser target chambers and laser amplifiers, insulating foam and energy collecting pipes for solar energy development, prototype metal Dewar bottles for particle accelerators, and devices for experiments with electron beam sources.

Facilities

To support its primary nuclear weapons component production mission, the plant develops both processes and materials.

The special plastics production facilities provide polymeric materials unavailable from commercial sources. Miniaturization, precision tolerances, and the use of sensitive materials cause many operations to require clean-room conditions and precise temperature and humidity controls. Weapons development activities range from plating 500-angstrom-thick films and detonator testing to modifying truck trailers in the Safeguards Transportation Safety Program.

Special technologies include organic coatings, metal deposition, etching of precision patterns into metal films, and formulating polymers and adhesives. Special machinery includes a hot-shear forming machine to fabricate axisymmetric assemblies from metal plate (FY 1983 procurement), high-speed (up to 20,000 RPM) turning machine and laser welder (FY 1983 procurement), and designing and fabricating instrumentation for product testing. Prototype fabrication capabilities are available for metal machining, welding, assembly of complex telemetry systems, fabricating miniature electronic devices, and producing polymers.

2 "The polymer production facility at Bendix will provide a capability to produce new resin used in the manufacture of nuclear weapons to replace a foreign sole source of questionable dependability." HASC, FY 1980 DOE, p. 106.

BUDGET[3]
($ million):

FY	DOE Defense Programs Total
1981	290.0
1982	429.8
1983	432.5
1984	449.0
1985	497.3
1986	531.8

ASSETS

Capital investment and equipment. $169.3 million (FY 1980).

PERSONNEL:[4]

End FY	DOE Defense Programs:
1971	7310
1972	6614
1973	6167
1974	5362
1975 (Sep)	4602
1976	4552
1977	5400
1978	5935
1979	6200
1980	6449
1981	7030
1982	7138
1983	7505
1984	7838
1985 (Mar)	7853

3 HAC, FY 1983 EWDA, Part 6, p. 133; Estimated costs from DOE, FY 1986 Budget Request Estimates for Labs/Plants, Office of the Controller, 22 February 1985, p. 36.

4 DOE, GOCO Employment, Computer printout for Office of Industrial Relations, R-5529309-014, 29 August 1985.

Lawrence Livermore National Laboratory (LLNL)[1]

Figure 19 Aerial View of Lawrence Livermore National Laboratory

Source: LLNL

ADDRESS: University of California
Lawrence Livermore National Laboratory
P.O. Box 808
Livermore, CA 94550
415/422-1100
Public Affairs: 415/422-4599
Director: Roger E. Batzel

LOCATION: Livermore, California, 50 miles east of San Francisco. 11.6-square-mile Explosive Test Site (Site 300) located about 15 miles east of main Livermore site. Adjacent to LLNL and to the south is Sandia National Laboratories-Livermore (SNLL).

MISSION: To perform the research, development, and testing associated with the nuclear design aspects of all phases of the nuclear weapon life cycle.

MANAGEMENT: GOCO facility operated for DOE by University of California (Board of Regents). Office of Military Application under the ASDP provides technical direction; Board of Regents contract administered by San Francisco Operations Office (expires 30 September 1987).

ESTABLISHMENT: 1952

1 Formerly a branch of E.O. Lawrence Radiation Laboratory, then Lawrence Livermore Laboratory.

BUDGET: $937.1 million, total lab funding (FY 1986)

PERSONNEL: 8541 total lab (March 1985)

FACILITIES:

- Explosive Test Site
- Tritium Facility
- High Explosive Application Facility
- 100 MeV Electron Acceleratory Facility
- 14 MeV Rotating Target Neutron Source
- High Explosion Flash Radiograph Facility
- High Speed Optics Facility
- Weapons Materials Research and Development Facility (in progress)
- One of the largest scientific computer complexes in the United States
- NOVETTE Experiment
- NOVA Laser facilities for Inertial Confinement Fusion Program
- Fusion Target Development Facility
- Magnetic Confinement Fusion Facilities
- Special Isotope Separation Laboratory
- Plutonium Facility
- 50 MeV Advanced Test Accelerator Facility (in progress)
- Diamond Turning Machine-3
- High Field Test Facility

Nuclear Weapons Activities

LLNL is organized to carry out research and development in all facets of nuclear device design, testing and stockpile certification (see Volume II, Chapter Two).

Throughout the seven phases of a warhead, from concept through retirement, LLNL scientists, engineers, and technicians are directly involved with their counterparts at the production plants and operations offices.

LLNL research with Strategic Defense Initiative application includes the development of the nuclear pumped x-ray laser, the development of rail guns (recently achieving a velocity record of 6.6 kilometers per second using a one gram projectile), and extensive research in free electron laser and particle beam technologies. The free electron laser research for the Strategic Defense Initiative Organization in DOD utilizes the two induction LINACs at LLNL, namely the 5 MeV Experimental Test Accelerator at the main site and the 50 MeV Advanced Test Accelerator at Site 300.

LLNL conducts verification technology studies to develop seismic and other techniques for verification of nuclear test ban treaties. Recently LLNL designed an array of twenty-six seismometers now in place in Norway (known as the Norwegian Regional Seismic Array) to study how well such an arrangement detects and locates weak seismic signals.[2] The Sandia-designed instruments are arranged in the center of and along four concentric rings up to two miles in diameter. LLNL also examined signals from the Soviet nuclear test site recorded at stations in China.[3]

LLNL conducts research on nuclear safeguards and security, focusing on the development of material accounting instrumentation and the evaluation of safeguards effectiveness.

For more than two years LLNL scientists have conducted research on the severe climatic effects of nuclear war known as "nuclear winter."[4] The program includes the following topics:

- Analysis of war scenarios
- Estimates of the fire potential of urban areas
- Microphysical and chemical processes that change the physical and optical properties of smoke
- Scavenging processes that determine the lifetime of smoke in the atmosphere
- Modeling of the global climate, including wind transport of smoke and the resulting influence of smoke on the climate
- Surveys of the biological consequences of unseasonably low temperatures and low light levels.

LLNL also conducts control technology and analytic studies to assess the capabilities of potential proliferators and develop and maintain a data base for the intelligence community.

ICF Program

LLNL is the lead laboratory in development of short wavelength neodymium glass lasers in the U.S. inertial confinement fusion (ICF) program.[5] Since the early 1970s a series of lasers with increasing pulse energy and peak

2 According to one expert, the Norwegian array is capable of detecting an explosion "of about one-half kiloton" at the Soviets' central test site 2600 miles away. HASC, Review of Arms Control and Disarmament Activities, 99th Congress, 1st Session, pp. 331-33.

3 "The Test Ban Treaties: Verifying Compliance," Energy and Technology Review, May 1983, pp. 1-9.

4 "Global Atmospheric Effects of Nuclear War," Energy and Technology Review (May 1985): 10-35; "Global Effects of Nuclear War," Energy and Technology Review (July 1985): 10-11.

5 Sources: HASC, FY 1985 DOE, pp. 91-92; HASC, FY 1985 DOE, pp. 124, ff.; LLNL Institutional Plan, FY 1984-FY 1989, pp. 11-14; Energy and Technology Review (February 1985); HASC, FY 1985 DOE, pp. 73-74.

Figure 20 Regional Map Showing Location of LLNL and SNLL

Source: PNL 4621 Draft, Pacific Northwest Laboratories, March 1983, p. 13.3.

power have been designed and constructed for research in weapons physics and military applications, x-ray lasing, and possible energy production. LLNL's support laboratories are the University of Rochester, KMS Fusion, and the Naval Research Laboratory. Other ICF program lead laboratories are LANL for the carbon dioxide laser and SNL for particle beams. An overall evaluation of the future of the ICF program is due in the FY 1987 time frame.[6]

The idea of ICF is that high-power laser (or particle) beams can rapidly heat the surface of a target microcapsule of fusion fuel, usually pellets of a deuterium-tritium (D-T) mixture. Blowoff ("ablation") of the plasma material formed from the surface drives the capsule inward and compresses the fuel to thermonuclear conditions. Were the D-T plasma created in the core to reach a density of 1000 to 10,000 times liquid hydrogen and a temperature of 100 million °C, the fuel would ignite to produce a high-gain thermonuclear microexplosion. A yield of more than 100 times the energy used to implode the fuel would be required for useful power generation.

There are two basic approaches to driving an inertial fusion target. The laser light can impinge directly on the target (direct drive) or can be converted to x-rays in an enclosure called a "hohlraum" containing the fuel mass and the x-rays used to drive the target (radiation drive).

The sequence of single-shot glass lasers developed at LLNL consist of JANUS (1974), CYCLOPS (1975), ARGUS (1976), SHIVA (1977), and NOVA (1985), preceded by NOVETTE (1982), which incorporated the first two NOVA amplifier chains. Each of these systems has been more powerful than its predecessor by a factor of five to ten. NOVA, which was completed in FY 1985 and is currently operating, delivers 120 kilojoules (kJ) of energy and a peak power of 100 terawatts (TW). Technology is being developed for a glass laser system scaled to 10,000 kJ and 500 TW.

The objective of high-gain fusion lasers in the near future has been dropped. The primary goal of the LLNL program (and the programs at SNL and LANL) is weapons physics research and the simulation of weapons effects. Elevated temperatures and densities in the compressed fusion targets approach conditions in nuclear weapons. Experimental diagnostics provide information on the behavior of target materials and on x-ray emissions. Soft x-ray lasing from exploding thin film targets was observed using NOVETTE as the driver, and research in this area will be continued with NOVA.

When the goals of the ICF program were being set in 1971 and 1972, the selection of appropriate laser technol-

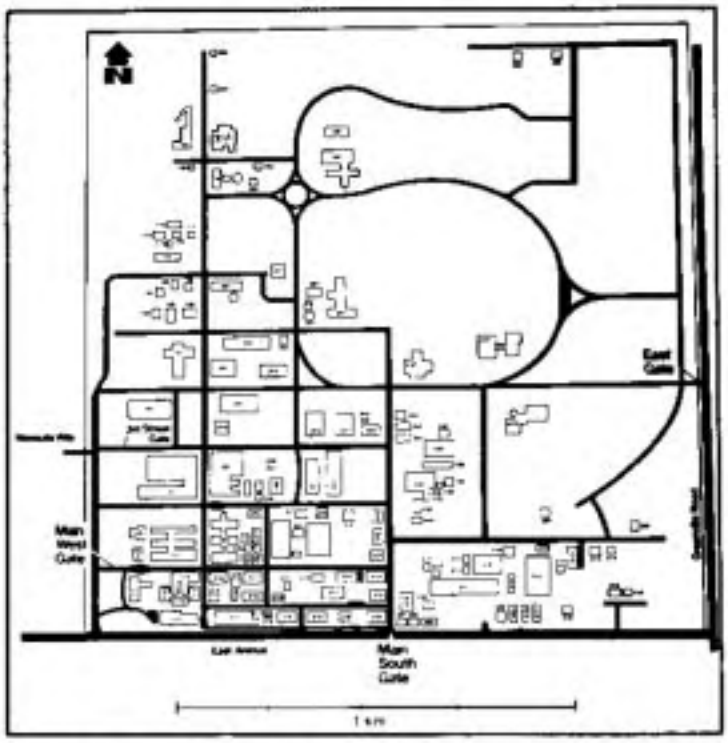


Figure 21 Site Map of LLNL

Source: PNL 4621 Draft, Pacific Northwest Laboratories, March 1983, p. 13.4.

6 HAC, FY 1985 EWDA, Part 4, p. 81.

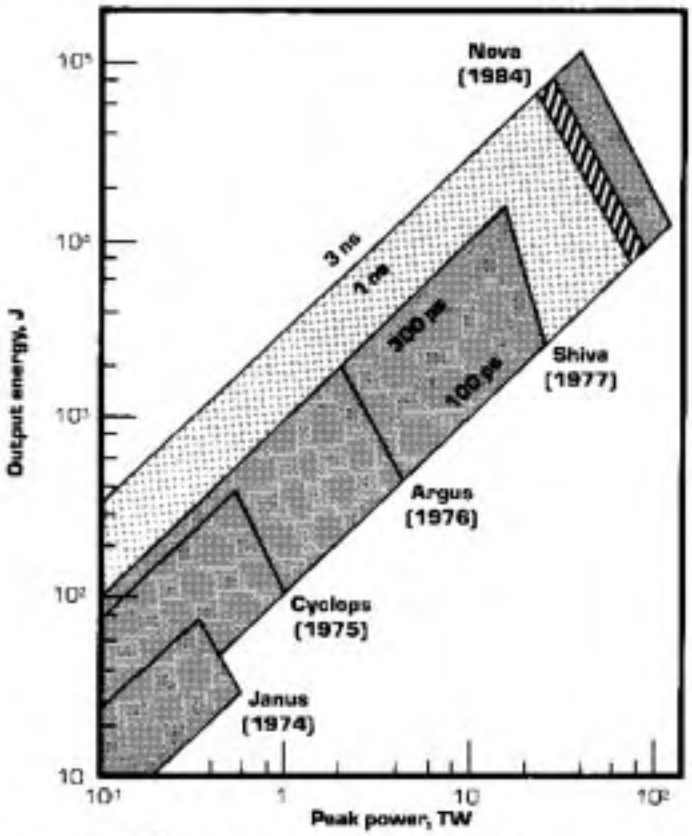


Figure 22 LL Neodymium-Glass Laser Capabilities

Energy, peak-power, and pulse-width capabilities of the neodymium-glass laser systems constructed and operated at LLNL during the past decade

Source: *Energy and Technology Review*, Lawrence Livermore National Laboratory, February 1985, p. 3.

ogy was based on laser operating wavelength, efficiency, and the potential for scaling to energy and power levels that would eventually be required. Livermore was assigned to short wavelength neodymium-glass laser for its ICF research while Los Alamos concentrated its research on possible advantages of the long wavelength carbon dioxide laser. It was subsequently confirmed that the shorter the wavelength of the incident laser light, the better the laser-target coupling for obtaining high compression of the fuel. At sufficiently short wavelengths, the D-T fuel pellet in the target is converted into a desirable thermal plasma, and undesirable competing energy absorption processes that would lead to a non-thermal plasma and deleterious preheating of the fusion fuel are of lesser importance.

Neodymium-glass lasers operate at the fundamental wavelength of 1050 nanometers (nm) (infrared). Experiments with ARGUS and SHIVA showed that this wavelength produced excessive numbers of "hot electrons" that caused preheating of the fusion fuel. The fundamental can be "harmonically converted" to shorter wavelengths at 525 nm (green) and 350 nm (blue) and, less efficiently, to 265 nm (ultraviolet) using KDP crystals. Experiments using shorter wavelengths (e.g., 525 nm) have shown a strong decrease in the hot electrons and an increase in the fraction of incident laser light absorbed and in the ablation pressure produced. NOVA is designed to operate at up to 120 kJ at 1050 nm, 80 kJ at 525 nm, and 70 kJ at 350 nm.

AVLIS

LLNL is the lead laboratory for the development of the atomic vapor laser isotope separation (AVLIS) process. The process is being jointly developed by LLNL and Martin Marietta Energy Systems at the Oak Ridge Y-12 Plant. AVLIS is being applied to the enrichment of both uranium and plutonium (see Volume II, Chapters Three and Five) in an integrated effort using common technology facilities and personnel. The Special Isotope Separation Laboratory, under construction at LLNL, will be the site of production-scale demonstration for both processes. LLNL, Rockwell Hanford Operations, and Bechtel National, Inc. are now developing the final conceptual design of an SIS production plant. If funding is approved in FY 1987 this plant could begin operation as early as 1992. Both Hanford and INEL are vying for the plant site.

Current Nuclear Warheads Designed by LLNL (with Sandia):

In the Stockpile (1986):	
W45	TERRIER
W48	155mm howitzer AFAP
W55	SUBROC
W56	MINUTEMAN II
W62	MINUTEMAN III
W68	POSEIDON C3 SLBM
W70-1,-2,-3	LANCE (Mod-3 Enhanced Radiation)
W71	SPARTAN
W79	8-inch howitzer AFAP
B83	Strategic Bomb
W84	Ground-Launched Cruise Missile
W87	MX/PEACEKEEPER ICBM
Under Development (1986):	
W82	155mm howitzer AFAP
Wxx	Short Range Attack Missile (Phase 2)
Wxx	Earth Penetrator Warhead (EPW)
Wxx	SICBM
Wxx	Strategic Relocatable Targets
Wxx	ASW/ND/SB Nuclear Depth/Strike Bomb
Wxx	Advanced Cruise Missile
Wxx	SABER

Other Weapons Activities (Non-Nuclear)

LLNL conducts research on non-nuclear weapons for five DOD agencies—the Navy, Army, Air Force, Defense Advanced Research Projects Agency (DARPA), and the Defense Nuclear Agency (DNA). This work, approximately seven percent of the laboratory effort, includes: upgrading computers and researching electromagnetic pulse effects on shipboard antennae for the

Navy; experimental support for the Army's Strategic Defense Initiative Lethality Program; shaped-charge warhead design for the Air Force; particle-beam and laser research for DARPA; and underground nuclear test phenomenology for DNA.[7]

Nonweapon Activites

Approximately 28 percent of the laboratory funding at LLNL is for nonweapons energy research, including one of the largest magnetic fusion research programs for the development of a controlled fusion reactor. Other nonweapon nuclear programs include uranium atomic vapor laser isotope separation (AVLIS) and nuclear waste management. Programs exist in geothermal energy, in-situ coal gasification, in-situ oil shale retorting, solar energy for industrial heat, and other energy applications. About 3 percent of the LLNL effort is work for the Nuclear Regulatory Commission, the Environmental Protection Agency, Federal Emergency Management Agency, the Federal Aviation Administration, and several Health and Human Services Institutes.

LLNL has one of the largest scientific computer complexes in the United States.[1] These are in two centers, the LLNL Computer Center (LCC) and the National Magnetic Fusion Energy Computer Center (NMFECC). About 75 percent of the computing capacity at the LCC is used by the nuclear weapons programs, and about 15 percent is used by the ICF program. These computers include one CRAY X/MP 48 (Class VI), four CRAY-1 (Class V), and three CDC 7600s. The NMFECC has two CRAY-1s, one CRAY X/MP 22, and one CRAY-2 (Class VII)[2] (see Figure 23).

Two laboratory-wide computer networks (one classfied, the other unclassified) are being built to connect computers and terminals throughout the laboratory.

Facilities

Facilities exist for fabricating all types of nuclear assemblies, including plutonium and high explosives. Precision machining capabilities are among the most advanced in the United States. Weapons related facilities include:

Explosive Test Site (Site 300). A 7000 acre high explosive research center located 15 miles east of LLNL (see Figure 24). Most experiments conducted at Site 300 are directly related to the design and development of nuclear warheads through what is referred to as "hydrotesting"—the testing of material components at pressures so high that solids begin to behave like viscous liquids. Explosive test bunkers and engineering test facilities are scattered throughout the site. These facilities are used for the dynamic mechanical and environmental

Figure 23 CRAY-2 Class VII Computer

testing of nuclear-explosive-like assemblies containing special nuclear material (SNM) and for the process and storage of SNM weapon parts. The Flash X-Ray Facility takes high resolution x-ray snapshots of nuclear warhead components as they are imploded by conventional explosives.

Tritium Facility (Building 331) Provides for continuing support of device tests at the Nevada Test Site, filling glass microsphere targets for the ICF program, and basic research in the physical and chemical properties of tritium.[10]

High Explosive Application Facility (HEAF). The design of HEAF was begun in FY 1979, and it will be completed in FY 1988. HEAF provides for high explosive (HE) storage, precision shot assembly, contact and remote control HE operations in support of test firing, test cells, firing chambers, a high velocity gas gun, and laboratories.[11]

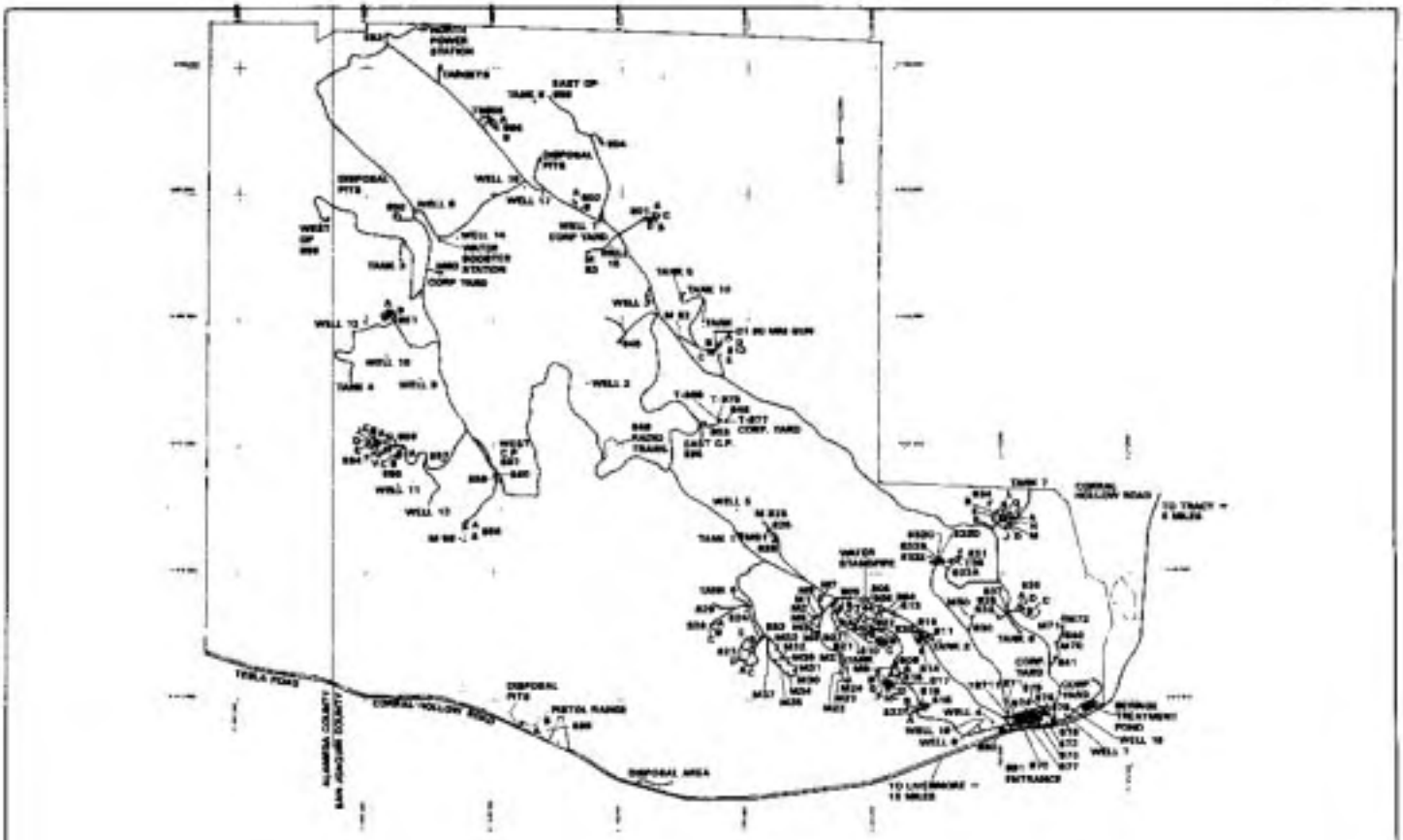
7 LLNL Institutional Plan, FY 1986-91, pp. 36-38, *Energy and Technology Review* (July 1984): 80-83.

8 Total computing capacity is a pacing item in nuclear weapons design.

9 A Class VII computer is defined as one having at least four times the computing capacity of a CRAY-1. See "Preparing for the CRAY-2," *Energy and Technology Review* (September 1985): 24-25.

10 HAC, FY 1986 EWDA, Part 4, pp. 199-200.

11 *Ibid.*, pp. 198-199.



Building List — Site 300

Bldg.	
801 A,B,C,D	Hydrodynamics Diagnostics
802 A,B	Hydrodynamics Diagnostics Complex
804	Limited Diagnostics Bunker
805	Cryotic Room
806	HE Lens Assembly
807	HE Machining Office
808	Process Testing
809	HE Programming
810	HE Machining/Remote Machining
812	HE Inspection Bay
813	Remote Machining
815	Radiography
816 A,B,C	HE Assembly
817 A,B,C,D	Hydrodynamics Diagnostics Complex
812 E	Universal Development Operations
813	Change House
813	HE Tech Office
813	Property Area Coordinator
814	High Speed Camera Facility
816	Central Vacuum & Air Plant
817	Photo & Oven Complex
818	HE Shipping & Receiving
819 C	Storage
819	Decontamination Building
820	Change House
821	Chemistry Storage
823	Radiography
825	Chemistry Test Process
826	Chemistry Test Process
827 A,B,C,E	Chemistry/HE Process Complex
831 D	HE Remote Machining
836 A,B,C	Machinability Complex
839	HE Disposal Area
838	Physical Properties Test
839 A,B,C,D	Physical Properties Test
839 E	Combustion Facility
853	Physical Properties Test
854 A,B,C,D,E,F,G,H,J,L,M	Thermal Environmental Test
855	Machine Shop
856 A,B,C,D	Dynamic Test Complex
858	Thermal Storage Building
860	Explosive Shop
861	Survey Building
865	Limited Diagnostics Bunker
869	Weather Station Office
869	Radio Transmitter
882	Hydrodynamics Diagnostics Bunker
884 A,B	Hydrodynamics Diagnostics Bunker
850	Laser Test Facility (out of service)
854 A,B,C,D,E,F,G,H,J,K	Dynamic Test Complex
850	Disassembly Complex
850	Storage
857	Thermal Storage Bldg
858	Drop Shaft and Area
862	Advanced Test Accelerator
865	826, Control Room
865	826, Hazards Control
870	826, Mix Area
892	826 Tunnel
870	Fire Department
870	Pass Office
870	Protective Services Bldg. Office
870	PAT Supervisor Office
871	B-Division Operations
871	B-Division Access
871	B-Division Photography
871	B-Division Shot Coordinator
871	Business Services
871	Hazards Control Admin
871	Hazards Control Coordinator
871	Hazards Control Explosives Testing
871	Hazards Control Explosives Safety
871	Hazards Control Field Support
871	High Explosives Technology
871	MFG Group Office
871	Resident Manager
871	Security Office
871	Weapons Operation
871	Weapons Test Group Support
872	Paint Shop
873	Plant Engineering Design
873	Plant Engineering Operations
873	Plant Engineering Shops
873	Lab
874	EE B Division Coordinator
874	EE Drafting
874	EE Engineer (Dept. Head)
874	EE Fabrication
874	EE Group Leader
874	EE Instrument Repair
874	EE Non-Programmatic Coordinator
874	EE Shops/Field
874	EE Technician/Supervisor
874	EE TV Repair
874	EE Weapons Test Cmpt. Coordinator
874	EE Weapons Test Group Engineering
874	ME
874	ME Coordinator
874	ME Drafting
874	Mechanical Technicians
874	Quality (Metal)
874	Welding Shop
874	Maintenance Mechanics
875	Supply Operations
875	Toxic Waste
875	Transportation
876	Warehouse
877	Janitorial
878	Storage Building
879	Minor Post & Storage
880	Cafeteria

POLICE POSTS

801 A	Main Site Post
801 B	Old Post
804	Process Area Post
805	Field Control Post (CCP)
806	CCP Operations
806	Test Observation Tent
807	West Control Post (WCP)
807	WCP Operations
808	West Observation Post
809	Pistol Range

MAGAZINE

M-9	Explosive Magazine
M-52	Storage Magazine
M-60	Ready Magazine
M-61	Ready Magazine

TRAILERS

830	Physics Test
139 (T-139)	Radiography
T-839E	839 Office
805	Kiosk

Figure 24 Site 300

Source: LLNL

Other Weapons Related Facilities:

- 100 MeV Electron Acceleratory Facility (Building 194)
- 14 MeV Rotating Target Neutron Source (Building 292)
- High Explosive Flash Radiograph Facility
- High Speed Optics Facility
- Weapons Materials Research and Development Facility (scheduled for completion in FY 1987)

Inertial Confinement Fusion (ICF) Facilities

SHIVA. Began operation in 1977; dismantled in 1981. SHIVA was an ICF laser system with twenty laser beams delivering up to 15 kilojoules (kJ) of energy per pulse in less than one billionth of a second and providing a peak power of 30 tera (trillion) watts (TW). It operated at a wavelength of 1050 nm in the infrared. SHIVA was the mainstay of the LLNL program, but it could not be color converted to shorter wavelengths. It achieved 100 times liquid density in target fuel and initiated x-ray physics experiments.

ARGUS. Began operation in 1976; now retired. It was a two kilojoule laser system. ARGUS was converted to operate at wavelengths of 530 nm (green) and 353 nm (blue), and at these shorter wavelengths demonstrated a dramatic increase in the laser light absorbed in D-T targets and in the pressure produced as well as a dramatic decrease in unwanted preheating of the fusion fuel.

NOVA. NOVA began operation at the end of February 1985. Completed at an estimated cost of $176 million. Although originally conceived as an upgrade of SHIVA to 250 kilojoule the final NOVA is a 10-beam neodymium-glass system able to provide laser light at 1050 nm (infrared), 525 nm (green), and 350 nm (blue) wavelengths.[12] The shorter green and blue wavelengths, produced by conversion of the infrared light in potassium dihydrogen phosphate (KDP) crystals, provide more favorable coupling of the laser energy to the D-T fuel target. Like the earlier lasers, NOVA is a master-oscillator power amplifier (MOPA) system. Each of NOVA's ten amplifier chains is 137 meters long. The diameter of each beam is 74 centimeters.

NOVA is more powerful than SHIVA by about a factor of ten. The NOVA laser beams concentrate 80 to 120 kJ of energy (about 10 kJ per beam) in a three nanosecond pulse at a 1050 nm wavelength, 50 to 80 kJ at 525 nm, and 40 to 70 kJ at 350 nm. The system will deliver a peak power of 80 to 120 TW in a 0.1 nanosecond pulse at 1050 nm.[13]

There are two target areas. NOVA's primary target chamber is an aluminum sphere 4.6 meters in diameter and 13 centimeters thick. After conversion to the desired color, the beams enter the chamber clustered in groups of five on each hemisphere. Lenses focus each cluster to an overlap spot of 250 millionths of a meter in diameter.[14]

The experimental program will consist of weapons physics, ICF experiments (to achieve D-T densities of 200 g/cm^3 or 1000 times the density of liquid D-T) and x-ray lasing at wavelengths shorter than achieved with NOVETTE.[15] NOVA ICF experiments will emphasize the radiation-drive approach in which fusion targets are irradiated with x-rays in a hohlraum.[16]

NOVETTE. Operated for eighteen months beginning in November 1982; dismantled in 1984 for incorporation into NOVA. NOVETTE was a testbed for NOVA components. It consisted of two NOVA amplifier chains (beams) constructed in the ARGUS high bay and configured with NOVA prototype hardware. The system deliver 15 kJ pulses of energy at 1050 nm (infrared) wavelength and 10 kJ pulses at 530 nm (green).

The 532 nm (green) NOVETTE beams were used in experiments to pump an x-ray laser by vaporizing "exploding" target foils of selenium and yttrium (materials with high atomic number). Soft x-ray emissions in the 15-20 nm range were produced by this method, providing the first conclusive evidence of soft x-ray lasing.[17]

Fusion Target Development Facility:

A facility for ICF target materials and fabrication R&D. Cryogenic and other complex targets necessary for high-density, high-yield experiments will be fabricated by the mid-1980s.

Magnetic Confinement Fusion Facilities:

- Magnetic Fusion Energy Facility
- Tandem Mirror Experiment
- Mirror Fusion Test Facility (MPTF-B) (under construction)

LAB ACTIVITIES BY PROGRAM (FY 1985):[18]

Defense Programs	60%
Energy Research	14%
Nuclear Energy	6%
Other DOE	5%
Reimbursables/Work for Others	15%

12 HAC, FY 1985 FWDA, Part 4, p. 226.
13 Energy and Technology Review, Lawrence Livermore National Laboratory, February 1985, p. 26.
14 Ibid., p. 15.
15 Ibid., p. 8.
16 HASC, FY 1985 DOE, p. 73.
17 Physics Today, March 1985, p. 17.
18 LLNL Institutional Plan, FY 1985-1990, p. 14 (Direct FTEs 1984).

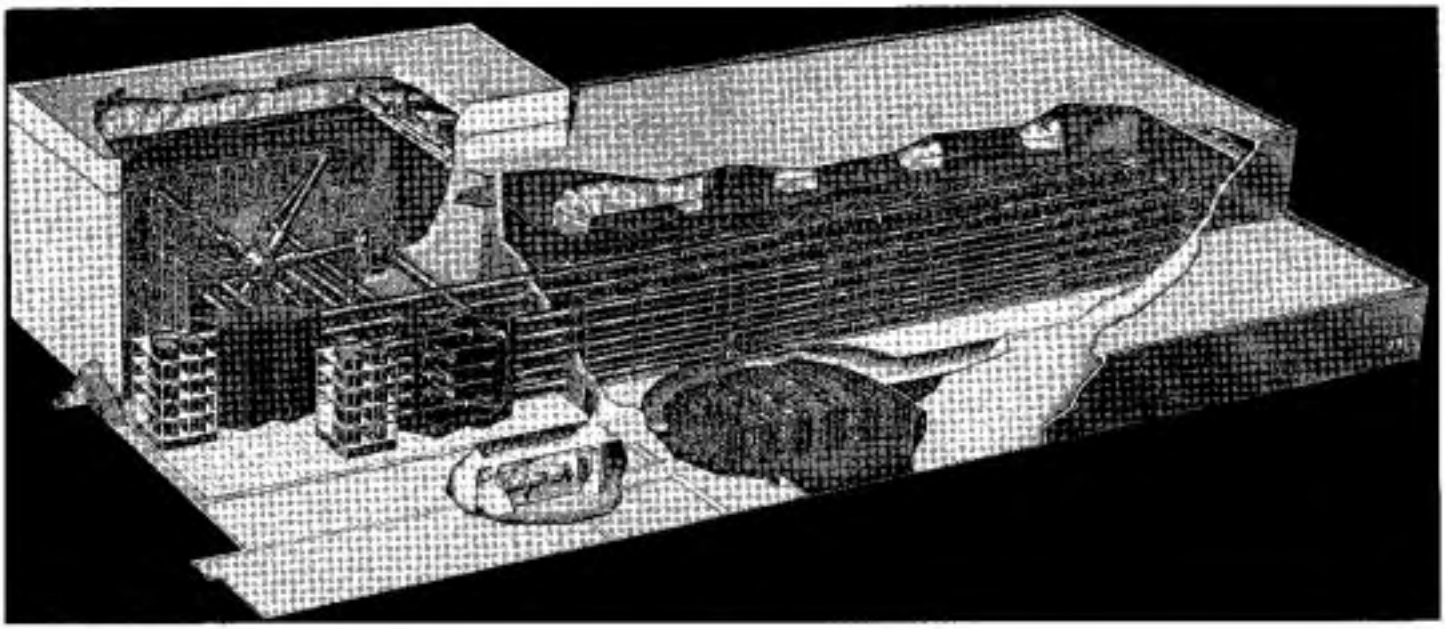


Figure 25 NOVA

BUDGET[19]
($ million):

FY	Total Lab Funding	DOE Defense Programs Total:
1983	677.8	420 .1(62%)
1984	808.5	463 .8(57%)
1985	882.7	499 .2(57%)
1986	937.1	549 .0(59%)

ASSETS

Capital Investment and equipment: $368.7 million in FY 1980. Laboratory and Office Space FY 1981: 3.9 million cu ft.

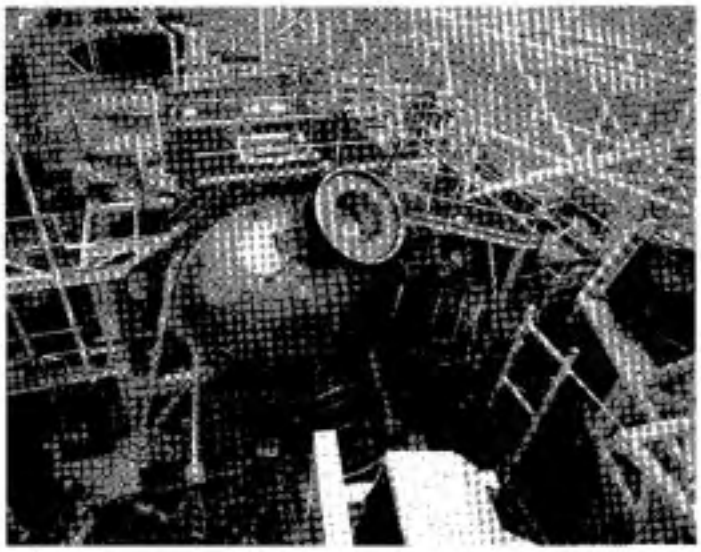


Figure 26 The NOVA target chamber, a massive aluminum sphere 4.6 m in diameter with walls almost 13 cm thick.

19 LLNL Institutional Plans, FY 1984-FY 1988; FY 1985-FY 1989; FY 1986-FY1990.

PERSONNEL (FTEs):[20]

End FY	LLNL	Mercury	Site 300	Total	Weapons Activities
1971	4835	146	258	5239	
1972	5105	132	226	5463	
1973	5007	125	221	5353	
1974	5066	112	216	5394	3382(63%)
1975 (Sep)	5483	106	188	5777	3287(57%)
1976	5909	106	197	6212	3168(51%)
1977	6369	103	201	6673	3323(50%)
1978	6659	100	232	6991	3258(47%)
1979	6729	94	236	7059	2894(41%)
1980	6984	95	254	7333	2838(39%)
1981	7256	99	286	7641	3064(40%)
1982	7138	104	285	7527	3779(50%)
1983	7400	105	304	7809	4147(53%)
1984	8108	109	333	8550	4472(52%)
1985 (Mar)	8095	113	333	8541	4322(51%)

20 DOE, COCO Employment, Computer printout for Office of Industrial Relations, R-55/29309-012, 29 August 1985. Percentage for weapons activities based on FTEs from Volume II, Table 2.2.

Los Alamos National Laboratory (LANL)[1]

Figure 27 Aerial View of Los Alamos National Laboratory

ADDRESS: University of California
Los Alamos National Laboratory
P.O. Box 1663
Los Alamos, NM 87545
505/667-5061
Public Affairs: 505/667-7000
Director: Siegfried S. Hecker

LOCATION: Remote mesa in New Mexico, about 60 miles north-northeast of Albuquerque and 25 miles northwest of Santa Fe; approximately 75 square mile site

ESTABLISHMENT: Decision to locate laboratory for weapons research (code name Site Y) at Los Alamos made November 1942

MISSION: To perform the research, development, and testing associated with the nuclear design aspects of all phases of the nuclear weapon life cycle

MANAGEMENT: GOCO facility operated for DOE by University of California (Board of Regents). University of California has served as prime contractor since 1 January 1943. Office of Military Application under the ASDP provides technical direction while Board of Regents contract administered by Albuquerque Operations Office (expires 30 September 1987).

1 Formerly Los Alamos Project; then Los Alamos Scientific Laboratory (LASL); then Los Alamos National Scientific Laboratory (LANSL). During the Manhattan Project, because the name "Los Alamos" was considered classified, the installation was variably identified as Site Y, Project Y, and Zia Project, Santa Fe, Area L, Shangri La, Happy Valley, and the like. Residents of Los Alamos and Santa Fe simply referred to "The Hill."

Los Alamos National Laboratory

BUDGET: $998.7 million, total laboratory funding (FY 1986)

PERSONNEL: 7368 total lab (March 1985)

FACILITIES:

- Small explosive assembly buildings
- High-explosive experimental facilities
- Plutonium Processing Facility
- Tritium Processing Facility
- HELIOS and ANTARES ICF Laser Facilities (shut down)
- One of the largest scientific computer complexes in the United States
- 800 Million Electron-Volt Linear Proton Accelerator (LAMPF)
- Weapons Neutron Research (WNR) Facility, including the Proton Storage Ring
- Stable Isotopes Production Facility
- 20 Terawatt CO2 Gas Laser Facility
- 8 Megasatt Nuclear Reactor
- Plutonium Research Facility
- Plutonium Heat Sources Fuel Production Facility
- National Security Resources and Studies Center

History

The Conant-Bush report, approved by President Roosevelt on 17 June 1942, recommended that a full-scale atomic bomb development project be initiated. Shortly thereafter, the Manhattan Engineer District was organized within the U.S. Army Corp of Engineers under the command of then Colonel (later Major General) Leslie Robert Groves. The decision to locate a laboratory for weapons research (code name Site Y) at Los Alamos was made in November 1942 by J.R. Oppenheimer, who became the laboratory director.

Nuclear Weapons Activities

LANL is organized to carry out research and development in all facets of nuclear device design, testing, and stockpile certification (see Volume II, Chapter Two). Throughout the seven phases of a warhead, from concept through retirement, LANL scientists, engineers, and technicians are directly involved with their counterparts at the production plants and operations offices.

LANL handles large quantities of high explosives and plutonium for weapon development.[2] There are storage facilities for prototype weapon devices and large quantities of SNM.[3]

LANL had a capability to fabricate and assemble nuclear test devices on site until FY 1984. Due to inadequate physical security at LANL the assembly of nuclear test devices since early 1984 has been performed entirely at NTS.

With the restart of PUREX in FY 1984 weapon grade plutonium oxide from Hanford was converted to metal at LANL. In FY 1985 this function was shifted to the Z Plant.

In 1983 LANL created a new program, Strategic Defense Research, to coordinate both nuclear and nonnuclear programs in response to President Reagan's Strategic Defense Initiative. This research involves neutral particle beams, free-electron lasers, electromagnetic rail guns, and warhead vulnerability.

Under a program sponsored by the Army Ballistic Missile Defense Project Office and DARPA, LANL has demonstrated a free electron laser at 7 kilowatts, the highest power reported in the world (1985), and have been able to tune it from 9 to 35 microns. Plans are to construct free electron lasers that will operate at 1 megawatt by FY 1988 and 10 megawatts by the early 1990s—the latter to be constructed at the White Sands Missile Range.

Verification and arms control technology is a major program at LANL in support of U.S. arms control measures. These include foreign technology assessments, technology transfer issues, and detection of nuclear explosions underground, in the atmosphere, and in space. The ionospheric monitoring and infrasonic programs are directed toward verification of nuclear test ban treaties. The programs seek to detect and measure atmospheric and undergound nuclear explosions by observing their ionospheric and atmospheric signatures. Satellite-based test detection is a continuing Los Alamos program that began about 1960 with design and preparation of the first pair of VELA satellites, launched in 1963. Satellite-based test detection is continuing in multimission Air Force satellite programs for which LLNL and SNLA jointly provide instrumentation for verification of compliance with the Limited Test Ban Treaty. In general, Los Alamos is responsible for instrumentation to detect x-ray, gamma-ray, neutron, and charged-particle radiations from nuclear detonations in space. This project also supports DOD requirements for obtaining wartime information on tactical nuclear bursts and conducts R&D in technologies for potential detection of directed-energy weapon testing.

2 Final Environmental Impact Statement, Los Alamos Scientific Laboratory site, U.S. DOE, December 1979, p.4-98.

3 HASC, FY 1986 DOE, p. 120. LANL has recently reduced the number of Category I Special Nuclear Material sites from eight in early FY 1984 to four in early FY 1985; HASC, FY 1986 DOE, p. 232.

LANL is the lead laboratory for ICF research using long wavelength lasers and heavy-ion drivers. The LANL ICF program has four main efforts: (1) the evaluation of CO2-laser-driven ICF by theory and experiments, (2) weapons research and experiments on unstable hydrodynamics for all ICF drivers, (3) R&D on advanced gas laser technology, and (4) the investigation of heavy-ion-driven inertial fusion. A substantial portion of the program resources have been devoted to three high-energy short-pulse CO2 fusion laser systems that have been used for target physics experiments: GEMINI (1976), HELIOS (FY 1978-83), and ANTARES (FY 1983-85).

The eight beam HELIOS laser operated at 5 kilojoules (kJ) before being placed on standby in FY 1983 in anticipation of the 30 to 40 kJ ANTARES that operated from FY 1983 to FY 1985. These machines provided data on laser/target interaction physics in the areas of absorption, laser energy conversion, and transport and plasma physics. ANTARES was shut down at the end of FY 1985 after it was learned that the CO_2's wavelength was too long for efficient coupling of the laser's energy to the ICF target.

LANL conducts research on nuclear material safeguards and security, primarily in the area of materials control and accounting, in support of the DOE complex and the commercial nuclear industry.

Research is also conducted on the application of light-ion particle beams as fusion drivers in conjunction with SNLA, the lead laboratory for electron and light ion beam drivers. LANL demonstrated (mid-1983) a short wavelength 20 kJ krypton fluoride (KrF) excimer laser (funded since 1975 by the Defense Advanced Research Project Agency's laser beam weapon research program) that might be a candidate ICF driver.[4]

LANL conducts plutonium processing and fabrication research and development. At times LANL has processed production quantities of plutonium residues or other feedstock for the weapons production complex. LANL is currently (1986) doing so in response to a reprocessing capacity shortage caused by the failure of the chemical recovery operations in Building 371 at Rocky Flats to perform as designed. LANL was the lead laboratory in research on plutonium laser isotope separation using the molecular laser isotope separation (MLIS) process. The process is being applied to the separation of the non-fissile isotopes Pu-240 and Pu-242 for research (see Volume II, Chapters Three and Five).

Current Nuclear Warheads Designed by LANL (with Sandia):

In the Stockpile (1986):	
B28	Bomb
W31	HONEST JOHN/NIKE-HERCULES
W33	Artillery Shell
B43	Bomb
W44	ASROC
W50	PERSHING 1a
B53	Bomb
W53	TITAN II
W54	SADM
B57	Bomb
B61	Bomb
W69	SRAM
W76	TRIDENT I C4
W78	MINUTEMAN III
W80-0/1	SLCM/ALCM
W85	PERSHING II
Under Development (1986):	
W81	STANDARD 2
W88	TRIDENT II
Wxx	ASW/ND/SB Nuclear Depth/Strike Bomb
Wxx	Advanced Cruise Missile
Wxx	SICBM
Wxx	Strategic Relocatable Targets

Other (Non-Nuclear) Weapons Activities

LANL conducts research on non-nuclear weapons for DOD agencies and military departments. This work, approximately thirteen percent of the laboratory effort, includes, among others: a Nuclear, Biological, Chemical (NBC) countermeasures program to develop antidotes for chemical agents and toxins, evaluate protective systems, and provide adequately sensitive NBC detection and warning systems; research on ceramic armor and improved anti-armor or projectiles; and a counterterrorism program.

Nonweapon Activities

Approximately 30 percent of LANL's funding (FY 1984) is in nonweapon activities, primarily funded by DOE. This includes light water reactor safety (NRC funded), magnetic fusion and molecular (uranium) laser isotope separation research programs. Non-nuclear

4 *Energy Daily*, 10 July 1983, p. 2.

energy research includes oil-shale, geothermal, conservation and environmental research programs. LANL does work for the Nuclear Regulatory Commission, NASA, CIA, EPA, the Departments of Agriculture, Commerce, Interior, Transportation, and Health and Human Services. The laboratory also does work for foreign governments (West Germany, Japan, United Kingdom) and corporations (IBM, TRW, Westinghouse, Rockwell International).

LANL has one of the largest scientific computer complexes in the United States.[5] About 62 percent of the computing capacity is used by the nuclear weapons programs, and about 10 percent is used by the ICF program. These computers include one CRAY X/MP (Class VI), five CRAY-1 (Class V), and four CDC 7600s. LANL is scheduled to acquire a Class VII computer in July 1986[6] and will add three more between FY 1987 and 1989.

LANL Technical Areas[7]

TA-2, Omega Site. Omega West Reactor, an 8 megawatt nuclear research reactor, that serves as a source of neutrons for fundamental studies in nuclear physics and associated fields.

TA-3, South Mesa Site. Main technical area of the Laboratory with administration building that contains the director's office and administrative offices and laboratories for several divisions. Other buildings house the Central Computing Facility, Materials Department, the Chemistry and Metallurgy Division, Physics Division, technical shops, cryogenics laboratories, and a Van de Graff accelerator.

TA-6, Two Mile Mesa Site. One of three sites (TA-22 and TA-40 are the other two sites) used in development of special detonators for initiation of high explosive systems. A new Detonation Systems Laboratory is under construction at TA-40.

TA-8, GT Site (or Anchor Site West). Nondestructive testing site operated as a service facility for the entire Laboratory. Principal tools include radiographic techniques (x-ray machines to 1 million volts, a 24-MeV betatron), radioactive isotopes, ultrasonic testing, penetrant testing, and electromagnetic methods.

TA-9, Anchor Site East. Studies of fabrication feasibility and physical properties of explosives. New organic compounds are investigated for possible use as explosives. Storage and stability problems are also studied.

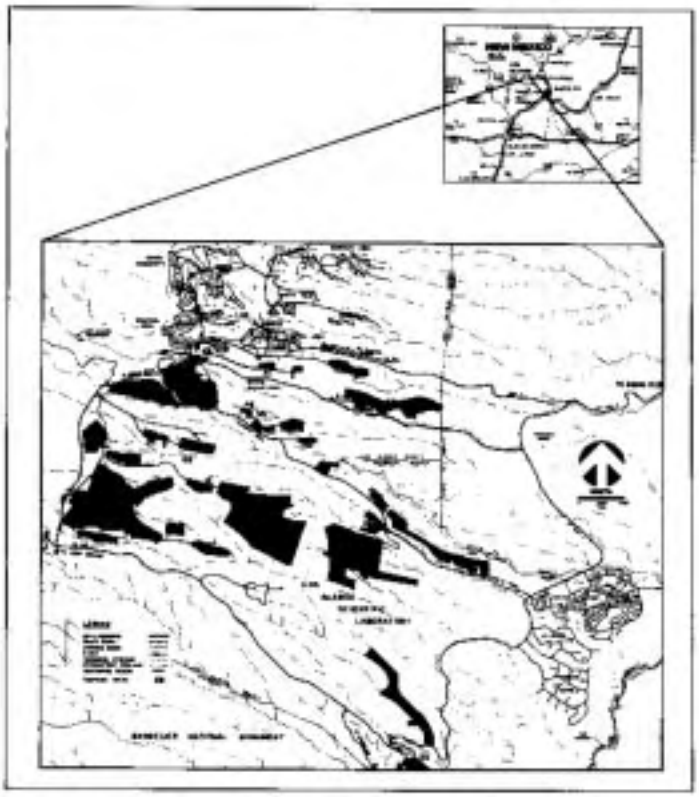


Figure 28 Los Alamos National Laboratory's Technical Areas and Adjacent Communities

Source: LANL

TA-11, K-Site. Facilities for remote testing of explosive components and systems under a variety of extreme physical environments. Devices tested contain explosives, radioactive materials, and nonhazardous materials.

TA-14, Q-Site. Firing site for running tests on relatively small explosive charges and for fragment impact tests.

TA-15, R-Site. Location of PHERMEX flash x-ray source—a multiple cavity electron accelerator capable of producing a very large flux of x-rays for weapons development including imploding assemblies. Space and time resolution data are achieved with ultrafast (subnanosecond) time resolution.

TA-16, S-Site. Development, engineering design, pilot manufacture, environmental testing, and stockpile

5 Total computing capacity is a pacing item in nuclear weapons design. For a historical overview of computers at LANL see Francis H. Harlow and N. Metropolis, "Computing & Computers," *Los Alamos Science* (Winter/Spring 1983): 132-141. "Electronic computers were developed a . . . during and after World War II to meet the need for numerical simulation in the design of nuclear weapons, aircraft and conventional ordnance." B.L. Buzbee, N. Metropolis, and D.H. Sharp, "Frontiers of Supercomputing," *Los Alamos Science* (Fall 1983): 66.

6 A Class VII computer is defined as one having at least four times the computing capacity of a CRAY-1.

7 *Environmental Surveillance at Los Alamos During 1980*, LA-8810-ENV, Los Alamos National Laboratory, 1981.

8 *Los Alamos News Bulletin* (20 June 1984): 3.

production liaison for nuclear weapon warhead systems. Development and testing of high explosives, plastics and adhesives, and process development for manufacture of items using these and other materials. Facilities include a slurry plant with a capacity of 300 pounds of explosive per batch.[8] Site no longer handles sensitive nuclear materials.

TA-18, Pajarito Laboratory Site. Location of low-power reactors for initiating chain reactions. The reactors are housed in buildings known as "kivas" and are used primarily to provide a controlled means of assembling a critical amount of fissionable materials. This is done to study the effects of various shapes, sizes, and configurations. Reactors are also used as sources of fission neutrons in large quantities for experimental purposes.

TA-21, DP-Site. Site has two primary research areas, DP West and DP East. DP West is concerned with tritium research. DP East is the high temperature chemistry site where studies are conducted on the chemical stability and interaction of materials at temperatures up to and exceeding 3300°C. Site no longer handles sensitive nuclear materials.

TA-22, TD Site. See TA-6.

TA-28, Magazine Area "A". Explosive storage area.

TA-33, HP Site. Design and development of nuclear and other components of weapon systems. A major tritium handling facility is located here.

TA-35, Ten Site. Nuclear safeguards research and development on techniques for nondestructive detection, identification, and analysis of fissionable isotopes. Research in reactor safety and laser fusion is also done here. HELIOS and ANTARES are LANL laser facilities for ICF research. HELIOS is a 10 kilojoule CO_2 laser fusion system (10 micron wavelength). ANTARES is a 40 kilojoule 24 beam CO_2 laser fusion driver. It was completed in November 1983 at a cost of $62 million.

TA-36, Kappa Site. Various explosive phenomena, such as detonation velocity.

TA-37, Magazine Area "C". Explosives storage area.

TA-39, Ancho Canyon Site. Nonnuclear weapon behavior. Investigations are also made into various phenomenological aspects of explosives, interaction of explosives, and explosions with other materials.

TA-40, DF-Site. See TA-6.

TA-41, W-Site. Engineering design and development of nuclear components, including fabrication and evaluation of test materials for weapons. Also located here is an underground laboratory that is used for physics experiments.

TA-43, Health Research Laboratory. Biomedical Research Group. Research here in cellular radiobiology, molecular radiobiology, biophysics, mammalian radiobiology, and mammalian metabolism.

TA-46, WA Site. Applied photochemistry, including development of technology for laser isotope separation and laser-enhancement by chemical processes. Solar energy research.

TA-48, Radiochemistry Site. Nuclear properties of radioactive materials. Measurements of radioactive substances are made in "hot cells," used for remote handling of radioactive materials.

TA-50, Waste Management Site. Treating and disposing of contaminated liquid waste received from Laboratory technical areas. Development of improved methods of waste treatment.

TA-51, Radiation Exposure Facility. Here animals are irradiated to determine biological effects of high and low exposures.

TA-52, Reactor Development Site. A wide variety of activities related to nuclear reactor performance and safety are done here.

TA-53, Meson Physics Facility. Site of the Clinton P. Anderson Meson Physics Facility (formerly the Los Alamos Meson Physics Facility (LAMPF), a linear particle accelerator, used to conduct research in the areas of basic physics, cancer treatment, materials studies, and isotope production. Also sited here is the Weapons Neutron Research (WNR) complex, which includes a proton storage ring (PSR). LAMPF provides 800 MeV protons to the spallation target in the WNR complex for the generation of neutron beams used in weapons and other research. The PSR is designed to increase the neutron pulse capability of the NWR by providing high quality proton beams that can be delivered to the NWR facility in intense pulses at high repetition rate.

TA-54, Waste Disposal Site. A disposal area for radioactive and toxic wastes.

TA-55, Plutonium Processing Facilities. Includes processing and recovery of Pu-239 from scrap materials, recycle, metal production, metal fabrication, and research and development.[9] This is the site of special isotope separation research. The SIS-III will provide special plutonium isotopes for LANL weapons research. The site also has responsibility for manufacturing heat sources for weapon-related programs.

TA-57, Fenton Hill Site. Location of Hot Dry Rock geothermal project.

TA-58, Two Mile Mesa. Undeveloped technical area.

TA-59, Occupational Health Site. Occupational health and environmental science activities.

9 A direct copy of the LANL facility is reported to be under construction at Aldermaston in the United Kingdom for operation as early as 1988 in TRIDENT warhead production and other weapons activities. Letter from Duncan Campbell, 26 February 1985.

Los Alamos National Laboratory

LAB ACTIVITIES BY PROGRAM (FY 1984):[10]

Defense Programs	57%
Energy Research	17%
Nuclear Energy	3%
Conservation and Renewable Energy	2%
Fossil Energy	1%
Other DOE	6%
Work for Others	14%
Nuclear Regulatory Commission	3%
Department of Defense	7%
Other	4%

BUDGET ($ million):[11]

FY	Total Lab Funding	DOE Defense Programs Total
1983	634.1	411.4(65%)
1984	689.4	438.3(64%)
1985	839.0	509.2(61%)
1986	998.7	526.2(53%)

ASSETS

Capital Investment and Equipment (FY 1980): $569.6 million.[12] Laboratory and Office Space: 5.7 million square feet.

PERSONNEL:[13]

End FY	U. California	Zia	Weapons Activities	
1971	4013	948		
1972	4298	836		
1973	4479	920		
1974	4711	930	2290	(49%)
1975 (Sep)	5393	828	2368	(44%)
1976	5801	969	2291	(40%)
1977	6120	1199	2448	(40%)
1978	6576	1272	2453	(37%)
1979	6837	1333	2338	(34%)
1980	7061	1392	2316	(33%)
1981	7381	1335	2524	(34%)
1982	6770	1428	2823	(42%)
1983	6781	1502	2875	(42%)
1984	7149	1679	3124	(44%)
1985 (Mar)	7368	1627	3198	(43%)

10 Los Alamos National Laboratory Institutional Plan, FY 1985-FY 1990, p. 17 (Total Direct FTEs 1984).
11 LANL Institutional Plans, FY 1984-89, FY 1985-90, FY 1986-91.
12 Capsule Review of the DOE Research and Development Field Facilities, U.S. DOE, DOE/ER-0002, September 1980, p. 17.
13 DOE, GOCO Employment, Computer printout for Office of Industrial Relations, R-5529309-012, 29 August 1985. Percentage for weapons activities based on FTEs from Volume II, Table 2.2.