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~~When finished please~~ return to Mr. Stanwood, Rm. E-220.

THE FUTURE ROLE OF THE ATOMIC ENERGY COMMISSION LABORATORIES

A Report to the Joint Committee on Atomic Energy

Draft No. 1 - Incomplete
October 1, 1959

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URGENT

Those Listed Below

October 22, 1959

C. L. Dunham, M.D., Director
Division of Biology and Medicine

COMMENTS ON REPORT - ROLE OF AEC LABORATORIES

There are attached two draft documents entitled "THE FUTURE ROLE OF THE ATOMIC ENERGY COMMISSION LABORATORIES - A Report to the Joint Committee on Atomic Energy" for your information and review. As I am sure you are well aware, the study of the future role of the AEC laboratories, particularly as it will have impact on the future conduct of the AEC Biomedical Program, is of considerable significance and well merits careful attention.

We are required to provide detailed comments on this draft study no later than October 28, 1959. To facilitate this endeavor I request that you provide me with comments as you may consider pertinent but, in particular, as related to the following:

1. Omissions, deletions or additions concerning the general statement of the Commission's Biomedical Program, its responsibilities, obligations and continuing requirements.

2. A review of the Biomedical program as proposed by us for the various laboratories in the next decade (Part II) and amendments thereto as necessary.

3. Review of Part IV, Summary of the Long Range Biomedical Programs, as submitted by the laboratories, and corrections thereto as necessary.

4. Compare material submitted under 2 and 3 above as to any significant inconsistencies between programs proposed by us and those planned by the laboratories, and provide statements reconciling such differences.

Please provide this material to Mr. Stanwood for coordination no later than Tuesday, October 27, 1959.

Attachments: (2)
As Stated.

Addressees:
Dr. Bruner
Dr. Zelle
Dr. Wolfe w/o att.
Dr. Shilling BMADA B&M DIR

HAStanwood:ns CLDunham
10/22/59 10/ /59

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INTRODUCTION

This report is submitted at the opening of a decade that may well hold the gravest challenge this Nation has yet faced.

It is peculiarly appropriate that, at the outset of this period, we should be considering and planning for the future of the Atomic Energy Commission's laboratories, for on them and on the other research and development institutions of the country rests the responsibility for providing the increased understanding of the physical world and of life processes and for achieving the rapid application of scientific knowledge to practical use on which our place among the nations depends.

Scientific and technical achievement alone will not guarantee that place; it must be merited by the preservation and fuller realization of the ideal of freedom whose many manifestations have been the basic strength of our society. But without continuous progress in the sciences and technology, we would soon find that we could not preserve the conditions of national security and material prosperity in which the ideals of freedom and individual fulfillment can be most completely attained.

With a challenging future before us, and with nearly two decades of federally-sponsored research and development in nuclear science and technology behind us, the request of the Joint Committee on Atomic Energy for a broad review of the present work of the AEC laboratories and future plans for them is welcome and timely.

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In the last decade, as removal of security restrictions has permitted the spread of knowledge of most of the work of the laboratories, they have become recognized world wide for their abilities and their performance; this report, therefore, makes no attempt to summarize the manifold contributions of these institutions to the national security, to the peaceful uses of atomic energy, and to the increase of man's understanding of nuclear processes.

One note of caution must be included, even though it may be quite obvious. In any field of human activity, an attempt at a ten-year prediction is hazardous at best. In scientific research and development, and particularly in so new and dynamic a field as atomic energy, the hazards are multiplied many times over. Therefore, it must be recognized that the forecasts included here can only be projections of what we know today; they will be certain to be changed in greater or lesser degree by tomorrow's findings. It is important to bear in mind that the statments concerning the future are not programs or proposals, but predictions.

Plan of the Report

In order to forecast intelligently what each AEC laboratory will be doing in the next ten years, it is necessary, first, to arrive at some conclusions as to what the agency as a whole should be doing

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during that period, and second, to determine what types of institutions should perform the needed work. Therefore, after a quantitative review, in terms of dollars and manpower, of the current size and past trends of research and development in the United States as a whole and in the AEC, the study examines first, the AEC's current view of its research and development objectives for the next decade, second, the levels of effort and trends of emphasis that will be required to meet these objectives, and third, the appropriate roles of the AEC laboratories, universities, industry, other non-profit research organizations, and other federal agencies in the work that lies ahead. Within this frame of reference, Part Two of the study consists of an individual brief statement on each major laboratory, describing its background, current program, and summarizing the AEC's future plans for it. Part Three is a summary of the conclusions reached in the study.

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Part I

THE RESEARCH AND DEVELOPMENT ACTIVITIES OF THE ATOMIC ENERGY COMMISSION

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Section One

BACKGROUND

(This section will consist of two parts; the first, still in preparation, will be made up of tables, charts, and naarative describing the size and trends of all research and development in the U. S. as a whole, the government's share, and the AEC's share. It will also discuss past trends in the AEC's research and development work in dollar and manpower terms, and will discuss specifically the relation of AEC-supported basic research to total basic research in the U.S. The second part, definitions of some terms, follows.)

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Definitions

At the outset, it might be well to define for purposes of this study a few of the terms that will be frequently encountered.

The term basic research will be used, as it is by the National Science Foundation, to mean research which is directed toward increase of knowledge in science. It is research where the primary aim of the investigator is a fuller knowledge or understanding of the subject under study rather than a practical application. This type of research is distinguished from all other research and development work by the fact that it alone has no immediately useful goal. It is not undertaken to answer an engineering question or to find a cure for a disease or to identify a material which will meet a specific structural requirement. Whether ultimately it will be of practical value frequently cannot be predicted by the researcher at the time he is working on the problem. An example is Enrico Fermi's work in Italy in 1934 when, in attempting to find some explanation for the peculiar results experienced in inducing artifical radioactivity in silver, he discovered that certain substances will slow down, or moderate, neutrons. This discovery was later to become an essential principle in the construction of atomic reactors.

The second aspect is applied research and general development. This term categorizes work undertaken or carried out because of the clear probability that it will have a useful end result. It is applied to work of a general nature as distinguished from the specific

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type of development encompassed in the next category. An example is the work of Argonne National Laboratory in the development of the fluidized bed. In traditional chemical processing, materials are frequently dissolved in order to react one with another. In the fluidized bed method, a solid is powdered, instead of being dissolved, and the gas to be reacted with it bubbled through the bed of powder as though it were a liquid. This work was undertaken to develop a technique which offered hope of eliminating the use of large volumes of liquid in chemical work. At the time it was started it was not directed toward the solution of any specific engineering or production problem, though its general potentialities were recognized. Subsequently the technique was adopted by private industry for the supply of feed materials to the Commission's production plants.

The third category is project development. It includes the substantial amount of effort devoted to the solution of specific problems encountered in producing an end product, such as a pressurized water power plant, or a recovery system for a specific reactor fuel. A good example is the Shippingport pressurized water reactor. The project development of this plant was undertaken after the feasibility of the construction and operation of pressurized water reactors for power production had already been demonstrated at the Nautilus prototype in Idaho. There remained, however, a great number of difficult problems to be solved in order to produce a large reactor that would meet the requirements of an

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operating utility. These problems included such matters as pumps, control systems, fabrication of maximum-life fuel, and shutdown systems necessary to assure the safety of the large population in the area.

The fourth category is process and product improvement. This is the type of work frequently encountered in industrial laboratories. It is concerned with lowering costs and increasing the efficiency of products or systems which have already been developed and put into production or operation. In the AEC the effectiveness of this work is evidenced by the great increases in production and reductions in operating cost per unit of product that have been achieved at the production facilities.

It is, perhaps, unnecessary to emphasize that the range of research and development work, from the most fundamental on the one hand to the most practical engineering development on the other, is made of indistinguishable gradations. Therefore, the application of the terms just defined is subject to degrees of interpretation, and their use will always be somewhat arbitrary. Nevertheless, they are helpful in enabling us to speak generally about related kinds of work.

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Section Two

OBJECTIVES

The AEC laboratories and their future role can be forecast either on the general basis that these institutions constitute important national assets which must be preserved in order to maintain in being a substantial body of technical personnel and facilities ready to attack problems as they arise or they can be considered more specifically from the standpoint of the individual objectives which constitute the current mission and the projected future program for each. Their importance as national assets is generally recognized, but the prescription of a program based on the desirability of preserving them rather than on the functional needs which they should meet in the future might well lead to an uncritical static forecast. This report proceeds on the assumption that the second type of analysis is the more meaningful.

The broad objectives of the AEC's research and development program, in the carrying out of which the laboratories are a major factor, are stated in the Atomic Energy Act. They stem from the national atomic energy policy:

> the development, use, and control of atomic energy shall be directed so as to make the maximum contribution to the general welfare, subject at all times to the paramount objective of making the maximum contribution to the common defense and security; and
>
> the development, use, and control of atomic energy shall be directed so as to promote world peace, improve the general welfare, increase the standard of living, and strengthen free competition in private enterprise.

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To effectuate this policy, Section 3 of the Atomic Energy Act of 1954 establishes these general objectives among others: the encouragement of maximum scientific and industrial progress, the encouragement of widespread participation in the development and utilization of atomic energy for peaceful purposes, promotion of the common defense and security and making available to cooperating nations the benefits of peaceful applications of atomic energy. Out of these general missions have been delineated the following objectives for research and development in each of the principal program areas:

Materials Programs

In the fields of raw materials, source materials, and special nuclear materials, the objectives of development work can be stated quite simply:

1. To assure adequate supplies
2. To reduce costs by developing more efficient production and processing methods.

The substantial research and development program formerly carried on in the raw materials field has been discontinued as an adequate supply of ores and concentrates has been assured. Commercial procurement has placed the responsibility on private industry for processing improvements.

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In source and special nuclear material manufacture, improvement programs will continue to be carried out in an attempt to continue the steady trend of increased production at lower costs that has characterized the production activities since their start-up. There are no requirements evident today that will call for the development of new production techniques or major new production facilities.

Weapons Development

Stated generally, the weapons work is aimed at the development of additional types of weapons, of improved design, and improved methods for weapons production, storage, and maintenance.

Nuclear Explosives (Plowshare)

The work on Plowshare is in its early stages. Its objective is to develop methods for utilizing nuclear explosions for peaceful purposes, including the design and development of nuclear devices to serve specific applications such as mining and excavation.

Maritime Reactors

The merchant ship program has as its major AEC objective the development of light-weight, compact nuclear plants, capable of remote operation, that can operate in commercial competition with conventional vessels. Supporting this primary objective are these subsidiary aims:

1. To develop operating and maintenance techniques for the U. S. Savannah and to establish a pattern for the servicing of future nuclear merchant ships.

2. To attain acceptance of the Savannah and future nuclear merchant ships in unrestricted domestic and foreign commerce.

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Military Reactors

In this field the AEC's broad objective is to provide specially designed and developed reactors to meet specific service uses determined by the Department of Defense and the National Aeronautics and Space Administration. The fields include reactors for the propulsion of a variety of naval vessels, manned aircraft, rockets, and ram-jets; stationary power plants for a wide range of sizes and field uses; and small auxiliary power sources.

1. Naval reactors.

   a. To continue the development of propulsion units for applications ranging from small submarines to large aircraft carriers.

   b. To investigate and develop improved types of propulsion systems, such as the natural circulation pressurized water plant.

   c. To obtain longer core life for present and future plants.

2. Manned Aircraft

   a. To determine the feasibility and performance characteristics of direct cycle and indirect cycle plants.

   b. To run a ground test of a complete aircraft pulsion system within five years.

   c. To achieve manned, nuclear powered flight within the next several years.

3. Missile Propulsion Systems. Present objectives are limited, in both the rocket propulsion and ram-jet systems, to a ground test demonstration of feasibility within the next five years. As that goal is approached, objectives for flight testing will be established.

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4. Auxiliary Power. This program is directed toward the development of lightweight, long-lived nuclear auxiliary power sources for special applications, including isotopically fueled units as well as reactors.

5. Army Reactors. The research and development objectives of the Army Nuclear Power Program are:

a. To develop a family of nuclear power plants in the power range of about 100 KWE up to 40,000 KWE for all three military services.

b. To increase power and core life.

c. To develop simpler and more rugged components.

d. To make plant operation as nearly automatic as possible and reduce crew size.

e. To reduce on-site construction time and costs.

f. To improve mobility.

Civilian Power Reactor Development

Current planning in this field is based on the following objectives:

1. The achievement of nuclear power generation costs that are comparative with power cost of fossil fueled plant on an equivalent station design basis, in high energy cost areas in this country by 1968. (High energy cost areas are defined as those where the cost of fossil fuel is 35 cents per million BTU's.)

2. The achievement of nuclear power generation costs that are comparative with fossil fueled plant cost on an equivalent station design basis in all but the low energy cost areas by 1975. (Low energy cost areas are defined as those where the cost of fossil fuel is 25 cents per million BTU's or less.)

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3. The successful development of breeder type reactors that will serve as a source of plutonium and uranium 233. This type of reactor offers the potential of full utilization of the latent energy in both uranium and thorium. The primary objective is to develop those systems that offer the best potential of breeding. A second objective is to develop a breeder system that will also produce competitive power.

4. The successful development of a reactor type that can operate independently of a continuous feed of enriched fuel from diffusion plants or separate breeding reactors. The prime objective for developing this reactor type is to obtain low power generation cost; however, there are two other basic objectives; conservation of fuel reserves by burning natural uranium; and assistance to friendly foreign nations who desire to be independent of outside sources of enriched fuel, in the development of nuclear power technology. This class of reactors would utilize natural uranium as a fuel or operate on a self-sustaining recycle basis after initial "spiking" with enriched fuel.

A fundamental role of the AEC, in pursuit of the above objectives, is to develop a broad technology that can be used by the nuclear industry and electric power producers in the achievement of economic power generation with nuclear reactor plants.

At this stage of the technology it is difficult to delineate the specific technical objectives or goals for each reactor type that, if reached, would lead to competitive power. It is possible, however, to state the broad technical objectives common to all reactor types which offer the potential of lower power generation cost. The manner in which these objectives will be approached is dependent upon the unique characteristics of each reactor type. The significant technical objectives that offer promise of meeting the program objectives are:

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1. To Increase the Thermal Efficiency of Nuclear Plants: Higher plant efficiency will reduce the reactor thermal power required and the amount of fissionable material burnup required for a given power output. Achievement of this objective offers the potential of reducing capital and fuel cycle cost. Higher plant efficiencies require higher coolant exit temperatures and higher operating temperatures for the fuel elements. There is an optimum temperature, beyond which additional increases will reduce fuel life and increase the fuel enrichment (due to the use of high temperature structural material in the clad and core) to the point where these factors may offset the economic gains due to the higher cycle efficiency. This optimum temperature will vary with reactor type and coolant.

2. To Obtain Lower Fuel Cycle Cost. A fundamental method of reducing fuel cycle cost is to increase the irradiation period for the fuel. This requires a large amount of excess reactivity in the reactor at beginning of core life and presents basic reactivity control problems for systems with relatively low average conversion ratios. Long irradiation periods also require more enrichment in the initial fuel load. The realization of this objective depends upon developing more effective control methods and fuel management programs. Longer fuel exposure also demands the development of fuel clad and material that will maintain mechanical and nuclear integrity over the anticipated fuel lifetime. Lower fuel inventories, lower cost fuel fabrication methods and cheaper chemical reprocessing will also lead to lower fuel cycle costs.

3. To Obtain High Specific Power in the Fuel and Higher Power Density. The successful achievement of higher specific power in the fuel and high power density in the core offer the potential of reduction in power cost of nuclear plants. The optimum value of specific power that is economically desirable is a compromise between such factors as further subdivision of the fuel which results in higher fabrication cost and the economic gain due to a reduced core volume. The optimum economic power density is a function of reactor type, fuel material, core power distribution, fabrication cost, heat transfer considerations, and other variables.

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4. To Obtain Better Nwutron Economy. The cost of power from nuclear reactors can be reduced by obtaining a better neutron economy in the core. This objective centers around achieving a higher conversion ration, i.e., an increase in the number of atoms of fissionable material consumed. The principal gain will be the extension in reactivity lifetime.

5. To Obtain Simplicity in Nuclear Plant Design. The capital cost of nuclear plants can be decreased in the following manner:

a. Use of conventional or less expensive materials in construction wherever practicable.

b. Simplification of plant design.

c. Improved and less expensive methods of containment.

d. Reduction in number and complexity of auxiliary system requirements.

e. Development of reliable components that do not require undue rigid specifications.

f. Improved understanding of reactor hazards.

The successful accomplishment of the above technical objectives will be instruments in reducing power generating cost from nuclear reactors.

In the field of military reactors the specific objectives are contained in requirements established by the Department of Defense.

Physical Research

The Commission's objectives in physical research fall into two groups: research in areas directly related to the development of practical utilization of nuclear energy and the more long-range objective of increasing human knowledge of the nature of matter and the physical universe. Work in the first category is supported because of its potential contribution to other primary missions of the AEC; work in the second category is deemed to be one of the primary missions.

Goals and objectives in direct support of the Commission's developmental responsibility include:

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1. providing the nuclear technologist and power engineer with information on nuclear constants and fundamental dynamic data for all nuclear reactions that influence reactor design and operation;

2. studying the elements and isotopes of interest to the atomic energy program, especially those from thorium and beyond in the periodic table, their chemical and physical properties, and methods of separating them;

3. determining chemical and metallurgical facts in fields related to feed materials and fuel reprocessing,

4. providing fundamental information, by studies in the fields of solid state sciences, high temperature chemistry and corrosion processes, on the properties and behavior of matter under normal conditions as well as under extreme conditions of temperature and radiation, so as to lay a firm foundation for increased engineering efficiency in nuclear power production.

The second major category of objectives in physical science research is that of encouraging scientific progress -- "to assist in the acquisition of an ever-expanding fund of theoretical knowledge." 1/

This work in basic physical sciences is supported with the recognition that the greatest applications of science have come from investigations undertaken with no thought of utility. Our aim is to maintain the United States in the forefront in nuclear science -- not just for purposes of national prestige, but because continuous rapid expansion in technology must be fed by constant impact of new, fundamental knowledge.

The fact that economic use, in one form or another and at one time or another, will ultimately come from basic research is not sufficient incentive for industry to finance such work on a large scale. Clearly

1/ Atomic Energy Act of 1954, Sec. 31(a)

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the pace of application has quickened -- years elapsed between the discovery of electrical induction by Faraday in 1841 and the completion of the first electric generating station in ; less than twenty years passed between the discovery of uranium fission by Hahn and Strassmunn in 1959 and the large scale production of power at Shippingport in 1957.

But the lag is still too long, and the risks too incalculable for industry to be able to support basic research on a large scale. It remains, then, for the government to contribute an important segment of the funds needed to support basic research. In administering this open-ended mission the AEC:

1. supports fundamental research aimed at identifying and understanding the subnuclear particles and at the acquisition of an improved understanding of the nature of the nucleus and its binding forces;

2. supports basic studies of nuclear phenomena, especially with respect to fundamental particles, their properties, their interactions, their transformations, and their role in nature.

3. supports studies of the basic properties of materials -- chemical, physical, metallurgical.

In the course of supporting basic physical science research, other important objectives sought after are to benefit in the applied fields from the current flow of ideas and the fresh point of view contributed by the basic researchers, and to attract imaginative and productive minds to the field of atomic energy problems.

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Controlled Thermonuclear Reactions

The controlled thermonuclear program has as its ultimate objective the development and demonstration of a system for the economical production of power by the fusion reaction. This goal is a long-range one, and probably can not be attained during the decade of this study. The current, intermediate objectives of the work are, in sequence,

1. reaching the ignition energy with a time of confinement sufficient for proper study of the thermonuclear plasma

2. proceeding toward the development and construction of a net power producer.

Biology and Medicine

In the field of Biology and Medicine the objectives toward which the program has been directed since its inception are:

1. To exploit the use of nuclear radiations and of radioactive materials in studies of basic biological processes, with emphasis upon those recognized as being especially urgent in the interest of human welfare. In the conduct of basic work in the life sciences, considerations identical to those outlined above for the physical sciences enter equally strongly.

2. To increase our knowledge of the biological effects of radiation, both from the point of view of empirical relationships between radiation dose and radiation effect and from the point of view of understanding the mechanisms by which radiation injury is produced.

3. To obtain information useful in the control of biological hazards of radiation, either through minimization of exposure or reduction of the biological effects.

4. To improve and develop techniques for the use of radiations in medical therapy.

5. To develop and encourage the use of radiations and of radioactive materials in agricultural research.

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Isotopes Development

The primary objectives of the isotopes Development Program are to:

1. Accelerate the uses of radioisotopes and radiation in the public interest.

2. Establish and maintain a position of world leadership in the United States in the peaceful applications of radioisotopes and radiation uses of atomic energy.

3. Encourage free enterprise pursuit of product and technical leadership in the peaceful applications of radioisotopes and radiation uses of atomic energy.

The following specific goals stem from these general objectives.

1. To conduct and foster pioneering research and development programs that contribute to technical leadership in peaceful applications of radioisotopes and radiation, including

a. Defining the physical and chemical properties of radioisotopes as pure elements and as various compounds.

b. Developing new uses for radioisotopes, radiation, and chemonuclear reactors based upon; i) radiation interaction with matter and physical or chemical changes brought about in matter, and ii) radiation interaction with any form of living matter and the changes that may occur.

c. Developing activation analytical techniques.

d. Establishing the technical feasibility of radiation processes utilizing radioisotopes and chemonuclear reactors for commercisl exploitation.

e. Developing the dosimetry necessary to satisfy the requirements of high level radiation processes.

f. Developing an engineering handbook for design of radiation sources and radiation processing faciliities.

g. Developing information and data on the specific distribution of absorbed energy in matter.

h. Developing basic knowledge of radiation effects necessary to apply these effects successfully in radiation processes.

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2. To insure the availability of radioisotopes and related byproduct services in support of United States needs as required for research and applications in agriculture, biology, industry and medicine, including

a. Developing the technology for production of radioisotopes in high flux reactors.

b. Developing process technology for the recovery, separation, concentration, enrichment and purification of reactor produced radioisotopes and the fission products from production and power reactor fuel reprocessing to supply high purity, large quantity, low cost radioisotopic sources.

3. To disseminate scientific results and technical information.

Training

Although not properly a part of research and development, the training objectives are discussed briefly here because, for the most part, they affect many of the institutions engaged in R&D work.

Training objectives include:

1. Providing opportunities for graduate and post-graduate study in fields within the scope of AEC programs, utilizing facilities not available on university campuses. Graduate students engaged in such study at AEC laboratories work under cooperative arrangements between the laboratory and the university from which they plan to receive their degree.

2. Aiding university faculties to offer up-to-date instruction in nuclear technology, by offering Summer institutes at which faculty members are brought current on developments in reactor and reactor related technology.

3. Meeting special needs on an ad hoc basis. Examples include the training of employees to operate new plants (such as Savannah River) and the International School of Nuclear Science and Engineering, which filled a need until the colleges and universities were prepared to handle such training.

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Probability of Change

Clearly, the more specifically that objectives are stated the more probable is it that they will be changed in the period under consideration. So far as can be foreseen at present, however, the objectives outlined above appear to be valid against which to evaluate the magnitude of the Research and Development program facing the Atomic Energy Commission for the next 10 years and the roles of the AEC laboratories in carrying out that program. There are three areas in which unforeseeable developments may have particularly significant effects on the course and volume of work projected. The first is in the field of weapons development where much of the program hinges upon international agreements as to testing and disarmament. The effect of these factors is clearly unpredictable.

The program for the development of peaceful applications of nuclear explosives is in so early a stage of exploration that detailed objectives are difficult to state at this time. The character and extent of future development work will be determined by the results of investigations and demonstration shots in the early years of the decade. The outcome of test ban discussions is an important imponderable in this area as well.

The future course of work in the controlled thermonuclear reactions, similarly, will depend upon results obtained from experimental programs now under way. Currently unexpected successes or failures may result in marked modification of the

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detailed objectives. For example, unexpected success in the present experimental program might lead to the establishment as an additional objective of the development of pilot plant technology during this period.

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Section Three

FORECAST OF PROGRAM TRENDS

It is apparent from the objectives stated in the preceding section that in relatively few cases is it possible to measure quantitatively the effort or cost that must be expended in carrying out these aims. In most cases, a judgment must be formed as to the desirable effort and expenditure, related wherever possible to present levels.

Each program of the AEC, and of each of its major laboratories, has been examined to determine what functions are expected to require more effort in the next ten years than at present, where decreases might be anticipated, where the present level appears to be appropriate, what tasks will be completed, what new fields might develop, what functions might more appropriately be discharged by other federal agencies, which ones no longer need federal support, etc. The results of this analysis follows:

Production Process Improvement

Over the last ten years costs for this work have been as follows:

Fiscal Year	R&D Costs (in millions)
1951	$ 17.8
1952	43.9
1953	40.0
1954	33.7
1955	32.9
1956	33.3
1957	34.0
1958	36.6
1959	37.8
1960 (Est.)	36.8

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The work is concerned with increasing efficiency in the production of enriched uranium, heavy water, and reactor products, and with improving separation methods for reactor products. Completion of development work on the New Production Reactor at Hanford (NPR) will result in a slight decline in the first years of the decade, after which no significant change is now foreseen.

Weapons Development

There remain many avenues of nuclear weapon research and development which promise designs which could improve materially our military capability. The scope and nature of the research and development effort in the field of nuclear weapons, however, necessarily can be affected radically by test cessation or limitations. Advancement in research and development will be retarded to some degree by any limitation placed upon testing. However, in view of the opportunities for evasion in any presently known detection scheme, it is believed unwise to make an early assumption that the Soviets will not progress. It, thus, becomes imperative that we, too, make whatever progress is technically possible while adhering strictly to whatever limitation applies. Our weapons research and development should be carried out on a high priority basis until disarmament deliberations have progressed to a point where over-all progress indicates that effective disarmament is an accepted objective to be respected by all nations.

In order to estimate the progress which can be made between 1960 and 1970, it is well to recall a past period of the same length, the period extending from 1948 to 1958. Beginning with Operation SANDSTONE in the spring of 1948, the United States has conducted 12 test series. These tests were designed to fulfill, and have fulfilled, the following purposes:

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1. The development of successive designs using less material and, therefore, increasing the defensive strength of the United States in terms of the amount of material available.

2. The development of designs of smaller configuration and lighter weight with the objective of providing weapons which can be more readily and effectively used.

3. The development of high-yield thermonuclear weapons. This development has been of vital importance to our striking force and to its capability to deter aggression.

4. The development of warheads for missiles designed to defend our populations and important installations against enemy attack.

5. The development of weapons of high yield but low production of fission products. The successful attainment of this objective will make it possible for us to have weapons with greatly reduced radiological hazard (fall-out).

In view of these past developments, it would be presumptuous, if not impossible, to predict the nature and extent of developments in the next ten-year period. The development of additional nuclear weapon requirements, however, has shown no signs of slackening.

The conditions for further progress are available. If, at the present time, the prospects for the next ten years look less impressive than those of the period since 1948, this probably is due to our limited imagination rather than to any objective reason. The best one can do in projecting the developments of the coming period is to consider carefully the developments on which we are working at the present time. During the coming period we expect:

1. Continued reduction in weight of weapons to enhance delivery capabilities and mobility to guard against loss or reduction of retaliatory power.

2. Continued development of small nuclear explosives which do not leave behind heavy radioactive contamination.

3. Development of weapons for very special tactical applications.

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It is in line with the usual development of instruments of war that the first years should see the development of destructive possibilities on an impressive scale. More discriminating uses are developed at a later stage and it is to these to which we expect to turn. The consequence of our failure to develop these uses while our competitors perfect them successfully might be of no smaller significance than the danger which would have arisen had we stopped at the level of the 1948 weapons while others proceeded to develop tactical weapons and the megaton weapons.

Because of the sensitiveness of research and development progress to the degree of test limitation imposed upon this program, it is necessary to consider what progress could be made under various degrees of limitation. Three assumptions, arbitrarily taken, are discussed below.

1. Early Ban on Atmospheric Tests (no other limitations). Such a ban would affect the speed with which the program described above could be pursued but would not prevent it. Tests underground could probably be carried out, in time, up to some fraction of a megaton. This limitation would, then, permit the exploration of full systems in the lower yield ranges, specialized applications, and the investigation of certain theories relating to high-yield devices. Laboratory effort could also be fruitful in such areas as the so-called clean weapon, greater weapon economy and safety, and radical departures from existing design theory. Outer space tests also might in time be used for the proof-testing of certain systems, although the costs involved might rule out their being undertaken. Although developments would be somewhat slower and much more expensive under this assumption, most lines of scientific development could be pursued.

2. Atmospheric, Underground, and Interplanetary Tests Not to Exceed a Few Tons. Under such conditions, the development of weapons would suffer most seriously. Prime development objectives probably could not be met but, possibly, small improvements on present models could be made. The development of tactical weapons and of small, clean explosions and the exploration and improvement of certain safety-handling aspects of weapons could proceed to some extent. A much greater effort would be needed in order to produce a lesser amount of technical progress and in a far narrower area than could have been obtained with greater testing.

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Under this assumed test limitation, some partial substitutes for testing will certainly be invented. Great emphasis will have to be given to improved calculational procedures and other methods for perfecting weapon systems for which it is possible to interpolate between physical situations explored in earlier test series.

3. Additional Atmospheric Tests up to 2 Megatons Per Year Plus Other Non-Atmospheric Tests. The long range value of being permitted to engage in limited atmospheric testing would probably lie in exploration of new phenomena such as has been disclosed by Teak, Orange, and Argus shots. Overall progress would cover the same areas as in the first assumption, but would be cheaper, easier, and faster -- particularly in the higher-yield areas where outer space techniques and vehicles must await further perfection.

In summary, it is doubtful if AEC support of weapons research and development can be reduced materially in the over-all in the next ten years. Depending upon the future of weapons testing, the emphasis may well change within the program as to techniques, avenues of approach, and areas for investigation. Under a long test ban, greater theoretical effort will have to be applied and greater inventiveness in the non-nuclear field will be necessary in order to keep abreast of United States nuclear weapons requirements.

Peaceful Nuclear Explosives

As is the case with weapons development, the level of activity in the Plowshare program and indeed, its whole future, is largely tied to the outcome of test limitation negotiations. Although the use of nuclear explosives for peaceful purposes has been considered seriously for only a few years and the total amount of effort so far has been relatively small, it is believed that the potentialities of this development may be great.

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Costs since its inception have been:

Fiscal Year	R&D Costs (in millions)
1958	$ .3
1959	2.4
1960 (Est.)	7.5

Nuclear explosions might affect water transportation by the digging of harbors and canals and greatly increase the usefulness of water resources by such means as the establishment of dams, increasing the permeability of underground formations, or by the diversion of water for irrigation purposes. Several attacks have been discussed on the problem of petroleum supplies and, while the difficulties seem great, the possible reward in the exploitation of tarsands, shales, and other presently unexploitable formations could have great consequences. The further possibilities of large scale underground chemical reactions, the creation of underground heat supplies, and other related proposals indicate the significant benefits that might be anticipated.

It is not to be expected that all of these possibilities can be realized and, even less, that they will come to fruition before 1970. On the other hand, very substantial successes can be achieved in the coming decade.

The role of the AEC in this program should consist primarily in the development of new tools and approaches. New tools include the invention of nuclear explosives which can be used for earth-moving purposes without disseminating dangerous radioactivity, the development of

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nuclear explosives of small yield at small cost, and the development of nuclear explosives designed for specialized applications. At present the estimated cost of a nuclear explosion competes favorably with other methods of blasting only for the larger yields. Another portion of the AEC effort might be the development of a nuclear explosive which would not reveal restricted data and would, thus facilitate usage.

The investigations of new uses of nuclear explosives are concerned with containment of nuclear explosions, distribution of the radioactivity produced, changes in the rock adjacent to the explosion, and, generally, effects of the intense heat and pressure produced by the explosion.

Unless barred or limited by international agreements, the amount of AEC research and development activity in the Plowshare program over the next decade is expected to increase somewhat as the problems become better defined and the program better understood.

Maritime Reactors

Costs for the AEC's research and development under this program have been:

Fiscal Year	R&D Costs (in millions)
1956	$ .1
1957	1.0
1958	1.7
1959	4.8
1960 (Est.)	7.4

As the program is presently conceived, the cost of the AEC's share in R&D activities is not expected to rise substantially from the current level.

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Military Reactors

The following table shows the trend of costs in these programs:

Fiscal Year	R&D Costs (in millions)
1951	$ 27.9
1952	37.1
1953	50.0
1954	39.9
1955	50.0
1956	91.4
1957	157.5
1958	173.3
1959	189.0
1960 Est.	206.9

Reactor development work for the Department of Defense and for the National Aeronautics and Space Administration is conducted in response to requests from these agencies for the development of nuclear power sources for specific applications. In the absence of firm requirements from these agencies for power sources over a period well beyond that covered by this report, our ability to predict related research and development programs over the coming ten years is severely limited. The forecasts that follow are based on the best judgment of the AEC staff.

Naval Reactors

AEC development costs in this field in the last ten years have been:

Fiscal Year	R&D Costs (in millions)
1951	$ 22.0
1952	26.2
1953	32.7
1954	25.2
1955	26.9
1956	41.0
1957	71.8
1958	90.2
1959	83.4
1960 (Est.)	86.9

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It has been less than five years since the NAUTILUS first went to sea. The successful completion of the NAUTILUS opened a whole new technical field for development and exploitation. This field will continue to reveal new possibilities for the foreseeable future in nuclear ship propulsion. Accordingly, naval reactor work is now expected to continue at approximately current levels over the next ten years.

Manned Aircraft

Costs incurred in AEC research and development over the last ten years have been:

Fiscal Year	R&D Costs (in millions)
1951	$ 5.5
1952	10.6
1953	17.3
1954	14.6
1955	22.6
1956	45.0
1957	69.0
1958	62.2
1959	66.8
1960 (est.)	66.4

Present levels of activity are expected to continue for the next three to four years with an increase of about 20 percent being required as the ground test program enters the heavy hardware phase. Assuming success in the ground test, continued increase in activity will be required in preparation for flight test. In addition, continuing investigation of advanced concepts for manned flight will be maintained throughout the period.

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Missile Propulsion

Costs since the inception of this work have been:

Fiscal Year	R&D Costs (in millions)
1956	$ 4.4
1957	12.5
1958	12.1
1959	22.1
1960 (Est.)	29.2

Both the rocket and ram-jet programs are currently geared to feasibility ground tests which are scheduled for accomplishment during the next 3 to 5 years. It would appear that the second five year phase will be required to demonstrate a prototype on the ground. Costs for the missile programs may be expected to increase substantially when full scale ground test prototypes enter the procurement stage.

Auxiliary Power Systems

The rapid expansion in this work is indicated by the following tabulation:

Fiscal Year	R&D Costs (in millions)
1956	$ .3
1957	1.5
1958	3.4
1959	7.7
1960 (Est.)	12.4

The AEC's role in the development of radioisotope powered units is expected to decrease since devices of this nature, being relatively small and cheap, should be of such interest to industry that product improvement will be privately supported. In the case of small

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reactors for auxiliary power; on the other hand, it appears that there will be a large number of requirements placed upon the AEC for development of units of increased power level for a variety of applications. Accordingly, it is anticipated that the AEC's role will increase during the next ten years both from the standpoint of variety of applications and cost of developmental work. Although a number of reactors will undoubtedly be brought to the point where industry will become interested in their further development, manufacture, and marketing, the variety of possibilities in this area will probably require the AEC to continue an expanding program in the development of power sources to meet new requirements.

Army Reactors

Research and development costs in this program have been:

Fiscal Year	R&D Costs (in millions)
1955	$ .6
1956	.9
1957	2.9
1958	5.4
1959	9.0
1960 (Est.)	12.0

The expansion that has been taking place in this program is expected to continue in response to additonal Department of Defense requirements.

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Civilian Power Reactors

The substantial and continuous growth of research and development costs for the civilian power reactor program, including general nuclear technology costs, is brought out in the following:

Fiscal Year	R&D Costs (in millions)
1951	$ 12.9
1952	22.6
1953	40.2
1954	44.3
1955	45.4
1956	60.0
1957	79.9
1958	115.3
1959	155.0
1960 (Est.)	168.0

The achievement of the ten-year objectives of the civilian power reactor program will require an intensive development effort on a broad front, necessitating a significant expansion over-all in the reactor development program.

Reactor systems now under development in the civilian program can be divided into three general groups:

1. Thermal Converter Reactors
2. Breeder Reactors
3. Natural Uranium and Plutonium Recycle Reactors

Within these groups, ten separate concepts are currently in varying stages of development. Detailed research and development programs which will be needed to prove out each of these concepts are now being formulated.[1/] These will encompass specific technical objectives and a chronological ten-year program for achieving them. Until these programs are formulated, a detailed forecast for each system cannot be presented. Generally, though,

1/ It is anticipated that, before preparation of the final draft of this study, these detailed plans will have been completed and can be reflected here.

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work in laboratories will be directed toward limiting the number of concepts under development. A concept will be eliminated from the AEC's development program either because it shows little or no potential for meeting the goals of the civilian program or by reaching the point at which its ability to compete with conventional power sources is established. In the first instance, further development work would be curtailed or eliminated. In the latter instance, industry would be expected to assume further development.

Even though ten year programs for each reactor system have not been completed, the following general assumptions with respect to the level of effort by AEC on each of the three reactor groups would appear valid:

Thermal Converter Reactors

This category includes pressurized water, boiling water, organic cooled and moderated, sodium graphite, and gas cooled enriched reactors. The program for each of these reactor systems will continue at approximately the present level for the next two or three years. After that time the worth of each system in meeting the goal of competitive nuclear power by 1968 should become clear. Those systems which do not give promise of meeting the goal will be eliminated from the program. AEC supported work on the remaining systems would be continued at a level consistent with attainment of the goal, but could be expected to be gradually reduced over the period through 1968 with increases in privately supported development work as economic goals are approached.

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Breeder Reactors

Both fast (U 238-Pu 239) and thermal (Th 232-U 233) breeders are being developed to provide maximum utilization of nuclear fuel reserves.

These are longer range programs and will require effort at least at current levels and possibly at higher levels for the next six or seven years. After that time work on the most promising systems will be increased.

Natural Uranium and Plutonium Recycle Reactors

Included in this category of reactors are the D_2O moderated reactors, the gas-cooled graphite moderated reactors and the Pu recycle program. These are also longer range programs, and much research and development is yet required to establish the potential of these systems for meeting longer-range objectives. Accordingly, it appears probable that developmental effort will be at least equal to present levels if not somewhat higher.

Nuclear Technology

This term includes the work, common to all reactor types, in the following fields:

1. Increasing thermal efficiency.
2. Reducing fuel cycle costs.
3. Obtaining higher specific power in the fuel and higher power density.
4. Improving neutron economy.
5. Simplifying plant design.
6. Improving utilization or disposal of radioactive by-product material.
7. Improving the provisions for health and safety of the general public in reactor design and operation.

Research and development in nuclear technology is so broad in scope, and there are so many problem areas which require resolution that no reduction in the overall level of effort is expected within the next ten

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years. On the contrary, it is to expected that a significantly expanded effort will be required.

As reactor systems reach a stage of economic competition with conventional systems, private industry may be expected to assume responsibility for at least portions of present development programs. Thus, work in the latter part of this period may be expected to shift to new areas with new objectives.

Controlled Thermonuclear Research

Costs for the controlled thermonuclear program are summarized below:

Fiscal Year	R&D Costs (in millions)
1951	$ .0
1952	.1
1953	.8
1954	1.8
1955	4.8
1956	6.8
1957	10.8
1958	18.4
1959	27.0
1960 (Est.)	36.6

As pointed out above, the work on fusion power has three successive goals:

1. To reach the ignition energy with a time of confinement sufficient for proper study of the thermonuclear plasma.
2. To proceed toward a net power producer.
3. To produce economical, thermonuclear power.

Efforts toward the first goal are supported by computations indicating that the devices under development can be used, singly or in combination, as the basis for designing pilot plants. The theoretical value for the ignition energy is 4,600 volts, so a figure somewhat

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superior to that value -- say 5,000 volts -- is desired. In the fiscal years 1958 and 1959, the level of ion energy attained went up by a factor of 10 from 100 to 1,000 volts, or in a few cases, somewhat more. This statement overlooks the approach pursued at Oak Ridge, in which ions are injected with a final energy of the order 300,000 volts, but where the density of the confined material is very low.

There is general confidence that the ignition energy can be attained probably by a variety of methods. While it is hoped that the ignition energy may be reached in a relatively short time, perhaps in one or two years, such a hope has been entertained earlier, only to run into new technical difficulties after some of the more apparent ones had been overcome. Therefore, it is safer to say that the time for attainment of Goal 1 may be five years.

When and if the ignition energy is reached the emphasis would shift to engineering and chemical studies, such as intensive work on wall materials, shielding, and magnetic coil design, preceded by a thorough-going feasibility study that will overlap the first five-year period.

No estimate can be made of the duration of an engineering phase leading to the first power producer. Experience in the fission reactor field suggests that this phase might last for 15 or 20 years. In any case, it is practically certain that it would extend beyond the ten year projection considered in this report.

It is anticipated that the scale of effort in the first five years of the decade, or until the ignition energy is achieved, will continue at approximately the current level, unless any of the existing programs should meet with apparently insuperable obstacles, in which case the level would be somewhat reduced. Once the ignition

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energy is reached, work toward goal two would involve a major step upward in financing, whose magnitude cannot be estimated at present.

High Energy Physics

Costs for research and development in this rapidly expanding field have grown in the last ten years as follows:

Fiscal Year	R&D Costs (in millions)
1951	$ 5.1
1952	5.7
1953	7.8
1954	7.3
1955	7.8
1956	11.3
1957	16.0
1958	17.8
1959	25.0
1960 (Est.)	33.8

Large accelerators under construction at Argonne, Brookhaven, Harvard, and Princeton will be completed during the early 1960's, and their operation, plus the cost of supporting experiments conducted by on-site and off-site researchers will lead inevitably to a continuation of this upward trend. In addition, existing machines will be improved for better utilization of their capabilities, and development of complex and expensive experimental apparatus will be required for observation and interpretation of experimental data. Studies of new machine designs will continue at a moderate level. All together, the effort is expected to be nearly trebled by 1965 over the 1960 estimate.

Other Physical Research

Because of the very nature of basic research, it is difficult to outline a ten-year program. The projections are based largely on current and past experience; no plans can take into account the effect of new discoveries and their exploitation.

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Costs of the physical research program, excluding controlled thermonuclear and high energy physics work, are summarized below for the last ten years:

Fiscal Year	R&D Costs (in millions)
1951	$ 24.4
1952	28.4
1953	29.6
1954	31.4
1955	31.1
1956	36.0
1957	37.8
1958	45.9
1959	51.9
1960 (Est.)	63.6

Physics.

Research in this area is related to low energy nuclear processes and the study of nuclear structure. One of the important fields is that of nuclear cross sections measurements, which is important to reactor technology and weapon design.

Low energy physics research centers around use of high flux research reactors and low and intermediate energy particle accelerators, such as cyclotrons, Van de Graaffs and linacs. High flux research reactors are being designed and are expected to be built at three of the laboratories, and a number of additional low and medium energy accelerators will come into operation at laboratory as well as university sites over the next few years.

A thorough examination of Commission-sponsored work in physical research at other Government agencies is under way to determine whether any research projects in areas less germane to AEC's mission, or of equal importance to the mission of other agencies, can be dropped

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by the AEC. The largest item under consideration is the AEC-ONR Joint Program in nuclear physics. It is being reviewed to determine its future - whether one or the other agency should take it over at its current or at a reduced level. Also, it is anticipated that physics research at the National Bureau of Standards, currently sponsored by the AEC, will be transferred from AEC support.

With the completion of additonal high energy physics research facilities in the 1960's, it is expected that AEC support of some of the older lower energy machines will cease. The 300 Mev electron synchrotron at the Lawrence Radiation Laboratory (Berkeley) will probably be the first to cease operation under AEC sponsorship.

Despite reductions in some of these aspects, the AEC-supported effort in low-energy physics as a whole is expected to grow steadily during the decade. The glamour that attaches to high energy physics at the moment, and the magnitude of the costs involved, must not be permitted to obscure the importance of and, as a matter of fact, the close relation to low energy work. Both are pursued for the same reason: to increase our understanding of the structure of matter and of the forces within the atom. It is just as important that we continue to utilize our scientific resources to the fullest in low-energy work as in the more spectacular high-energy field.

Chemistry.

Under the programs in chemistry research, it is expected that isotope separation studies will be reduced as methods are developed for the currently difficult-to-separate isotopes. It is also anticipated that uranium fuel processing by volatility and aqueous

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methods will be reduced or terminated. Certain phases of research on rare earth separations and purifications will eventually be transferred to private industry. Steps have been taken for the U. S. Geological Survey to support in fiscal year 1961 work previously supported by AEC on the geochemistry investigations of uranium. Also, it is expected that responsibility for financing work in electrochemistry and labeled organic compounds being conducted by the National Bureau of Standards will be transferred to that agency.

Increased effort is anticipated with respect to (a) the chemistry of the actinide elements (the elements following actinium in the periodic table), especially plutonium and the transplutonium elements, (b) separations of the heavy actinides from the lighter actinides and rare earth fission products, (c) the chemistry and thermochemistry of high temperature materials, (d) corrosion chemistry, and (e) analytic chemistry and hot laboratory techniques, to work with higher levels of radioactivity.

The synthesis of larger quantities of the very heaviest of the transplutonium elements in high flux reactors, and the synthesis of heretofore unknown isotopes beyond element 102 in heavy ion accelerators will open up new fields of chemistry and physics research. New problems in the separation, handling, and analysis of these highly active, generally spontaneously fissioning, and probably shortlived nuclides are anticipated. The spontaneous fissioning of such nuclides as californium 252 will enable these nuclides to serve as intense, portable sources of neutrons. Also, the operation of additional high

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energy particle accelerators in the 1960's will open new fields for investigation in nuclear chemistry.

Metallurgy and Materials.

Fundamental studies in the field of metallurgy and materials are recognized as requiring an immediate expansion of effort. Materials research is of the utmost importance across the board with respect to the AEC's development programs, as well as the nation's effort in outer space research. Some of the facilities needed for this expanded work are already under way or planned, including the metallurgical facility being built at Argonne and the high flux research reactors referred to above. In planning additional facilities, careful consideration will be given to arrangements, both location and operation, which will enable them to contribute to, rather than detract from, the country's ability to train the additional qualified personnel so critically short in this field at present.

In the early years of the decade, some of the effort that has previously been concentrated on the basic metallurgy of uranium will be reduced to permit expanded work on plutonium, and a similar reduction in plutonium work can be anticipated for some years later. Considering the history of uranium research, and the large voids in plutonium knowledge that remain to be filled, it is doubtful if a downward trend in plutonium work can be expected during the decade of the 60's, however. Dislocation studies and investigations of fundamental radiation effects in elemental semiconductors and in face centered metals also may be reduced, in some cases terminated, over the next ten years. No transfer of AEC activities in metallurgy and materials to private industry or universities for private support are envisioned.

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The current level of support under the radiation effects program appears about adequate, although some new low temperature facilities are needed. Increased effort in crystal structure research other than cubic lattices, heavy ion bombardment of surfaces, surface physics in general, high temperature and high pressure research, and high flux neutron radiation studies are anticipated. New areas of study are foreseen on metastable phases in solids, ultra high temperature research and extremely high flux radiation effects other than neutrons.

Biology and Medicine

During the last ten years, the trend of research and development costs in the field of biology and medicine has been:

Fiscal Year	R&D Costs (in millions)
1951	$ 20.0
1952	23.2
1953	24.4
1954	24.7
1955	26.6
1956	27.8
1957	30.7
1958	33.7
1959	40.2
1960 (Est.)	47.0

There follows a consideration of prospective changes in the individual components of the biomedical program.

Radiation Effects

Studies of the molecular and cellular effects of irradiation are basic to an understanding of radiation effects on man. In this field, much of the work on the alterations produced by radiation in

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isolated biochemicals is either being curtailed or reoriented. Instead, the emphasis is now being placed on (1) biophysical studies to determine the actual mechanisms which lead to the inactivation of critical cellular components, and (2) biochemical studies of the radiation effects on the large, organized structures found in cells (such as mitochondria, microsomes, chloroplasts, etc.).

The potential hazards resulting from detonation of atomic devices, from reactor operations, and from the beneficial applications of atomic energy create an increasing need for data concerning effects on organs and organ systems resulting from continuous and intermittent low-level intake of fission products and reactor effluent radioisotopes.

The program on whole body irradiation effects has been a continuing one that progressively changes emphasis to meet demands for new information pertinent to AEC operations and problems. The emphasis has in past years shifted more toward the evaluation of long-term or chronic radiation hazards, and an expansion of program is underway to study the effects of very low doses. The AEC has extensive facilities for this program and has always provided the principal scientific knowledge required for the setting of radiation health standards. Since irradiation effect decreases with decreasing dose, the existing extensive facilities must be further expanded to permit studies on the scale required and testing of theoretical concepts that have arisen.

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Genetics

The AEC genetics program is the only federally supported genetics research program specifically directed toward the analysis and interpretation of the genetic hazards of radiation exposure. While much of the program is at a stable level, that portion concerned with the direct estimation of mutation rates in animals needs to be expanded to exploit recent findings on the dose-rate dependence of mutation induction. Studies of radiation genetic effects and mechnisms must be continued since ultimately it may emerge that damage to the genetic apparatus of somatic cells is the basic radiation damage responsible for many somatic effects. New programs are anticipated on the biochemical genetics of man, a type of investigation suited to the AEC's installations where a variety of scientific disciplines are closely integrated. The research programs in population and biometrical genetics will also be expanded. The major studies in the genetics program continue to serve as sources of data for the whole scientific community.

Environmental Radiation

This program is one in which the AEC laboratories should play an expanding role in the future.

Reports of world-wide radioactive contamination from nuclear weapons tests have created a strong interest throughout the world in more detailed information on the distribution and variation of natural and artificial radioactivity in the environment, on the actual range of radiation doses received by man from these sources, and on the effects of these doses on the human population as a whole and in specific localities. As a result of the lack of clear evidence regarding the effects of low doses

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on the health of large populations, and also as a result of recent changes in recommended occupational exposure limits, the distribution and effects of environmental radiation at levels which were formerly thought to be insignificant have become mandatory subjects of careful study in connection with all atomic energy activities.

A minor part of the responsibility for food and milk monitoring now carried on by the Health and Safety Laboratory and the Los Alamos Scientific Laboratory may ultimately be transferred to the Department of Health, Education and Welfare.

Both for the AEC program and in cooperation with other agencies which will gradually be building up their own analytical facilities, it will be important that the unique talent and varied analytical facilities existing at the AEC laboratories be more fully exploited. During an interim period support should be expanded even for such routine activities as food monitoring in order to speed up the development of an adequate national capacity for investigating local anomalies and the effects of regional climatic and dietary characteristics. Thus, both the physical and biological transport processes affecting the distribution of contaminants dispersed on a world-wide scale by high-energy sources, such as bombs or rocket propulsion systems, will require more intensive study. New projects along these lines should be initiated in some of the AEC laboratories.

On the other hand, the part of the program dealing with the atmospheric transport of contaminants from low-altitude, low-energy sources such as land-based power plants and chemical processing facilities can continue at about the present level. However, during the next decade, attention must be shifted more toward

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the interactions of airborne contaminants with the earth's surface and its vegetative cover and to mechanisms by which different nuclides enter the food chain.

The terrestrial ecology, marine biology, and oceanography programs are still undergoing development, being of recent origin compared with other biological researches supported by the AEC. Continued development of the environmental aspects of these diciplines is anticipated to require 6-8 years before continuing, long-time programs can be in effective productivity.

Radiation Protection

Studies on the means of combating radiation injury have been at a fairly steady level for several years. No major expansions are anticipated. As present studies on protection against acute effects reach completion, an increased effort should be placed on combating long-term injury and ameliorating genetic damage. Any efforts in this direction will require cooperative activity with the AEC laboratory programs in genetics and radiation toxicity.

The development of prophylactic and therapeutic procedures to combat the deleterious effects of radiation has been recognized as a responsibility of the Division of Biology and Medicine for many years. Although the number of workers accidentally exposed to lethal doses of ionizing radiation has been small, the need for rational procedures of evaluation and therapy is, nevertheless, important.

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The blood-forming cells of the bone marrow are particularly susceptible to damage by penetrating radiation, and destruction of these cells is the underlying cause of death following both acute and chronic over-exposure. Commission-supported laboratories have investigated many therapeutic schemes during the past decade. Some of these continue to hold promise and will receive continued support as long as the Commission retains the responsibility of insuring the health and safety of its workers. A number of drugs and natural products have been evaluated in Commission laboratories, for example, antibiotics, flavonoids, properdin and various blood fractions. These investigations have been, in general, unproductive and the present level of effort is not high. No increase is planned unless new ideas are forthcoming.

A second method of treating acute radiation sickness may be the transplantation of new marrow in the patient to replace that destroyed by radiation.

The application of bone marrow treatment to larger animals and to man has been carried out principally by off-site contractors, because the technique seems to work best in the hands of surgeons. It is anticipated that the clinical evaluation of the bone marrow treatment will receive increased support in those Commission-supported laboratories affiliated with university medical schools.

With particular reference to burns and blast as a program category, it appears that this subject has more direct relationship to the traumatic medical effects on man associated with actual warfare. Accordingly, studies on burns and blast are being phased out or will be transferred to the appropriate group within the Department of Defense.

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For reasons of practical necessity, much past effort has been concerned with two very critical problems in radiobiology: (1) improving the physical measurements of the dose absorbed from both external radiation sources and internally deposited radioisotopes; and (2) quantitatively determining the biological changes (such as mutations, tumor formation, cataract formation, death, etc.) which appear hours, days, weeks, months, or even years later. However, the accumulating knowledge from these studies has demonstrated that even in cases where there are good measurements of the dose neither the extent of the resulting biological change nor the exact time of its onset can be precisely predicted. This is, of course, not surprising because individual biological changes are undoubtedly initiated by different biochemical events. Many of our detection and measurement procedures are rapidly nearing the point where they are entirely adequate for our health physics needs. Thus, we need to reorient much of our effort toward utilizing the physical measurements more efficiently in predicting the radiobiological damage which will result from a given exposure. To do this requires the incorporation of many physical and biological factors into complex mathematical equations. The development of such prediction equations will require the coordinated talents of men competent in at least six disciplines. Expansion of these efforts is planned for the immediate future.

Radiation detection instrumentation is keyed directly to both the biomedical research and the radiation safety control programs. Certain specific areas of instrumentation will be reduced or terminated by the natural completion of the effort. Of interest to note here

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is that the production engineering and fabrication of developed instrumentation has already been turned over to industry for support. The only exceptions to this are found where urgency requires the fabrication of a small number of instruments for the laboratories' immediate use.

The proportional level of support of radiation instrumentation as related to the biomedical research and radiation control programs is considered to be adequate. The opening of new areas of research, such as bio-energetics or low-level effects of radiation, will require intensified supporting instrumentation, but it is not anticipated that the proportionate cost should exceed the current ratio.

Moratoria on nuclear weapons testing, as a by-product, cut off field experiments on the civil effects of nuclear weapons. Increased laboratory studies and theoretical work must, therefore, be substituted.

Toxicological Research

Inherently, atomic energy operations are not only faced with hazards from external radiation sources but with numerous other potentially hazardous agents which may be deposited within the body and must be regarded as either chemically toxic, radio-toxic, or both. Many of these hazards are associated with the mining, milling and concentrating operation in the procurement of raw materials and ores and in the purification, fabrication and reprocessing operations found in the manufacture of nuclear weapons and fuels. Research must continue, to evaluate these hazards, to set tolerance limits, and to develop protective or corrective methods to control or neutralize these hazards.

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Cancer Research

This program is expected to remain at about its present level. In all probability, it will take another three to five years to accumulate sufficient information to determine accurately the effectiveness of the various radiotherapeutic devices currently being investigated in the program.

Plant Sciences

The AEC should maintain its present level of activity in fostering the application of radiation techniques for the improvement of economic crops. This, at present, is largely a cooperative program involving many State Agricultural Experiment Stations. The AEC installations perform pilot studies and provide radiation facilities and radiobiological back-up for the college and university scientists. The basic plant science program as related to radiation effects will be expanded, especially at the organism level, as recommended by an ad hoc committee of botanical scientists.

Isotopes Development

Isotopes development costs are summarized in the table below:

Fiscal Year	R&D Costs (in millions)
1951	$ [illegible].9
1952	[illegible].5
1953	[illegible].5
1954	[illegible].3
1955	[illegible].3
1956	[illegible].3
1957	[illegible].3
1958	[illegible].2
1959	[illegible].2.9
1960 (Est.)	[illegible].3.7

The trend of effort in isotopes development is expected to be substantially upward in the next few years. Much of the work that will be needed to develop the technology on which private exploitation of isotope potentialities must be based is in the incipient stages.

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Increases are required in the development of chemical processes techniques for the recovery of fission products from reactor fuels. Greater knowledge of the physical and chemical properties of solid radioactive compounds is mandatory to insure safe and efficient utilization of radioisotopic sources. More reliable and rugged equipment must be developed for use in environmental testing operations and process control.

Development of the use of high level radiation as a process tool and as a useful form of energy similar to heat and pressure has only recently been ititiated at a very modest level of effort. However, the potential applications in such fields as pasteurization, medical supply sterilization, and industrial processing are so broad that early success will lead to a substantial expansion of this work. The new programs to be entered into and requiring increased support are:

1. Fundamental mechanisms of radiation interaction with matter. This field is concerned with the characterization of specific primary products of the interaction of radiation with matter which lead to chemical changes, and development of a theory of radiation interaction with matter which will permit the prediction of specific radiation processes meriting research and development efforts.

2. Techniques for controlling radiation reactions. This includes efforts directed towards continually improving knowledge about the effects of conveniently contolled parameters (i.e., temperature, pressure and phase) on known radiation reactions.

3. Radiation as an engineering operation. Information concerning the specific distribution of absorbed energy in matter and radiation physics will be developed. This will permit development of a useful radiation engineering handbook to allow engineers to design, with minimum research and development work, demonstration and pilot plant facilities for radiation processes that have been found to be technically sound and appear economically feasible.

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4. High level dosimetry. Development of dosimetric systems that will satisfy the requirements of high level radiation processes is a major step necessary before high level radiation can become a processing tool for industry. No truly acceptable technique for high level radiation process control exists today.

5. Nuclear reactors as sources of ionizing radiation. Such reactors, so-called Chemonuclear Reactors, appear to be a promising area for long range research and development.

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Section Four

ROLE OF THE AEC LABORATORIES

The accomplishment of so large and varied a program as that just described requires the utilization of all available talents and facilities; it frequently encounters the need for training new talent and constructing additional facilities. Consequently, the work is carried on at universities and in industrial laboratories, by privately endowed research institutes and hospitals and in the laboratories of other government agencies, as well as in institutions created specifically for the purpose.

Although the aim of this study is to re-examine the role to be played by the latter institutions, both as a group and individually, it will be necessary to consider as well the fields of work that are appropriate for the other types of research and development organizations as well. Although there are no hard and fast distinctions that can be drawn in all cases between the areas of work appropriate to each class, it should be clear from this analysis that there are logical and adequate guidelines which are applied in determining where work should be accomplished and which should serve for the future as currently foreseen.

At the outset, the meaning of the term "AEC Laboratory" as used here should be defined, and the institutions to be discussed individually should be determined. There is no clear distinction between an AEC laboratory and a non-AEC installation at which research and

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development work for the Commission is performed. Taking either the government investment or the annual costs as a criterion, there is a broad range, with steady gradations and no sharp breaks, from such large and wholly-AEC institutions as the Oak Ridge National Laboratory on the one hand (with completed and authorized plant totaling $180 million and annual operating costs of $52 million) down to the many small groups performing AEC contract research at university campuses, using, to cite one example, a $180,000 Van de Graaff generator and incurring annual costs of $85,000. Examples of intermediate points are: the AEC's $1.7 million investment in a linear accelerator and associated equipment at the University of Minnesota, housed in a University-owned building; the Ames Laboratory at Iowa State University, with completed or authorized AEC facilities totaling $14 million but also utilizing University-owned buildings and facilities including a 70-MEV synchrotron; and the Lawrence Radiation Laboratory at the University of California in Berkeley, where the great bulk of the facilities are AEC-owned, immediately adjacent to the campus ($48 million completed or authorized) but some of the work is done in campus facilities.

It has been necessary, therefore, to draw an arbitrary line in determining which institutions would be dealt with individually in the report. The following criteria have been established to determine the institutions to be treated specifically:

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1. The work is conducted in government-owned facilities the value of which (completed or authorized) exceeds $3,000,000. All of the 21 AEC laboratories considered are housed in facilities that have been provided by the AEC with the exception of the two aircraft nuclear propulsion activities (CANEL and Lockland) which are housed in Air Force facilities.

2. The activity is recognized as a research and development institution as distinguished from an investment in a special piece of apparatus or an experimental facility forming a part of a larger, non-AEC complex. This criterion excludes the small submarine reactor prototype and the sodium reactor experiment, both of which meet the first criterion.

3. It must be engaged in research and development work as its major mission, rather than training, plant support, quality control, or special production assignments.

The institutions meeting these criteria, and treated individually in this study are:

Ames Laboratory
Ames, Iowa

Argonne Cancer Research Hospital (ACRH)
Chicago, Illinois

Argonne National Laboratory (ANL)
Lemont, Illinois

Bettis Laboratory
Pittsburgh, Pennsylvania

Brookhaven National Laboratory (BNL)
Long Island, New York

Cambridge Electron Accelerator (CEA)
Cambridge, Massachusetts

Connecticut Aircraft Nuclear Engine Laboratory (CANEL)
Middletown, Connecticut

Hanford Laboratory
Richland, Washington

Knolls Atomic Power Laboratory (KAPL)
Schenectady, New York

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Lawrence Radiation Laboratory (LRL - Berkeley)
Berkeley, California

Lawrence Radiation Laboratory (LRL - Livermore)
Livermore, California

Lockland Aircraft Nuclear Propulsion Laboratory
Cincinnati, Ohio

Los Alamos Scientific Laboratory (LASL)
Los Alamos, New Mexico

National Reactor Testing Station (NRTS)
Idaho Falls, Idaho

Oak Ridge Institute of Nuclear Science (ORINS)
Oak Ridge, Tennessee

Oak Ridge National Laboratory (ORNL)
Oak Ridge, Tennessee

Princeton-Pennsylvania Proton Accelerator (PPA)
Princeton, New Jersey

Princeton Stellarator
Princeton, New Jersey

Sandia Laboratory
Albuquerque, New Mexico

Savannah River Laboratory
Augusta, Georgia

University of Rochester Atomic Energy Project
Rochester, New York

Among the organizations excluded from detailed consideration are the Health and Safety Laboratory in New York City; the Puerto-Rico Nuclear Center; the Biomedical project at the University of California, Los Angeles; the Atomic Bomb Casualty Commission at Hiroshima; Mounds Laboratory near Dayton; the accelerators at such universities as Yale, Minnesota, Carnegie Institute of Technology, and Columbia; and many others. They have been excluded, on the

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basis of the criteria listed above, to keep the study in manageable proportions within the time allotted for it, and with the thought in mind that the 21 institutions which are covered are representative of the programs and problems that will be encountered by the others.

Despite the fact that the 21 institutions to be studied all fall within the criteria outlined, they still represent a wide range from the standpoint of type of work performed, size, relation to other institutions, etc. In considering their roles, therefore, it will be useful to recognize several categories within the AEC laboratories.

Multi-Program Laboratories

This group consists of Argonne, Brookhaven, Oak Ridge, Ames, Lawrence Radiation Laboratory (Berkeley and Livermore), and Los Alamos. Because of the close relationships between the Oak Ridge National Laboratory and the Oak Ridge Institute of Nuclear Studies, ORINS is considered along with ORNL in this group of multi-program laboratories. Each of these institutions is engaged in a wide range of research and development activities, both as to the fields of science and technology involved and the type of work conducted -- basic research, applied research and general development, etc. All are operated by university contractors except Oak Ridge, where ORINS provides a mechanism for interaction with the university community.

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This group could be further subdivided into three so-called "National" laboratories, Argonne, Oak Ridge, and Brookhaven; the weapons laboratories, since weapons development is the largest responsibility of both Los Alamos and IRL - Livermore; and the on-campus laboratories, Ames and IRL - Berkeley.

Project Engineering Laboratories

In this category are included Bettis, CANEL, KAPL, Lockland, and Sandia. In contrast to the first category, each of these institutions has one or a limited number of specific development objectives. All are operated by industrial contractors, all are conducting work exclusively (or primarily in the case of Bettis) directed to meeting military requirements, and none is engaged in basic research.

Production Plant Laboratories

This category consists of two laboratories, those at Hanford and Savannah River. Their common characteristic is their primary orientation to the development problems of the production plants which they were built to serve.

University Laboratories

Included here are the Argonne Cancer Research Hospital, the Cambridge Electron Accelerator, the Princeton-Pennsylvania Proton Accelerator, the Stellarator, and the University of Rochester Biomedical Project. They are distinguished from the on-campus, multi-program laboratories by the fact that the program of each is limited to a specific field of work. All are research-oriented, and all provide research opportunities for graduate students.

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National Reactor Testing Station

NRTS does not fit neatly into any of the categories described, since it consists of a number of operations, some of which are interrelated, and others of which have little more than geography in common. Much of the facilities and work consists of test installations connected with project development carried on elsewhere, although substantial programs in project development and process improvement are based at NRTS.

The following table summarizes the categories of laboratories and the types of research and development work in which they are engaged. The column "Biological and Medical Research" includes both basic and applied research.

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AEC Laboratories by Type and by Character of Mission

	Mission				
	Physical Sciences and Engineering				
	Basic Research	Applied Research and General Development	Project Development	Process & Product Improvement	Biological & Medical Research
Multi-program Laboratories					
Argonne National Laboratory	x	x	x		x
Brookhaven National Laboratory	x	x			x
Oak Ridge National Laboratory	x	x	x		x
and Oak Ridge Institute of Nuclear Studies					x
Ames Laboratory	x	x			
Lawrence Radiation Laboratory (Berkeley)	x				x
Lawrence Radiation Laboratory (Livermore)	x	x	x		
Los Alamos Scientific Laboratory	x	x	x		x
Project Engineering Laboratories					
Bettis Laboratory		x	x	x	
Connecticut Aircraft Nuclear Engine Laboratory		x			
Knolls Atomic Power Laboratory		x	x	x	
Lockland Aircraft Nuclear Propulsion Laboratory		x	x		
Sandia Laboratory			x	x	
Production Plant Laboratories					
Hanford Laboratory		x	x	x	x
Savannah River Laboratory		x	x	x	
University Laboratories					
Argonne Cancer Research Hospital					x
Cambridge Electron Accelerator	x				
Princeton-Pennsylvania Proton Accelerator	x				
Princeton Stellarator	x	x			
University of Rochester Biomedical Project					x
National Reactor Testing Station		x	x	x	

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Respective Roles in Development and Applied Research

In determining the assignment of work in this category as between the laboratories and private industrial establishments the AEC is concerned with the following principal considerations: the qualifications of prospective performers of the work, the effect of additional large projects on the size and stability of its laboratories and the impact on the statutory policy of strengthening free competition in private enterprise.

The functions that private industrial establishments are expected to perform are those most akin to normal industrial activities. The profit motive is industry's primary goal. This fact dictates that industry's best technical and managerial skills must be placed on work which promises a normal commercial return in a reasonably short period of time. A further factor influencing the determination to seek a private industrial establishment as a development contractor is the extent of special facilities needed for the instant task. Where these are substantial, industry cannot be expected to supply them.

AEC, therefore, views as one class of work appropriate for assignment to private industrial establishments that which is well advanced toward commercial attractiveness. In the reactor development field, such projects would be those involving a cycle for which feasibility has been established, and in which no major technical breakthroughs are required to make the system economically competitive.

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Substantial portions of the fuel cycle development work similarily fall into this class. The prospect for an eventual volume of commercial fuel processing business provides an incentive to a number of companies to devote talent to development work for the AEC.

The Army reactor program is a good example of a class of development work being successfully conducted in large part in private facilities. The prospects for repeat business and the limited amount of heavy experimental work (which also means limited special facility requirements aside from prototypes constructed at AEC sites) have combined to make this program appropriate for handling in private establishments.

In seeking the best qualified contractor for development work, the AEC looks to industry, rather than to its laboratories, for non-nuclear components to meet special applications or unusual service conditions. Often, these are substantial and challenging assignments. Wherever industry is prepared with the facilities and skills to carry them out, the diversion of the government laboratories from their main tasks is avoided.

The AEC laboratories, on the other hand, have the function of performing work in areas too far from commercial application to provide a normal incentive to industrial management. Projects which are long range, or where the probabilities of a successful outcome are risky belong in this class. Examples, of the project development type are the thermal and fast breeder reactor systems. Examples drawn from applied research and general development are:

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1. More complete measurement of the nuclear cross sections needed for reactor design.

2. Studies needed to gain a better understanding of the mechanism of reactor fuel performance.

3. Heat transfer studies needed to establish parameters for the reactor engineer.

4. Critical (zero-power reactor) experiments.

5. Studies of shielding design and shielding materials.

6. In the isotopes field, development of the technology necessary for isotope production, separation, and safe handling, leaving to private industry the development work involved in the application of isotopes to specific uses.

A second function of the AEC laboratories is the investigation of new reactor concepts. This type of work is appropriate to the laboratories not only because of its long-range nature, but because it calls for the combination of pioneering ingenuity and broad, inter-disciplinary teamwork which is found in the multi-program laboratories. Clearly, private industrial establishments should not be excluded from AEC support in investigating ideas which they generate and which fit both their capabilities and the AEC's objectives, but for the most part the laboratories will continue to be looked to as the principal source of new concept work. A factor militating in this direction is the desirability of making government-sponsored work initially available to industry on an equal basis. This aim can best be accomplished by performing the pioneering work -- establishing feasibility -- in the AEC laboratories

A primary reason for the establishment of the major laboratories as permanent institutions at the end of World War II was to assure the availability of organized research and development installations capable of turning to a variety of problems if and when the need arose. This requirement is as real today as it was in 1947. There have been many occasions on which the AEC has turned to the laboratories with such assignments. A few of them are:

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1. Conceptual design and early development work on the submarine thermal reactor at Argonne while facilities and equipment were being assembled and personnel were being acquired and trained by Westinghouse.

2. The undertaking of controlled thermonuclear research at Los Alamos, LRL - Livermore, and ORNL, in addition to the project established for this specific purpose at Princeton.

3. Long-range detection of nuclear events.

In these types of assignments, the breadth of talents available at these installations has been particularly important in permitting work to be undertaken without delay and in contributing to the approaches available toward solutions of the problem. The talents of outstanding basic researchers have been brought to bear on important applied problems when the need arose.

However, their importance as available reservoirs of knowledge and talent does not imply that a principal reason for their existence is a standby one. Their availability as reservoirs is simply a by-product of the specific missions which each of the laboratories has as an individual institution. Unless they continue to offer challenging opportunities in their usual work, they will lose the people needed to enable them to undertake the unusual when the occasion demands.

In the field of weapons development, prime responsibility is assigned to AEC laboratories. Special facility needs, stringent security requirements, the lack of commercial potentialities, and the need -- arising from the urgency of the work and the relationships with the Department of Defense -- for keeping the program in a limited number of large, integrated organizations combine to make it impractical to look to private industrial establishments for weapons development. However a substantial portion of the development work in non-nuclear components of weapons is subcontracted to industry.

The process improvement function, as related to AEC manufacturing activities at the gaseous diffusion plants, production reactors and chemical

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processing facilities must, of necessity be carried on in close proximity and continuous contact with the production plants themselves. These interrelationships dictate that such process and product improvement continue to be conducted in AEC laboratories.

The laboratories are coming to play an increasingly important role as unbiased technical evaluator advisors both to the AEC and to industry in the reactor field. Finally, they will continue to furnish opportunities for training on the job and in formal courses in fields where such training is not otherwise available.

The laboratories of other federal agencies are utilized in the development and applied research wherever they have facilities or capabilities that can be effectively brought to bear. The Bureau of Mines, Public Health Service, Geological Survey, Coast and Geodetic Survey, Weather Bureau, Fish and Wildlife Service, National Academy of Sciences, and National Bureau of Standards are all assisting the AEC in research and development matters. This utilization of the talents and facilities of other agencies is expected to continue and grow, especially in the area of Sanitary and Environmental Engineering.

The non-profit research institutes are the remaining class of organizations with a role in applied research and development. For both their private and governmental clients, these institutions ordinarily work on the solution of specific problems, or at the development of information and understanding about a particular material, phenomenan, etc., as distinguished from complete systems development. The AEC has turned to the research institutes since its creation, for help on a wide variety of tasks including

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materials, components, metal refining, and fabricating techniques. It is anticipated that these organizations will continue to carry on similar functions.

Roles in Basic Physical Science Research

There is no unanimity, even among those in academic life, as to the extent to which government research programs should be conducted on university campuses. The extreme positions may be stated as follows:

On the one hand it is argued that the function of the universities is to instruct the young, and that extensive research programs distract from that main objective. At the opposite pole are those who fear that the growth of strong basic research programs at centers away from university campuses will lure to these non-teaching establishments able people who should remain on the campus to devote a portion of their time to training new generations of scientists.

The AEC's view of the role of the universities as performers of research, and of the related role of its laboratories, has attempted to avoid both extreme positions. With rather insignificant exceptions in the physical sciences, AEC-supported research at the universities has been quite basic in nature, there has been no attempt to persuade universities to take on major applied research or development programs. A single major exception to this statement might be the controlled thermonuclear research project at Princeton University, but this almost becomes a matter of definition, since so much of the effort is directed at a fundamental understanding of the phenomena involved (and therefore, one might argue, within the traditional scope of university research).

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The training function of the universities is clearly recognized in determining the types of work and the specific projects to be carried on at university campuses. From the outset of the off-site research program a guiding principle in its administration has been that "the project should be a proper training ground for graduate students."[1/]

As the apparatus necessary for basic research in some fields has become larger and more complex, high energy physics being the prime example, the question of whether the installations required would, in fact, threaten to overwhelm the universities as teaching institutions has had to be faced. In the three or four instances in which really large experimental devices have been undertaken at or near the campus, the conclusion was reached that, despite the facility cost, the construction and operation of the devices would not disrupt the academic institution.

On the other hand, the acquisition and utilization of large facilities, expensive both to build and to operate has always been recognized as a principle function of the multi-program laboratories. Even if the resources were available to provide such devices for numbers of universities, there are only a handful of academic communities which possess the numbers of qualified scientists required to make full utilization of them. The AEC laboratory, then, is a mechanism for making expensive apparatus available to qualified researchers nationally. The laboratory, as well as the university scientist, gains from these participating programs, since it is assured of access to fresh ideas that help to provide the stimulus needed to maintain an alert and imaginative staff.

A second function to be performed by the AEC laboratories in basic research is the conduct of studies in fields fundamental to the agency's immediate development goals. In terms of current problems, such work

1/ June 1, 1947, Report to the Commission from the General Advisory Committee.

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would include studies in the mechanism of corrosion, high temperature chemistry, and the solid state sciences, in all of which additional data is needed as a basis for development of fuels and components to extend the limits on reactor operating conditions.

Multi-program laboratories are specially qualified to undertake research which requires an inter-disciplinary approach. The ability to undertake work requiring experts in several fields is not confined to the laboratories, but their administrative organization, their equipment and facility resources, and their ability to call upon development engineers to help on basic problems combine to provide a set of conditions contributing to rapid progress in important fields. The creation and investigation of the elements beyond plutonium is a clear example.

A limited amount of basic research is most appropriately done in the AEC laboratories because of the need for special precautions arising from health hazards or security restrictions.

Lastly, the multi-program laboratories must continue to conduct a significant amount of research, in areas relevant to the AEC's objectives, in order to acquire and retain first rate scientists. The laboratories can be expected to fulfill their roles of pioneering leadership and of meeting urgent needs in an outstanding fashion only so long as they have on their staffs scientists with alert, vigorous, and imaginative minds. The laboratories must continue to be attractive to a reasonable number of able men with these qualities. Experience, in industry as well as in government, has shown that such a nucleus of talent can be retained only if it is provided with opportunities to seek new knowledge through basic research.

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Provision of such opportunities in the laboratories means that they will continue to conduct research and to employ scientists which might otherwise be supported in university research. So long as the magnitude of such laboratory-conducted research is kept within bounds that do not threaten to deplete the universities of teaching and research strength, it will strengthen rather than undermine our scientific resources as a whole.

Some indication of the extent to which the growth of AEC-supported physical research programs (excluding controlled thermonuclear nuclear research and high energy physics) has affected the relationship between university-centered research and the off-campus laboratories can be gained by looking at comparative cost figures for the last decade. During this period the AEC supported work at the campuses has increased 3.8 times, while the work at the off-campus laboratories has doubled. If Ames and Berkeley are excluded from the university-centered research, the increase is 5.7 times.

Looked at in another way, 27 percent of the physical research dollars (again excluding controlled thermonuclear and high energy physics) were spent on university campuses in 1951; this year about 40 percent of a much larger total will go to campus research.

It is apparent, then that support of university research in basic physics has grown much more rapidly than have the programs at the off-campus laboratories. This trend is expected to continue.

Industry, the non-profit research foundations, and the laboratories of other federal agencies play much more limited roles in the performance of AEC-supported basic physical research. In each case, the work is

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supported on an individual project basis because of the availability of special competence, or, in the case of the government laboratories, because the work is closely related to main missions of the performing agency. Thus, the U.S. Geological Survey has carried on AEC-financed work on the geochemistry of uranium, starting in 1952 when expanding needs for raw materials in the AEC's current program required this fundamental knowledge. The success of ore explorations having satisfied the AEC's current requirements, further investigation in this area is more pertinent to the ultimate national need for uranium as a replacement for fossil fuel; therefore, future funding of the program will be the responsibility of the Geological Survey.

Roles in Biomedical Research

The respective roles of the classes of institutions performing biomedical research, both basic and applied, do not differ markedly from their roles in basic physical research. A fact that might be noted in passing is that much of the research work of university medical schools, regardless of the source of funds, is applied rather than basic; this situation differs from the physcial sciences, in which universities do only limited amounts of applied work.

The factors making it necessary for the AEC to conduct a substantial portion of its biomedical program in the laboratories are similar to those already stated in discussing basic physical research. The need for expensive facilities holds true in this area -- in addition to irradiation devices such as reactors, accelerators and high-level cobalt sources, large colonies of experimental animals must be kept under controlled conditions for long range investigations.

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As research complexity increases, the need for pos-graduate training grows; the unusual facilities of the AEC laboratories, both on university campuses and off, offer unusual opportunities for post-graduate research training. Such training is an important function of the biomedical work at the University of Rochester, Argonne Cancer Research Hospital, Lawrence Radiation Laboratory - Berkeley, and the University of California (Los Angeles). It should become increasingly important at the off-campus laboratories as well.

Much of the work on understanding and controlling health hazards is conducted in the laboratories. In this environment it is closest to the problems and consequently receives continued direction and attention. The research programs falling under this head account for about three-fourths of the total bio-medical program. Although in theory some of this work could be done under other sponsorship or by other institutions, nowhere else could the sustained interest in its performance and results be found.

The staffs and facilities of other government laboratories conduct studies for the AEC in their fields of specialization, as, for example, the Department of Agriculture's Agricultural Research Center at Beltsville, Maryland. During the course of the period under review consideration will be given to the desirability of turning over funding responsibility to the agency conducting the research.

A limited amount of biomedical research is performed for AEC by industrial organizations and non-profit research institutes, in specialized fields. Industry, for example does development in instrumentation fields.

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The share of total research expenditures at the major off-campus laboratories has tended to be more stable in the biomedical program than in physical research. In 1951 it accounted for 42.5% of the total, declining only slightly, to 38% in the current year.

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PART II

THE INDIVIDUAL LABORATORIES IN THE NEXT DECADE

Section Five

MULTI-PROGRAM LABORATORIES

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Note on Tables and Charts:

As used throughout the tables and charts in Part II, the term "All other" applies to plant facilities in the total exclusive of reactors and accelerators. The term "Other physical research" is the total exclusive of high energy physics and controlled thermonuclear research.

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ARGONNE NATIONAL LABORATORY

Argonne National Laboratory is the direct successor of the wartime Metallurgical Laboratory of the Manhattan Engineer District. The primary objectives of that Laboratory were to demonstrate the feasibility of a self-sustaining nuclear chain reaction, to develop the relevant technology to the point where nuclear reactors for the production of plutonium could be constructed, and to develop a process for the separation and isolation of plutonium. A very important ancillary responsibility was to develop information concerning the hazards involved in the use of radiation and radioactivity. To attain these major objectives within the time schedule, it was necessary to carry out, essentially simultaneously, engineering design and development, and applied research in the fields of physics, chemistry, metallurgy, biology, and medicine.

On July 1, 1946 Argonne was established as a permanent laboratory and The University of Chicago was selected as the operating contractor. As originally conceived the laboratory's primary responsibility was that of basic research in the many areas of science pertinent to the long range development of atomic energy. However, on January 1, 1948, the AEC assigned the laboratory major responsibilities in the field of reactor development in addition to the research activities in which it was already engaged. This two-fold responsibility of basic research on the one hand and applied research and development on the other has continued to the present.

Since the early fifties the work of the laboratory has been almost equally divided (in staff man years) between basic research and the applied and developmental work.

The major effort in development work since 1948 has been on water moderated reactors [basic design for the prototype of the Nautilus reactor (STR), the

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physics design of the Savannah River reactors, the CP-3 and CP-5 research reactors at Argonne, the series of Boiling Reactor Experiments in Idaho called BORAX, the Experimental Boiling Water Reactor (EBWR), and the Argonne Low Power Reactor (ALPR)], on fast reactors for power and breeding (Experimental Breeder Reactors - EBR I and II), on the development of chemical processes for irradiated fuel, and on the development and experimental fabrication of fuel elements.

The laboratory's physical research program was initially in the following broad areas of research: (1) low energy neutron physics; (2) nuclear properties of the many new isotopes discovered during the Metallurgical Project or made available as a result of the Project; (3) chemical and physical properties of elements either newly discovered or available in significant quantity and purity for the first time; (4) effects of radiation on solids, liquids and gases; and (5) application of the special techniques developed during the Metallurgical Project to physical research in other areas. From this has grown the present extensive program of research in physical science which involves a wide variety of investigations in the fields of physics, chemistry and metallurgy.

The present physics research is primarily in the field of low energy nuclear investigations; in preparation for utilizing the Zero Gradient Synchroton (ZGS), a multi-billion electron volt accelerator now under construction, increased emphasis is being placed on problems in high energy physics. The current basic chemistry program gives major emphasis to the inorganic and physical chemistry of the heavy elements, to nuclear chemistry and radiation chemistry. The program in physical metallurgy emphasizes the study of the properties of uranium, plutonium, and thorium with growing emphasis on plutonium. Although this work is basic in nature, much of it

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is concerned with problems that must be solved before plutonium can become a practical fuel for power reactors. High temperature research and solid state research are carried out at present on a relatively small scale.

Work in the life sciences is directed toward achieving an understanding of the action of radiation on living systems, with emphasis on the effects of neutron radiation. Studies of the effects of external and internal radiations are carried out on animals and, where appropriate, on humans who have been exposed to particular environmental conditions or who bear significant body burdens of radioactivity.

The laboratory's International School of Nuclear Science and Engineering, established as a part of the Atoms for Peaceprogram, has given training to some 400 scientists and engineers from other countries who are now taking prominent parts in the development of atomic energy in their own countries all over the world.

Argonne occupies a tract of 3700 acres about 25 miles from Chicago, as well as two sites at the National Reactor Testing Station in Idaho. Among the many special facilities of the laboratory are the CP-5 research reactor, the Experimental Boiling Water Reactor (EBWR), the Argonaut training reactor, exponential and critical assemblies, hot laboratories and many other facilities for handling radioactive materials, a new facility for developing fabrication techniques for plutonium, many specialized engineering test facilities, a 60-inch cyclotron, Van de Graff generators, mass and optical spectrographs, several gamma irradiation facilities, counting equipment for all levels of radioactivity and facilities for animal experiments. The construction of the ZGS accelerator began in June 1959. At the NRTS the laboratory operates the Experimental Breeder Reactor I and a fast critical experiment facility (ZPR III) and is constructing a prototype size fast breeder (EBR II). The tables and charts on the following pages give a summary of dollar and manpower levels of the laboratory's operations for the last ten years, and a detailed tabulation of the current budget.

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ARGONNE NATIONAL LABORATORY
Lemont, Illinois

Ten Year Trend - Costs, Staff and Facilities
(dollar amounts are in millions)

Fiscal Year	1960 b/	1959	1958	1957	1956	1955	1954	1953	1952	1951
Research and Development Costs: a/										
Production Program	$ -	$ -	$ -	$ -	$ -	$ -	$ .1	$ 1.9	$ 3.9	$ 1.8
Weapons Program	-	-	-	-	-	-	.2	.2	.4	.4
Reactor Development Program:										
Civilian Power reactors	16.1	11.8	10.6	9.6	8.4	7.5	5.1	3.1	1.2	.8
Army Power	-	.4	.4	.3	.1	.1	-	-	-	-
Naval propulsion	-	-	-	-	.2	.2	.5	2.1	4.7	6.6
General reactor research and development	7.9	7.4	6.9	4.5	3.3	2.7	2.9	2.9	2.1	1.6
Total Reactor Development	24.0	19.6	17.9	14.4	12.0	10.5	8.5	8.1	8.0	9.0
Physical Research Program:										
High energy physics	2.9	2.3	1.0	.9	.4	-	-	-	-	-
Controlled thermonuclear research	.1	.1	.2	-	-	-	-	-	-	-
All other physical research	10.1	9.2	8.0	7.5	6.4	6.1	6.2	6.1	5.5	4.8
Total Physical Research	13.1	11.6	9.2	8.4	6.8	6.1	6.2	6.1	5.5	4.8
Biology and Medicine Program:										
Radiation effects on biological systems	2.5	2.1	1.6	1.5	1.2	1.3	c/			
Combating radiation detrimental effects	.6	.5	.6	.6	.8	.5				
Beneficial applications of atomic energy	.5	.4	.4	.4	.4	.4				
Biomedical problems in atomic energy operations	.2	.2	.2	.2	.2	.3				
Dosimetry and instrumentation	.1	.1	.1	.1	.2	.2				
Total Biology and medicine	3.9	3.3	2.9	2.8	2.8	2.7	2.6	2.4	2.8	2.6
Training, education and information	.9	.6	.8	.4	.7	.4				.1
Total Research and Development Costs	$ 41.9	$35.1	$ 30.8	$26.0	$ 22.3	$ 19.7	$ 17.6	$ 18.7	$ 20.6	$ 18.7
Personnel at June 30:										
By Type										
Scientific and engineering		844	800	698	577	531	488	519	521	513
Other		2735	2499	2216	1911	1820	1828	2190	2462	2314
Total employees		3579	3299	2914	2488	2351	2316	2709	2983	2827
By Location										
Lemont, Illinois		3480	3248	2872	2453	2315	2289	2682	2957	2800
National Reactor Testing Station, Idaho		99	51	42	35	36	27	27	26	27
Completed Plant and Equipment at June 30: d/										
By Type										
Accelerators		$ 3.3	$ 3.2	$ 3.0	$ 3.0	$ 3.0	$ 3.0	$ 2.9	$ 2.9	$ .4
Reactors		11.5	9.6	9.6	4.2	4.1	4.1	.8	.8	.8
All other		92.7	81.2	77.3	74.5	66.8	63.9	67.7	49.4	11.8
Total		$ 107.5	$ 94.0	$ 89.9	$ 81.7	$ 73.9	$ 71.0	$ 71.4	$ 53.1	$ 13.0
By Location										
Lemont, Illinois		103.6	92.3	88.2	80.6	72.8	69.9	70.3	52.0	11.9
National Reactor Testing Station, Idaho		3.9	1.7	1.7	1.1	1.1	1.1	1.1	1.1	1.1

a/ Excludes depreciation on AEC facilities and the cost of source and nuclear materials consumed in research
b/ Estimated
c/ Detail not available for this and prior years.
d/ Plant projects authorized but not completed at June 3, 1959, total $103.5. Of this amount $71.7 is to be built at the Lemont site and $31.8 will be at the NRTS.

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ARGONNE NATIONAL LABORATORY

Current Budget and Recent Costs by Categories of Work
(In thousands)

	F. Y. 1958 Costs	F. Y. 1959 Costs	F.Y. 1960 Budget
TOTAL	$30,795	$35,050	$41,878
Reactor Development - Total	17,918	19,599	24,005
Civilian Power Reactors - Total	10,644	11,784	16,153
Boiling Water Reactor - Total	3,495	3,721	4,700
Research and Development	2,585	3,121	2,900
Fuel Fabrication	-	11	1,000
Test Operations	610	575	800
Reactor Experiment Fabrication	299	14	-
Fast Power Breeder Reactor - Total	6,627	7,594	11,300
Research and Development	6,007	6,723	7,600
Fuel Fabrication	388	619	2,600
Test Operations,	185	252	1,100
Reactor Experiment Fabrication	47	-	-
Liquid Metal Fuel Reactor - Total	163	94	-
Research and Development	163	94	-
Studies and Evaluation	-	182	153
Assistance under Power Demonstration Program PRDC	360	193	-
Nuclear Technology of and General Support - Total	6,881	7,451	7,852
Engineering Physics and Advanced Reactor Dev.	1,482	1,455	2,005
Reactor Fuels and Materials Development	962	894	965
Reactor Components Development	934	1,147	1,290
Separations Development - Total	1,552	1,409	1,695
Aqueous Chem. Process Development	229	315	427
Volatility Processing Development	836	607	635
Closed Cycle Process Development	487	486	633
Reactor Safety - Total	1,765	2,372	1,670
Thermal Reactor Safety	305	503	570
Fast Reactor Safety	1,460	1,869	1,100
Radioactive Residues Process and Control - Total	186	175	227
Treatment Development	186	175	227
Army Power Reactors - Total	393	364	-
Stationary Low Power - Total	393	364	-
Research and Development	284	225	-
Fuel Fabrication	101	17	-
Test Operations	8	122	-

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ARGONNE NATIONAL LABORATORY - Cont'd

	F.Y. 1958 Costs	F.Y. 1959 Costs	F.Y. 1960 Budget
Physical Research Program - Total	$9,203	$11,568	$13,120
Physics Research - Total	3,752	5,234	5,997
High Energy Physics	994	2,313	2,865
Nuclear Structure and Neutron Physics	2,172	2,326	2,512
Extra Nuclear Properties of Matter	340	336	365
Physical Methods of Isotope Separations	-	-	-
Computer Research and Development	245	259	255
Chemistry Research - Total	4,336	5,042	4,897
Process Chemistry	732	935	1,012
Chemical Properties and Reactions	3,084	3,628	3,420
Special Projects	520	480	465
Metallurgy and Materials Research - Total	946	1,184	2,166
Production, Treatment, and Properties of Material	652	807	963
Alloy Theory and the Nature of Solids	182	203	1,009
Effects of Irradiations on Materials	112	174	194
Controlled Thermonuclear Research - Total	169	108	60
General Research and Development	169	108	60
Biology and Medicine Program - Total	2,918	3,257	3,900
Radiation Effects on Biological Systems - Total	1,581	2,055	2,547
Medical Research	82	41	128
Biological Research	1,463	2,014	2,419
Biophysics Research	36	-	-
Combating Radiation Detrimental Effects - Total	557	496	599
Medical Research	312	339	415
Biological Research	245	157	184
Beneficial Applications of Atomic Energy - Total	431	388	474
Cancer Research	64	103	111
Biological Research	367	285	363
Biomedical Problems in Atomic Energy Operations - Total	226	187	170
Medical Research	5	-	-
Biological Research	67	-	-
Biophysical Research	154	187	170
Dosimetry and Instrumentation - Total	123	131	110
Dosimetry	92	131	110
Instrumentation	31	-	-
Training, Education and Information Program - Total	756	626	853
Operation of Schools	583	510	728
Assistance to Schools	93	79	75
International Confs., Exhibits, Studies and Other Assis.	80	27	-
Publications and Libraries	-	10	-
Other Training, Education and Information	-	-	50

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Future Plans

Current planning for Argonne National Laboratory contemplates stabilization of the growth of the laboratory personnel at or below about 4,000 employees including about 1,000 professionally trained scientists and engineers, approximately ten percent above the present size. It is anticipated, however, that during the period under consideration there will be significant changes in program emphasis.

Physical Research: The most readily foreseeable change in basic research will occur in high energy physics. With the construction of the ZGS, the laboratc will be in a position to carry on one of the Nation's major programs in this field This facility, however, is intended to serve not just as a piece of experimental apparatus for the staff of the laboratory but as a device available to the high energy physicists of the Nation and of the free world. Therefore, the laboratory management and the AEC intend to limit the staff expansion at ANL in the high energy physics field to a point at which only a fraction - half or less - of the available time on the machine is taken by permanent staff of the laboratory. The balance of the users of the facility are expected to be visiting faculty members and graduate students from universities and other research institutions.

In the low energy physics program, the present level of effort is not expected to change markedly, although there will be significant changes in the direction of some of the work, particularly as facilities presently authorized or contemplated become available. Principal new facilities now foreseen include the 10 Mev Tandem Van de Graaff (already authorized) and a high flux research reactor to alleviate the current large backlog of work on CP-5 and to make available higher neutron fluxes. Such an additional reactor would also permit greater use of the research reactor facilities of the laboratory by faculty and graduate students of mid-western universities that can now be accommodated.

In the chemistry program increasing attention will be devoted to the transplutonium elements. The chemistry of plutonium will also receive increased

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attention. Counterbalancing these expansions, that part of the laboratory's work on inorganic chemistry which has been pursued because of interest stemming from separations process interests will be phased out as its productivity diminishe

Because of the limitations on technology now-imposed by our knowledge of the behavior of materials under the new conditions met within reactor operations, both the chemistry and metallurgy programs will devote increased attention to studies of the behavior of materials at high temperatures and to corrosion phenomena. The expansions in these field will also be accomplished by the transfer of effort from other areas.

Expansion is anticipated in solid state studies; considerable expansion is expected in ceramics research and in theoretical metallurgy studies.

There will be only minimal activities in plasma physics, and no activity in large scale controlled thermonuclear research is envisaged.

With the growing need to develop our ability to use plutonium as a reactor fuel, the basic properties of plutonium as a metal and an alloy material must be intensively investigated. The metallurgy program is already in process of shiftin its emphasis away from uranium to plutonium. Although the basic properties of uranium will continue to receive some attention, it now appears that as the decade advances, more and more of the Metallurgy Division's basic research effort will be concerned with plutonium.

Reactor Development: The reactor development work of the laboratory over the last several years has occupied about half of the laboratory's professional scientific and engineering staff. So far as can be foreseen in the period under study, this approximate division of effort will continue. The laboratory's major responsibility in the boiling water reactor field will be gradually phased out as the pioneering types of questions on the boiling cycle are answered and industr takes over the problems of engineering development and process refinement which will remain. The fast breeder reactor as a source of power and fissionable materi

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will continue to occupy a significant part of the laboratory's development effort through the decade.

Investigations will be continued on advanced concepts as they appear fruitful. Such investigations are expected to culminate in simple reactor experiments of the BORAX type, intended to determine feasibility of advanced concepts and the desirability of further, more elaborate engineering development. Such concepts to be investigated might include the boiling slurry reactor or particle fueled reactors.

Fuel cycle work on both the boiling water reactor and fast breeder types are expected to continue throughout the period.

In the field of general reactor technology, work will be expanded on the heat engineering problems arising from the use of sodium as a coolant. Metallurgical investigations of high temperature fuel materials will receive increased attention.

Work on the fluidized bed technique for fuel reprocessing will continue through the next few years but is expected to drop out in the latter half of the decade.

It is also probable that there will be a modest increase in the chemical separations program off-set by a modest decrease in the reactor physics program.

Biology and Medicine: As knowledge of the acute effects of radiation has increased, greater emphasis has been placed on the chronic effects of low-level exposure to radiations, in anticipation of the increasingly important problem which will result from widespread use of nuclear reactions for power production. Consequently, a major program expansion on long-term biological effects of low-dose radiation is underway. Because of the low doses and dose rates involved, such studies require a considerable expansion of experimental animal facilities. In addition to studying the effects of fission neutrons, high-energy gamma radiation, and strontium-90 deposition, the program will undertake to evaluate the effects of a variety of mixed fission products, both short and long lived. Emphasis will b on the life shortening and carcinogenic effects.

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In addition to the large-scale laboratory animal studies with dogs and mice, a detailed epidemiological study on human populations is rapidly gaining impetus. Between 500,000 and 700,000 persons in Illinois are routinely drinking well water that contains above-average levels of radium: some waters contain levels near the maximum permissible content. Body radium burdens will be measured and correlated with estimates of the incidence of bone pathology and bone tumor mortality. These studies are integrated with the continuing follow-up of radium dial painters and other persons known to be carrying significant body burdens of radium. Basic biochemical and cell structure research programs could be shifted to universities or reduced in scope as the above programs expand. Studies on human biochemical genetics will increase. Certain projects in the plant sciences concerned with radioisotope labeling of compounds involved in biosynthesis will be brought to completion. Studies of the biochemical factors which account for differences in the radiosensitivities of individual cells within a population will be expanded as they are required by the long-range neutron and gamma ray toxicity project. A comprehensive program of the biological effects of fission neutrons at dose rates varying from about .0001 to 10,000 rad per hour will be initiated upon the completion of a special biological research reactor facility in 1960.

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BROOKHAVEN NATIONAL LABORATORY

Brookhaven National Laboratory was established in 1946 in recognition of the need for large and expensive equipment and concentrations of scientific manpower in conducting nuclear research. The laboratory is operated by Associated Universities, Inc. (AUI), a non-profit corporation formed for the purpose under the sponsorship of nine leading northeastern universities. The Brookhaven program is characterized by emphasis on basic research and by large scale participation of scientists and engineers from other institutions.

The laboratory occupies the former Camp Upton in central Long Island. Some 150 Army buildings are still in use; although some are permanent, a large number are of temporary barracks type construction and are gradually being replaced. New construction to date includes centers containing the major technical facilities, part of the Biology Laboratory, a new Medical Center, and a few small, special purpose buildings. Under design are a Physics Laboratory and the first phase of a Nuclear Engineering Building. A comprehensive Master Plan contemplates an orderly process of replacing temporary structures, relieving overcrowded conditions and providing for future requirements.

The research is centered around, though not confined to, the use of several large machines and other special facilities, including: a large research reactor; a 3 billion electron volt proton synchrotron (this "Cosmotron," completed in 1952, was the first accelerator to deliver particles of energies above one billion volts); a 60" cyclotron, and several smaller accelerators; a hot chemistry laboratory; and several high level radiation facilities including a gamma field and a gamma greenhouse for the irradiation of growing plants. The new medical center incorporates a small research hospital and its own nuclear reactor especially designed for clinical neutron irradiations and other special purposes. A 30 billion electron volt (BEV) protron synchrotron, to be completed in 1960, will keep the laboratory

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in the forefront of research in high energy physics. A high flux research reactor now under design will provide much higher intensity external neutron beams for use in many facets of the program.

The scientific program covers a wide range of subjects in the physical and biological sciences and in engineering. It can be broadly described under five major headings.

1. Fundamental studies of atomic nuclei, the particles which constitute them, and the forces involved in their structure. This work, which is the laboratory's largest single effort, uses all the major machines. Especially significant results have been achieved in high energy particle physics, in neutron physics and in certain important aspects of nuclear structure.

2. The physical, chemical, and biological effects of nuclear particles and radiations. Such effects are utilized to study physical and chemical structures and the more complex properties of living systems and the changes which they undergo in their life and reproductive cycles. Of direct practical interest are deleterious effects of neutrons and other radiation upon biological systems and upon structural and other materials involved, for example, in reactor construction. Of equal importance are the potentially beneficial effects in the treatment of disease, in inducing useful genetic changes in plants or animals, and in assisting manufacturing processes. Special emphasis is placed on the use of neutrons in much of this work.

3. The use of nuclear tools, such as radioisotopes and neutrons, to study physical, chemical, and biological systems in an undisturbed state. In addition to applications of isotopic tracers in studying physical, chemical and biological systems and processes, this category includes the use of neutrons and other particles as probes to study the microscopic details of physical and chemical structures by observing their penetration and reflection.

4. Research and development, not necessarily itself involving nuclear phenomena, directed at the problems of atomic energy development. In its more basic aspects this category includes the chemistry and metallurgy of substances of special interest and the neutron scattering and absorbing properties of materials used in reactors and atomic weapons. In its immediate application it includes the development of reactor components such as fuels, structures and shields; of components and processes for the chemical processing and useful recovery of reactor products; and theoretical and experimental studies in the field of reactor physics.

5. The development of specific devices. This includes both the design and the construction of special research tools such as accelerators, reactors and other technical equipment, and the development of radiation sources and other devices utilizing atomic energy.

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The scientific staff presently includes slightly more than 300 scientists and engineers on the Brookhaven staff proper, approximately 70 Research Associates, and some 300 visitors from other institutions who average somewhat more than one-third of their time at the laboratory. About 60 foreign nationals are in residence on temporary appointments as research associates or visiting scientists.

Tables and charts on costs, budget, facilities, and staff follow.

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BROOKHAVEN NATIONAL LABORATORY
Upton, Long Island, New York

Ten Year Trend - Costs, Staff, and Facilities
(dollar amounts are in millions)

Fiscal Year	1960 b/	1959	1958	1957	1956	1955	1954	1953	1952	1951
Research and Development Costs: a/										
Reactor Development Program:										
Civilian power reactors	$ .9	$ 3.5	$ 4.2	$ 2.8	$ 1.6	$ 1.1	$ 1.1	$ 1.1	$ .7	$ -
General reactor research and development	2.0	.9	.9	.9	1.0	.8	.6	.6	.5	.5
Total Reactor Development	2.9	4.4	5.1	3.7	2.6	1.9	1.7	1.7	1.2	.5
Physical Research Program:										
High energy physics	5.6	3.8	3.0	2.6	2.1	1.7	1.5	1.3	-	-
Other physical research	7.2	5.6	5.3	4.3	3.9	4.1	4.1	4.2	5.3	5.1
Total physical research	12.8	9.4	8.3	6.9	6.0	5.8	5.6	5.5	5.3	5.1
Biology and Medicine Program:										
Radiation effects on biological systems	2.2	2.3	2.0	1.6	1.4	.7	c/			
Combating radiation detrimental effects	-	-	-	-	-	.2				
Beneficial applications of atomic energy	1.9	1.6	1.4	1.2	1.1	1.5				
Biomedical problems in atomic energy operations	.2	.2	.1	.1	.1	.1				
Dosimetry and instrumentation	.1	.1	.1	.1	.1	.1				
Total Biology and Medicine	4.4	4.2	3.6	3.0	2.7	2.6	2.4	2.2	2.2	1.8
Isotope Development	.3	.1	-	.1	.2	-	-	-	-	.1
Training, Education and Information	.1	-	.1	-	-	-	-	-	-	-
Total Research and Development Costs	$20.5	$18.1	$17.1	$13.7	$11.5	$10.3	$ 9.7	$ 9.4	$ 8.7	$ 7.5
Personnel at June 30:										
Scientific and engineering		440	408	379	368	366	342	331	319	285
Other		1,395	1,268	1,206	1,135	1,092	1,045	1,092	1,096	1,092
Total employees		1,835	1,676	1,585	1,503	1,458	1,387	1,423	1,415	1,377
Completed Plant and Equipment at June 30: d/										
Accelerators		$19.3	$ 7.5	$ 7.5	$ 6.8	$ 6.2	$ 6.1	$ 5.4	$ 2.8	$ 1.5
Reactors		17.0	17.0	16.9	16.9	16.9	16.9	16.8	16.8	16.5
Other		38.4	35.8	34.2	34.1	34.8	34.1	34.4	31.4	30.3
Total		$74.7	$60.3	$58.6	$57.8	$57.9	$57.1	$56.6	$51.0	$48.3

a/ Excludes depreciation on AEC facilities and the cost of source and special nuclear materials consumed in research.

b/ Estimated.

c/ Detail not available in this and prior years.

d/ Plant projects authorized but not completed at June 30, 1959 totaled $55.4 million.

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BROOKHAVEN NATIONAL LABORATORY

Current Budget and Recent Costs by Categories of Work
(in thousands)

	F.Y. 1958 Costs	F.Y. 1959 Costs	F.Y. 1960 Budget
TOTAL	$ 17,019	$ 18,019	$ 20,365
Reactor Development Program - Total	5,114	4,411	2,951
Civilian Power Reactor - Total	4,239	3,475	877
Liquid Metal Fuel Reactor Research and Development	4,165	3,360	750
Studies and Evaluation	74	115	127
Nuclear Technology and General Support - Total	875	936	2,080
Engineering Physics and advanced Reactor Development	447	433	995
Reactor Fuels and Materials Development	50	71	425
Reactor Components	-	-	100
Separations Development - Total	378	432	450
Aqueous Chemical Process Development	88	158	150
Residue Treatment Development	105	110	100
Residue Disposal Development	185	164	200
Reactor Safety	-	-	110
Physical Research Program - Total	8,282	9,396	12,758
Physics Research Program - Total	5,138	6,089	8,470
High Energy Physics	2,966	3,771	5,580
Nuclear Structure and Neutron Physics	1,854	1,907	2,315
Design and Development Devices for Physics Research	272	266	305
Computer Research and Development	46	144	270
Chemistry Research - Total	2,339	2,427	3,033
Process Chemistry	327	321	468
Chemical Properties and Reactions	1,916	2,019	2,450
Preparation and Purification of Special Research Materials	96	88	115
Metallurgy and Materials Research - Total	805	880	1,255
Alloy Theory and Nature of Solids	648	741	1,025
Effects of Irradiations on Materials	157	139	230

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BROOKHAVEN NATIONAL LABORATORY - (Cont'd.)

	F.Y. 1958 Costs	F.Y. 1959 Costs	F.Y. 1960 Budget
Biology and Medicine Program - Total	$ 3,609	$ 4,173	$ 4,415
Radiation Effects on Biological Systems - Total	1,992	2,273	2,170
Medical Research	1,275	1,471	1,450
Biological Research	607	802	720
Biophysics Research	110	-	-
Beneficial Applications of Atomic Energy - Total	1,419	1,639	1,935
Cancer Research	517	598	700
Medical Research	373	424	425
Biological Research	509	593	780
Distribution Isotopes	20	24	30
Biomedical Problems in Atomic Energy - Total	88	133	170
Biophysics Research	88	-	-
Environmental Research	-	133	170
Dosimetry and Instrumentation - Total	100	128	140
Dosimetry	80	89	100
Instrumentation	20	39	40
Civil Effects Test Program - Total	10	-	-
Isotope Development Program - Total	126	104	255
Radioisotope Production and Process Development	105	-	-
Industrial Process Radiation	17	104	255
Training, Education and Information Program - Total	110	39	90
Assistance to Schools	24	5	5
International Conferences, Exhibits, Studies and other Assistance	43	5	55
Other Training, Education and Information Activities	43	29	30

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Future Plans

Measured in terms of scientific and technical effort, considerably more than half of the work at Brookhaven is in the physical sciences; the remainder is about equally divided between nuclear technology and life sciences research. Over the coming ten years, an expansion of 50 percent of more in the total Brookhaven effort is anticipated with a substantial portion of this increase occurring during the first five years.

Physical Sciences: Of the growth in basic research in the physical sciences, nearly half is expected to be in the high energy physics program as a result of the new 30 Bev alternating gradient proton synchrotron, scheduled for initial test operations in 1960, and of improved research facilities at the Cosmotron. Additional emphasis also is envisaged with respect to the solid state physics and metallurgy programs and in radiation chemistry.

The Brookhaven scientific staffs in high energy physics, nuclear structure and neutron physics are expected to increase significantly. The nuclear structure and neutron physics program is expected to move into new relatively unexplored fields through the acquisition of (1) the high flux beam research reactor and (2) a planned high intensity, intermediate energy cyclotron.

Research in basic chemistry currently represents approximately one-fourth of research effort in the physical sciences program. Radiation chemistry will be given relatively more emphasis, and the overall chemistry effort is expected to expand somewhat.

In metallurgy and solid state physics, some increases and diversification are anticipated. The currently contemplated expansion in metallurgy facilities is not expected to allow substantial expansion in this field, and only minor expansion is envisioned in solid state studies.

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Biology Program: In the Biology Department which constitutes about 40 percent of the total research effort in the life sciences at Brookhaven, there are at present about 20 staff scientists, 10 research associates, and an average of 15 visiting scientists engaged in the research program. It is currently anticipated that the research program will continue to expand until an equilibrium level of 30-35 staff scientists, 25 research associates, and an average of 30 visitors is attained.

The biology research program emphasizes research in genetics, radiation biology, molecular biology, mammalian physiology, and cellular physiology.

This laboratory provides our principal facility for the cooperative programs in the application of radiation for crop improvement. No further expansion in this effort is anticipated. The research program in plant radiobiology will be expanded following the recommendation of an ad hoc committee of botanical scientists who recently examined critically the entire plant science research program of the AEC. Since the existing program at Brookhaven is already strong in molecular level studies, the expansion will emphasize effects on tissues, whole plants, and plant communities.

It is anticipated that the general program in genetics will remain at about its present level of activity. Particular emphasis will be given to the effects of radioisotopes incorporated into the genetic materials. Strontium-90 may present a special problem in this regard since it can partially replace calcium in the molecular structure of chromosomes.

The radiation biology program has emphasized mammalian studies. Although the numbers of animals employed in radiation toxicity studies will not be greatly increased, there will be an expansion of the basic studies at the molecular and cellular levels necessary for understanding whole body radiobiological effects. Estimates of cell renewal and turnover times are important in predicting radiation effects on specific tissues of importance in maintaining the physiological levels of activity

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consistent with survival. Efforts in theoretical biology will be considerably expanded to aid in the prediction of radiobiological damage.

The molecular biology program will be strengthened by expansion of studies in free radical chemistry, of protein and nucleic acid biosynthesis and their interrelationships, of protein structure, and of the mechanism of enzyme action.

Medical Program: The program of nuclear medicine includes application of atomic components in the treatment and diagnosis of disease and in the elucidation of fundamental biological processes. During 1959 a medical reactor (the first designed for medical use only) was brought into operation. Rapidly, the research and service activities are being oriented around this special facility.

In view of the unique facilities, the special competence, and the unusual associations available at Brookhaven, every effort will be made to determine, utilize, and test therapeutic advantages provided by a medical reactor.

Nuclear Technology: Brookhaven National Laboratory contributes in all of the nuclear technology programs, though the overall level of effort is of moderate size. Significant increases are expected in reactor components and chemical separations programs, moderate increases are expected in fuels and materials and reactor physics programs, and the current level of support is expected to be continued in the sanitary and environmental engineering program and the reactor safety program. An overall increase of approximately 70 percent is to be expected over the ten year period.

Isotopes Development: Current planning contemplates expansion of the high-level radiation research and development program to about three fold the current level of effort over the next five years. The high-level radiation program will experience significant changes in program emphasis during the next ten years. These changes will, of course, depend on the results of research and development of large radiation source designs, radiation physics, chemonuclear reactors,

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high-level dosimetry and engineering designs of high-level irradiators. The Brookhaven program will be concerned primarily with the more fundamental aspects of applied radiation chemistry, physics, and engineering necessary to supplement and accelerate an industrial radiation program.

OAK RIDGE NATIONAL LABORATORY

ORNL developed around the facilities established to scale up the plutonium project work started at the Metallurgical Laboratory in Chicago. The first laboratory facilities at Oak Ridge were the reactor for production of gram quantities of plutonium and a pilot chemical plant for separation of plutonium from irradiated uranium. Virtually from the start, this work was supplemented by basic physical research and by development assignments. Biology and medicine programs were also undertaken early, to begin to explore the hazards associated with these new materials and with radiation. The basic orientation of ORNL toward chemical technology and process development which began with its original mission has persisted. Likewise, the emphasis on neutron physics, research and test reactors as well as power reactor development and isotope production was a natural course for the post-War program, centered as it was around the graphite reactor, the oldest operating nuclear reactor in the world.

The laboratory has grown by expansion of its projects in these historical fields of research, by absorption of the wartime electromagnetic development laboratory, and by assignment of major project responsibilities, such as the Aircraft Nuclear Propulsion Project, as well as by gradual strengthening of existing basic research programs. As a result, the laboratory's interests and skills have continually widened until ORNL is now involved in research and development in most fields of Commission activity.

The laboratory's mission is weighted on the side of applied research, development, and isotope preparation, with about 75 percent of the budget going into

these activities. The laboratory is the country's central establishment for producing both stable and radioisotopes, the latter both in a wide variety for research and medical therapy and also in large quantities for industrial use. The two largest areas of applied work are reactor development and chemical processing.

The applied program of the laboratory involves the following major efforts:

Thermal Breeding. In accord with the Commission's over-all reactor program in which breeding is a major long-range objective, ORNL has been assigned the responsibility for developing the thermal breeder systems.

Gas-Cooled Reactor. The laboratory has the responsibility for technical aspects of the gas-cooled reactor program, including technical features of the 85 Mw reactor to be built in Oak Ridge and the continuing research program to improve the performance of gas-cooled reactors. This is an example of a role which the major AEC laboratories may be expected to play to an increasing extent; i.e., to serve as the Commission's center of know-how and research on the major types of power reactors.

Technical Assistance. The laboratory provides to the Commission technical assistance on specific reactor problems, ranging from conceptual design of the Army Package Power Reactor, now operating at Fort Belvoir, to general responsibility for the shielding portion of the Aircraft Nuclear Propulsion program. In addition, assistance is now being provided on the Maritime Reactor Program (NS Savannah), the Puerto Rican reactor, the AEC's small power plant program, and the Enrico Fermi reactor.

General Reactor Development. To provide the bases for continued growth and improvement in the power reactor field the laboratory carries on research or development in metallurgy, chemistry and solid state physics aimed at improving reactor fuel elements and construction materials, in electronics to improve reactor

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control and safety systems, in engineering (a) to increase the knowledge of heat transfer and hydrodynamics and thus reactor performance, (b) to improve components, and (c) to evaluate the corrosive behavior of materials under reactor conditions. Contributing to general reactor development has been the succession of test reactors for which the laboratory has been wholly or partially responsible; the LITR, the MTR, the Swimming Pool Reactor, the Tower Shield Reactor, and the ORR.

Chemical Processing. Beginning just after the War with the development of a solvent-extraction process for recovery of uranium from the Hanford waste tanks, the laboratory has played a major role in development of processes for extraction of plutonium, recovery of uranium from production reactors, and the enriched fuel recovery process used at Idaho. Most of the laboratory's effort in chemical process development has now turned to processes for power reactor fuels. A pilot plant complex utilizing existing structures, supplemented by a new head-end treatment plant, will permit the laboratory to process fuels from several of the power reactors in the course of the developmental program.

Waste Disposal. As an outgrowth of the necessity for providing safe means of disposal of its own radioactive wastes, the laboratory is engaged in a broad study of safe and economical methods for disposal of gaseous, liquid and solid wastes.

Controlled Thermonuclear Program. The approach taken at Oak Ridge to this problem involves the injection, at high energy, of molecular ions through a carbon arc in a magnetic bottle. The atomic ions produced by break-up of the molecules in the arc are confined and, when proper conditions are achieved, may produce a continuous thermonuclear reaction. The attainment of these proper conditions in the DCX device is the focus of a sizeable program at the laboratory.

The basic research work of ORNL, though representing not more than 25 percent of the whole budget, is actually very large, involving over 600 scientific man years of effort out of a total of 1,420. The fields covered range, for example from radio-biology to mathematics, from plasma physics to solid state physics.

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Physics. A large fraction of the physics research is concerned with the reactions of neutrons, especially those pertinent to reactor development, or the utilization of neutrons as tools for research. Thus, the laboratory has broad programs to determine nuclear cross sections, to investigate the mechanisms of reactions with materials and to determine the structure of crystals as disclosed by the diffraction of neutrons.

Chemistry. The laboratory is concerned with the chemistry of the fission process, fission products, chemical effects of radiation, and chemical properties and reactions in aqueous and non-aqueous media at high temperatures.

Metallurgy and Solid State Physics. This work is concentrated on the fundamental properties and reactions of metals, ceramics, semi-conductors and organic materials, primarily under conditions encountered in nuclear reactors.

Biological Sciences. The major problems studied in this field are those central to the use of nuclear energy, the investigation of the biological effects of radiation and the development of means to alleviate or counteract such effects. An extensive program is concerned with elucidating the genetic consequences of exposure to radiation.

The Oak Ridge National Laboratory is operated by the Union Carbide Nuclear Company under contract to the Commission. A good example of the laboratory's capability to perform functions of a semi-industrial character was the coordination of the United States' Sherwood exhibit at Geneva in 1958.

The laboratory is in the midst of a $45,000,000 building program which, upon completion, will provide outstanding facilities for advanced work and adequate space for the staff. The laboratory is equipped with several research reactors, chemical pilot plants, cyclotrons, and Van de Graaff accelerators, and plans are now underway for construction of an ultra-high performance isotope-producing reactor which will be used for manufacturing very heavy isotopes in large quantities for research purposes.

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OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee

Ten Year Trend - Costs, Staff and Facilities
(dollar amounts are in millions)

Fiscal Year	1960 b/	1959	1958	1957	1956	1955	1954	1953	1952	1951
Research and Development Costs: a/										
Production Program	$ 2.5	$ 2.8	$ 1.8	$ 1.3	$ 1.2	$ 1.3	$ 6.4	$ 6.7	$ 3.1	$ 1.6
Weapons Program	-	-	.2	.3	.3	.4	.4	.3	.9	.8
Reactor Development Program:										
Civilian power reactors	16.7	18.0	15.3	10.2	9.2	7.6	3.8	3.4	4.1	2.3
Merchant ship	.8	1.2	.3	-	-	-	-	-	-	-
Army power	.2	.2	.6	.5	.4	.4	-	-	-	-
Manned aircraft propulsion	3.0	3.6	7.0	20.6	15.9	10.0	6.7	7.1	6.5	4.8
Satellite power sources	.4	.5	-	-	-	-	-	-	-	-
General reactor research and development	7.6	5.6	4.3	4.0	2.7	1.4	.9	.5	.6	.9
Total Reactor Development	28.7	29.1	27.5	35.3	28.2	19.4	11.4	11.0	11.2	8.0
Physical Research Program:										
High energy physics	.1	-	-	-	-	-	-	-	-	-
Controlled thermonuclear research	5.6	4.0	3.4	.9	.6	.4	.1	-	-	-
Other physical research	12.7	10.9	9.7	8.7	8.0	8.1	7.7	7.5	6.0	4.8
Total Physical Research	18.4	14.9	13.1	9.6	8.6	8.5	7.8	7.5	6.0	4.8
Biology and Medicine Program:										
Radiation effects on biological systems	3.2	2.8	2.5	1.9	1.7	1.5	c/			
Combating radiation detrimental effects	.6	.6	.3	.3	.3	.2				
Beneficial applications of atomic energy	-	.3	.2	.2	.2	-				
Biomedical problems in atomic energy operations	.8	.5	.4	.4	.3	.3				
Dosimetry and instrumentation	.2	.1	.1	.4	.4	.4				
Civil effects	.4	.3	.2	.1	-	-				
Total Biology and Medicine	5.2	4.6	3.7	3.3	2.9	2.4	2.3	2.3	2.2	1.9
Isotope Development	.6	.5	.3	.2	.2	.3	.3	.5	.5	.8
Training, Education and Information	.7	.3	.4	.4	.5	.4	.4	.4	.5	.3
Total Research and Development Costs	$56.1	$52.2	$47.0	$50.4	$41.9	$32.7	$29.0	$28.7	$24.4	$18.2
Personnel at June 30:										
Scientific and engineering		1,457	1,398	1,350	1,223	1,143	1,028	1,011	884	763
Other		3,566	3,330	3,413	3,191	3,035	2,943	2,974	2,952	2,494
Total employees		5,023	4,728	4,763	4,414	4,178	3,971	3,985	3,836	3,257
Completed Plant and Equipment at June 30: d/										
Accelerators		$ 6.2	$ 7.1	$ 7.0	$ 3.9	$ 2.5	c/			
Reactors		15.7	14.8	9.3	8.4	6.9				
Other		113.5	117.9	118.7	106.8	97.6				
Total		$135.4	$139.8	$135.0	$119.1	$107.0	$102.8	$ 99.0	$ 62.9	$ 33.3

a/ Excludes depreciation on AEC facilities and the cost of source and nuclear materials consumed in research.

b/ Estimated.

c/ Detail not available in this and prior years.

d/ Plant projects authorized but not completed at June 30, 1959 totaled $45.0.

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OAK RIDGE NATIONAL LABORATORY

Current Budget and Recent Costs by Categories of Work
(in thousands)

	F.Y. 1958 Costs	F.Y. 1959 Costs	F.Y. 1960 Budget
TOTAL	$ 47,010	$ 52,142	$ 56,037
Production Process Development - Total	1,772	2,797	2,500
Weapons Development - Total	258	5	5
Reactor Development - Total	27,548	29,048	28,696
Civilian Power Reactors - Total	15,308	17,964	16,700
Pressurized Water Reactor - Research and Development	-	-	250
Gas Cooled Reactor - Research and Development	1,139	5,331	9,250
Fluid Fuel Reactors - Total	13,880	12,554	6,900
Homogeneous Reactor - Total	11,397	9,663	4,900
Research and Development	9,416	7,813	2,900
Operations	1,981	1,850	2,000
Fused Salt Reactor - Research and Development	2,483	2,891	2,000
Studies and Evaluation	289	79	300
Nuclear Technology and General Support - Total	4,315	5,632	7,621
Thermal Reactor Safety	172	327	380
Engineering Physics and Advanced Reactor Development	578	1,188	1,867
Reactor Fuels and Materials Development	571	1,075	1,779
Reactor Components Development	-	60	240
Aqueous Chemical Processing Development	1,666	1,685	1,500
Volatility Processing Development	462	432	805
Low Decontamination Studies	60	-	-
Residue Disposal Development	806	865	1,050
Maritime Pressurized Water Reactor - Total	273	1,235	775
Army Power Reactors - Total	612	161	200
Stationary Medium Power	161	-	-
Gas Cooled Reactor Systems	451	-	-
General Support	-	161	200
Airplane Propulsion Reactors - Total	7,040	3,582	3,000
Indirect Cycle	2,227	-	-
General Support	4,813	3,582	3,000
Auxiliary Power Sources, SNAP I	-	474	400
Physical Research Program - Total	13,076	14,919	18,363
Physical Research - Total	3,082	3,924	4,649
High Energy Physics	-	56	100
Nuclear Structure and Neutron Physics	2,273	2,416	2,591
Extra-Nuclear Properties of Matter	193	192	160

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Oak Ridge National Laboratory - Cont'd	F.Y. 1958	F.Y. 1959	F.Y. 1960
Design and Development of Devices for Physics Research	290	550	945
Physical Methods of Isotope Separation	289	676	813
Computer Research and Development	37	32	40
Chemistry Research - Total	5,510	5,711	6,315
Process Chemistry	2,719	2,471	2,321
Chemical Properties and Reactions	2,230	2,417	2,705
Chemical Isotope Separation Studies	255	318	479
Special Projects	176	333	505
Preparation and Purification of Special Research Materials	130	171	305
Metallurgy and Materials Research - Total	1,146	1,304	1,829
Production, Treatment and Properties of Materials	-	-	69
Alloy Theory and the Nature of Solids	713	762	865
Effects of Irradiations on Materials	433	541	895
Controlled Thermonuclear Research - Total	3,338	3,980	5,570
Biology and Medicine - Total	3,660	4,588	5,203
Radiation Effects on Biological Systems - Total	2,453	2,824	3,195
Biological Research	2,063	2,408	2,782
Biophysics Research	390	416	413
Combating radiation Detrimental Effects - Total	328	600	618
Biomedical Problems In Atomic Energy Operations - Total	420	503	827
Biophysics Research	251	305	571
Environmental Research	169	198	256
Dosimetry and Instrumentation - Total	64	102	225
Dosimetry	64	56	90
Instrumentation	-	46	135
Civil Effects Test Program - Total	161	279	338
Beneficial Applications of Atomic Energy	234	280	-
Isotope Development Program - Total	263	455	570
Radioisotope and Process Development	263	382	570
In FY 1959, ORNL included Start-up Costs in Isotope Program	-	73	-
Training, Education and Information Program - Total	433	335	700
Operation of Schools	284	198	1/
Assistance to Schools	47	33	
International Conferences, Exhibits, Studies and Other Assistance	33	43	
Other training, Education and Information Activities	69	61	

1/ Detail not available

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Future Plans

It is anticipated that personnel growth at the Oak Ridge National Laboratory will be minimal during the next ten years.

Reactor Program: The civilian nuclear power reactor program presently includes work at seven of the AEC laboratories, including the Oak Ridge National Laboratory. Since the ten year program for civilian reactors is unknown, a detailed program forecast for each laboratory cannot be presented. In addition to the present reactor systems, there will be new systems which may be added to a laboratory's work in the future - the number of these new systems, the magnitude of effort, or the location where the work will be done is not known at this time.

The civilian reactor work at ORNL is presently in the areas of gas cooled reactors and thermal breeder reactors. Because the gas cooled reactor is one of the thermal converter reactors, the research and development will be continued at the present level for the next two or three years. At that time the program will be terminated or will probably be reduced gradually each year so that by 1968 there will be no program expenditures. Since the thermal breeder reactor program is a long range program, the present level of expenditures will be maintained for six or seven years. If at that time the system or systems under development show the most promise of meeting the breeding program objectives, the work on the systems will be increased.

The field of Nuclear Technology (Chemical Separation and Development, Fuels and Materials, Reactor Components, Reactor Physics, and Sanitary and Environmental Engineering) is so broad in scope and the problem areas which require resolution are so numerous that only an expanded program can be envisioned for the next ten years. The national laboratories are the best qualified and equipped locations at which to conduct the major part of this work.

ORNL is a large contributor in all areas of Nuclear Technology. The current level of support is relatively high, and it is expected to increase by approximately 25 percent during the ten year period. Minor changes in emphasis will occur within

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the over-all program, with the largest increase in the Reactor Components development program.

The ANP program at ORNL has carried a substantial shielding program which is expected to continue.

Physical Science Program: In basic physics, ORNL over the next ten years will continue to supply much of the nuclear data fundamental to the whole technology; this task will be made easier by the new Oak Ridge Relativistic Isochronous Cyclotron (ORIC), and by the acquisition of a 10 Mev Van de Graaff accelerator. The laboratory will venture somewhat further into high energy physics, though these steps will be taken carefully so that the demands in this field do not reduce ORNL's capacity to perform precision work in the binding energy region.

Basic chemistry, solid state physics, and mathematics will continue much as they have been with shifts in emphasis as needed to shore up the applied programs. The addition of the ORIC and the proposed High Flux Isotope Reactor (HFIR) will stimulate research in heavy element chemistry, and in this field some expansion is anticipated. In metallurgy, expanded effort is expected in metal physics and ceramics research. Space limitations will probably keep solid state studies at their present size. A large expansion is anticipated in the research materials program, making use primarily of existing personnel and facilities.

Controlled thermonuclear research should develop naturally over the next decade along the lines already established - high energy injection into a mirror geometry. It may take five years to bring the science of plasma physics to a point where it will be possible to assess realistically the outlook for fusion power. The projections must, therefore, be considered very tentative and almost sure to be modified as more information is acquired. It appears probable that the AEC may call on ORNL for direct collaboration with other controlled thermonuclear laboratories. For example, if it becomes necessary to inject ions into a stellarator, a joint effort on the part of Princeton and ORNL might be desirable.

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Biomedical Program: The large project in cytology and genetics emphasizes basic studies of cellular structure and function, and of the action of radiation on the cell and especially on the genetic apparatus. This program will continue at the present level.

ORNL is the site of the AEC's major program in mammalian genetics. Work here has recently shown that the induction of gene mutations occurs at a lower rate when the radiation exposure is protracted over a long period at a low dose rate. This is extremely significant to consideration of the genetic hazards of fallout and occupational exposures. The present level of activity will continue although new projects will be initiated as major studies are completed.

In the mammalian recovery work, laboratory studies of protection by chemicals and by bone marrow transplantation in the mouse have been emphasized. The program has developed into a broader one concerned with tissue transplantation in general, with emphasis upon related immunological problems. No expansion of effort is planned.

The pathology-physiology studies have been concerned with the pathogenesis of early and delayed somatic radiation effects in mammals with emphasis on the induction of leukemia and neoplasia. This program will be expanded to encompass the life shortening and carcinogenic effects in mice of chronic low-level radiation.

The major objective of the work in cell physiology is the determination of the molecular basis of cell function. The findings will provide a background to facilitate determination of the effects of radiation and other insults on cellular function. No major increase in this program is anticipated.

The biophysics research is concerned with the understanding of the basic primary physical and chemical events which underlie and govern the action of radiation in biological systems. Significant advances have been made by the application of electron spin resonance methods to biological materials. It is anticipated that these studies will be expanded in conjunction with an overall

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increase in AEC supported effort in biophysics and bioenergetics.

Radiation immunology investigations are concerned with the fundamental immunological aspects of bone marrow and other tissue transplantation, and with fundamental immunological investigations. A modest expansion is planned, with emphasis on the immunogenetic aspects of the problem.

The biochemistry projects at ORNL have been concerned with three major proble intermediary metabolism in bacteria and plants, nucleic acid biochemistry, and protein synthesis. Considerable expansion is planned with emphasis on the interrelationships and genetic control of nucleic acid and protein biosynthesis, biochemical studies of gene action, and studies of cellular differentiation at the molecular level.

Isotopes Program: Current planning contemplates expansion to approximately double the current level of effort during the next five years. It is anticipated, however, that this level of effort will diminish gradually during the latter part of the next decade. An increased effort during the early years is needed to devel information about the physical and chemical properties of radioisotope products. An accelerated process development program is also required to make new radioisotopes available and to increase the purity, yield, and quantity of radioisotopes currently available. The long range program is directed toward developme of information to stimulate applied research in industrial laboratories.

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OAK RIDGE INSTITUTE OF NUCLEAR STUDIES

The Oak Ridge Institute of Nuclear Studies is a non-profit corporation of 37 Southern universities and colleges. The Institute serves as a device for facilitating research and training relationships between Oak Ridge National Laboratory and the universities, in addition to conducting programs of its own. Though not a multi-program laboratory (its research activities being limited to the medical field) it is included here because of its close ties to ORNL. The Institute consists of four divisions: Medical, Special Training, University Relations, and Museum.

The Medical Division was formally organized in January 1949 as a research unit, the broad interests of which are directed toward the preliminary investigation of promising possibilities in the application of radioactive substances to the study of cancer and related disease. It was located in Oak Ridge with the intent of developing a medical center which would exploit the special research opportunities of that location. The presence and personal interest of a large staff of outstanding electronic, nuclear instrumentation and isotope production specialists of the Oak Ridge National Laboratory has contributed greatly to the successful pioneer work in radioisotope therapy, teletherapy design and patient treatment.

A primary reason for establishing a clinical research program at Oak Ridge was the availability of short-lived isotopes from the reactors. The extensive clinical evaluation of gallium-72 with a half-life of fourteen hours is an example of a study carried out at ORINS that would

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have been impossible to undertake at a more distant location from an isotope producing reactor. Currently the efforts in the clinical program are directed toward the internal use of new isotopes plus studies involving external irradiation followed by bone marrow transplantation. Extensive basic and pre-clinical studies are being pursued in an effort to learn more about the distribution and metabolism of man in the diseased state. Thus far, over 1,000 patients have been admitted for treatment.

An accompaniment of this program is the training of physicians and scientists from the United States and foreign countries. One hundred and forty-four American physicians and twenty-seven from other nations have spent from three months to two years in the Medical Division, in addition to thirty-six scientists in the life sciences.

It is contemplated that the Medical Division will continue to operate at about the present level of effort for the coming decade. The completion of the Whole-Body Irradiation facility will undoubtedly lead to an expanded fundamental study on the effects of whole body irradiation with perhaps less emphasis on the use of new isotopes. The new facilities will permit radiation to be directed at patients from several directions with a resulting more uniform dose distribution. Efforts will be continued to develop biological tests that will help in determining doses so that persons exposed to known or unknown amounts of radiation can be properly evaluated and treated.

It is expected that the leukemia and bone-marrow transplantation will separate into two paths of investigation: One will be the evaluation of the treatment of acute leukemia by whole-body irradiation

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without the addition of bone marrow; the second will be further efforts to transplant bone marrow. Greater emphasis will be given to questions of distribution and metabolism of isotopes. Training of physicians and scientists in the medical use of radioisotopes and teletherapy methods will be continued.

The Special Training Division was organized to train doctors, scientists and other technically trained people in the use of radioisotopes. The first class was given in the summer of 1948 and since that time three thousand participants from the United States and 54 foreign countries have completed the one-month course of basic isotope training.

The University Relations Division facilitates participation in ORNL research by university faculty members and students. In addition, members of the ORNL travel under ORINS auspices to the schools to give lectures and seminars. During the academic year of 1958-59, a total of 1,701 student fellowships were handled by this Division. These included 987 pre- and post- doctoral fellowships, 452 in radiobiological science, 46 in industrial hygiene and 216 in nuclear science and engineering.

The American Museum of Atomic Energy opened in Oak Ridge in March, 1949. Since that time three quarters of a million people have visited this museum. A traveling exhibit program was initiated in order to bring portions of the museum to people throughout the United States. It is estimated that 27 million people have seen these exhibits.

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OAK RIDGE INSTITUTE OF NUCLEAR STUDIES
Oak Ridge, Tennessee

Ten Year Trend - Costs, Staff and Facilities
(dollar amounts are in millions)

Fiscal Year	1960 b/	1959	1958	1957	1956	1955	1954	1953	1952	1951
Completed Plant and Equipment at June 30: c/										
All other	$	$ 2.8	$ 2.4	$ 2.3	$ 2.1	$ 1.9	$ 1.6	$ 1.5	$ 1.7	$ 1.3
Total Completed Plant		2.8	2.4	2.3	2.1	1.9	1.6	1.5	1.7	1.3
Research and Development: a/										
Biology and Medicine Program:										
Beneficial applications of atomic energy	1.1	1.0	.8	.8	.8	.7	d/			
Total Biology and Medicine	1.1	1.0	.8	.8	.8	.7	.7	.7	.6	.6
Isotope development	.1	.1								
Training, education and development	1.9	1.6	1.4	1.0	.7	.5	.5	.9	1.2	.4
Total Research and Development Costs	$ 3.1	$ 2.7	$ 2.2	$ 1.8	$ 1.5	$ 1.2	$ 1.2	$1.6	$ 1.8	$ 1.0
Personnel at June 30:										
Scientific and engineering		105	98	80	69	63	62	61	60	60
Other		140	139	143	136	121	127	111	86	69
Total employees		245	237	223	205	184	189	172	146	129

b/ Estimated
a/ Excludes depreciation on AEC facilities and the cost of source and special nuclear materials consumed in research.
c/ Plant projects authorized but not completed at June 30, 1959, totaled $0.3.
d/ Detail not available in this and prior years.

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OAK RIDGE INSTITUTE OF NUCLEAR STUDIES

Current Budget and Recent Costs by Categories of Work
(in thousands)

	F. Y. 1958 Costs	F. Y. 1959 Costs	F. Y. 1960 Budget
TOTAL	$2,249	$2,654	$3,120
Biology and Medicine Program - Total	871	962	1,055
Beneficial Applications of Atomic Energy - Total	871	962	1,055
Cancer Research	871	746	784
Medical Research	-	216	271
Isotope Development Program - Total	-	73	116
Radioisotope Technology Training	-	73	116
Training, Education and Information Program - Total	1,378	1,619	1,949
Operation of Schools	231	196	212
Fellowships	534	793	1,080
Assistance to Schools	4	-	30
International Conferences, Exhibits, Studies and other Assistance	8	17	25
Museums and Exhibits	601	613	602

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DOE ARCHIVES

AMES LABORATORY

The Ames Laboratory has grown from contract work undertaken by Iowa State University for the Manhattan Engineer District in February, 1942. Its principal mission was conduct of basic research and development work in metallurgy and chemistry, with special emphasis on the lesser known elements and metals.

Besides obtaining basic information needed in the design of the first reactors, the laboratory was successful in developing inexpensive methods for producing very pure uranium metal. These processes were turned over to industry and are still in use today. While the industrial producers were being established, Ames produced over 2,000,000 pounds of metallic uranium for experimental use and for the early reactors.

Other projects on which the laboratory has worked include development of technology concerning uranium and its alloys, including a very much cheaper method of casting the metal; development of a process, now used industrially, for producing metallic thorium; and processes for separating the rare earths and for producing the pure rare earth metals. These processes, too, are now in industrial production.

The Ames Laboratory maintains strong groups in basic inorganic chemistry, solid state physics, physical and chemical metallurgy, surface chemistry, kenetics (rates of reactions), ion exchange, structural chemistry, etc., and it is from these basic studies that the applications mentioned above developed. Work is also carried on in nuclear physics and nuclear chemistry.

The laboratory maintains a vigorous program in high temperature metallurgy and has strong analytical groups to develop methods for analysis of the unusual materials dealt with in the program.

The laboratory is housed in two AEC-built structures on campus land leased from Iowa State College. A third building, the Metals Development Building, is

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under construction at present, and a research reactor facility is in design.

The laboratory is close to the campus more than by reason of location alone; its research staff is made up, to a substantial extent, of personnel who spend part time at the laboratory and part time in academic pursuits. They range from senior professors to graduate students. Thus, the laboratory plays a significant training role, and benefits from close interrelation with academic research. Over 240 PhD's and nearly 220 M.S.'s have been granted by Iowa State on the basis, in part, of work done at the Ames Laboratory.

DOE ARCHIVES

AMES LABORATORY
Ames, Iowa

Ten Year Trend - Costs, Staff and Facilities
(dollar amounts are in millions)

Fiscal Year	1960 b/	1959	1958	1957	1956	1955	1954	1953	1952	1951
Research and Development Costs:a/										
Production Program	$ -	$ .1	$ .2	$ -	$ .1	$ .2	$ .1	$ .6	$ .6	$ -
Reactor Development Program:										
General reactor research and development	.6	.6	.4	.3	.2	.2	.2	-	-	-
Physical Research Program:										
High energy physics	.1	-	-	-	-	-	-	-	-	-
Other physical research	3.1	2.7	2.4	2.3	2.0	2.0	1.8	1.9	1.9	1.7
Total Physical Research	3.2	2.7	2.4	2.3	2.0	2.0	1.8	1.9	1.9	1.7
Total Research and Development Costs	$ 3.8	$ 3.4	$ 3.0	$ 2.6	$ 2.3	$ 2.4	$ 2.1	$ 2.5	$ 2.5	$ 1.7
Personnel at June 30:										
Scientific and engineering		336	324	310	287	256	225	247	233	220b/
Other		247	271	272	238	255	251	300	349	306b/
Total employees		583	595	582	525	511	476	547	582	526b/
Plant and Equipment at June 30:c/		$ 7.6	$ 7.2	$ 6.7	$ 6.5	$ 6.3	$ 4.0	$ 3.1	$ 2.8	$ 2.3

a/ Excludes depreciation on AEC facilities and the cost of source and special nuclear materials consumed in research.

b/ Estimated.

c/ Plant projects authorized but not completed at June 30, 1959 totaled $6.4 million.

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AMES LABORATORY

Current Budget and Recent Costs by Categories of Work
(in thousands)

	F.Y. 1958 Costs	F.Y. 1959 Costs	F.Y. 1960 Budget
TOTAL	$2,993	$3,418	$3,836
Production Process Development	139	80	-
Reactor Development - Total	388	615	645
Nuclear Technology and General Support - Total	388	615	645
Reactor Fuels and Materials Development	318	536	575
Seperations - Development Program	70	79	70
Physical Research Program - Total	2,445	2,716	3,191
Physics Research - Total	233	236	288
High Energy Physics	41	39	65
Nuclear Structure and Neutron Physics	192	197	223
Chemistry Research - Total	1,315	1,445	1,690
Process Chemistry	177	202	223
Chemical Properties and Reactions	1,056	1,119	1,326
Chemical Isotope Separation Studies	82	125	141
Metallurgy and Materials Research - Total	897	1,034	1,213
Production Treatment and Properties of Materials	246	352	419
Alloy Theory and the nature of Solids	651	682	794
Effects of Radiations on Materials	-	-	-
Training, Education and Information Programs - Total	21	7	-
Summer Institute for Engineering Faculty	21	7	-

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DOE ARCHIVES

Future Plans

The completion of the Metals Development Building and the Ames Laboratory Research Reactor will round out facilities needs as currently foreseen. Completion of these facilities will not mean a corresponding increase in personnel. The total increase now anticipated over the coming ten years is quite modest, possibly about 10 percent above the present level.

While no major changes in the over-all objectives of Ames are envisioned for the foreseeable future, the availability of the Metals Development Building in late 1960 will greatly enhance its ability to produce quantities of highly pure metals and alloys and will also free space for more basic research. In addition, the availability of the Ames Research Reactor will remove a serious limitation imposed upon the laboratory's ability to study the nuclear properties of solids.

Research programs in the field of reactor development will consist of work on metals, alloys, and ceramics. Emphasis will be concentrated on metals such as thorium and its alloys, yttrium and its alloys, rare-earth metals and their alloys, properties of metals and ceramics at temperatures above 1000°C, effect of non-metallic impurities on metal properties, the measurement of engineering properties such as fatigue and corrosion rate at relatively high temperatures, new pyroprocessing techniques, and the measurement of physical properties at high temperatures.

Fundamental research in the physical sciences will continue in physical chemistry and metallurgy. Work in High Energy Physics will continue to use nuclear emulsions, although it may be supplemented by the use of solid luminescence chambers. Work in Nuclear Structure and Neutron Physics will continue to take advantage of the unique characteristics of the Iowa State Synchrotron.

Chemistry research will consist of fundamental studies on the mechanism of various separation processes such as ion exchange, solvent extraction, and

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sublimation as well as the development of analytical and spectrochemical analytical methods.

Future work in metallurgy and materials research and solid state physics will take advantage of new techniques such as de Haas-van Alphen effect measurements on single crystals, the use of ionic crystals, the measurement of magneto-acoustic effects on metallic crystals at cryogenic temperature, high-pressure work, and the measurement of fundamental properties that will help determine the real nature of the solid state.

The laboratory will continue to develop fundamental pyrometallurgical data in support of low-decontamination, closed cycle separations systems. Advanced metallurgical studies will be continued in the development of alloys for nuclear energy applications. The level of effort will gradually be expanded by approximately 25 percent in materials development, but the program will remain relatively small in the over-all materials development program.

DOE ARCHIVES

LAWRENCE RADIATION LABORATORY - BERKELEY

The Lawrence Radiation Laboratory (LRL) at Berkeley has developed, with the support first of the Manhattan Engineer District and later of the AEC, from the Radiation Laboratory established by Professor Ernest Lawrence at the University of California in 1936. Much of the present character of the laboratory derives from this historical background. It still maintains close connections with the academic departments of the University, and is oriented toward basic research, with a strong interest in graduate and post-doctoral training.

Early in the Manhattan project the Laboratory devised and developed the Calutron for separation of isotopes, and assisted in the design and construction of the electromagnetic separation plant at Oak Ridge which used the calutron technique for the first separation of uranium 235 from normal uranium. The laboratory also discovered the element plutonium, and undertook work on its chemistry prior to transfer of plutonium chemistry responsibilities to the Metallurgical Laboratory at Chicago.

The laboratory started with the cyclotron idea, and its activities are still largely centered around the development of and research with particle accelerators and their products. Nuclear physics at low and high energy, radio-chemistry, and radio-biology are obvious applications. These led naturally into broader fields in physics, chemistry, biology and medicine. LRL is particularly noted for its high energy nuclear physics and for its work in the transuranic elements, many of which were discovered there.

The accelerators now operating at the laboratory are the Bevatron (6.2 BEV), the synchrocyclotron (740 MEV), the electron synchrotron (300 MEV), the 60-inch cyclotron, and the heavy ion linear accelerator (HILAC). Under construction is a high-current spiral ridge cyclotron, which will replace the 60-inch cyclotron.

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Experimental Physics is the largest division of the laboratory. It is engaged almost entirely in high energy physics, which investigate the elementary particles, and is an extremely active and growing field. In addition to large accelerators, it needs large and elaborate observing equipment, such as bubble chambers.

The Theoretical group covers a wide range of activities; Elementary particle theory, nuclear structure, accelerator theory, magneto hydrodynamics, etc. Part of this work is in support of Livermore activities.

The Chemistry Division is concerned with transuranic elements, nuclear spectroscopy, systematics of nuclear reactions and radioactivity, and some general chemistry.

The Bio-Medical Division is concerned with radiation biology, use of radioactive tracers, therapeutic use of radiation, and related fields. The Bio-Organic Division started with the use of radiocarbon in studies of photosynthesis; now it covers a wider range in the field of molecular biology.

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LAWRENCE RADIATION LABORATORY - BERKELEY
Berkeley, California

Ten Year Trend - Costs, Staff, and Facilities
(dollar amounts are in millions)

Fiscal Year	1960 b/	1959	1958	1957	1956	1955	1954	1953	1952	1951
Research and Development Costs: a/										
Production Program	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 2.9	$ -
Weapons Program	-	-	-	-	-	-	-	-	.5	.2
Physical Research Program:										
High energy physics	11.8	9.6	7.2	5.8	3.6	2.8	2.8	3.0	2.5	2.8
Controlled thermonuclear research	1.3	1.0	.8	.5	-	-	-	-	-	-
Other physical research	4.4	4.1	3.3	3.3	3.6	2.2	1.8	1.7	2.3	1.9
Total Physical Research	17.5	14.7	11.3	9.6	7.2	5.0	4.6	4.7	4.8	4.7
Biology and Medicine Program:										
Radiation effects on biological systems	.5	.4	.2	.2	.2	.2	c/			
Combating radiation detrimental effects	.1	.1	.2	.1	.1	.1				
Beneficial applications of atomic energy	1.2	1.4	1.4	1.2	1.4	1.3				
Biomedical problems in atomic energy operations	.2	-	-	-	-	-				
Dosimetry and instrumentation	.1	.1	.1	.1	.1	.1				
Total Biology and Medicine	2.1	2.0	1.9	1.6	1.8	1.7	1.7	1.7	1.6	1.5
Total Research and Development Costs	$19.6	$16.7	$13.2	$11.2	$ 9.0	$ 6.7	$ 6.3	$ 6.4	$ 9.8	$ 6.4
Personnel at June 30:										
Scientific and engineering		693	624	588	536	495	493	519	556	546
Other		1,501	1,283	1,177	1,173	1,029	1,048	1,149	1,024	1,035
Total Employees		2,194	1,907	1,765	1,709	1,524	1,541	1,668	1,580	1,581
Completed Plant and Equipment at June 30: d/										
Accelerators		13.2	12.6	13.0	10.9	10.9	10.8	2.3	2.3	1.8
Other		18.5	15.0	12.7	12.1	11.6	9.2	10.4	8.8	7.4
Total		$31.7	$27.6	$25.7	$23.0	$22.5	$20.0	$12.7	$11.1	$ 9.2

a/ Excludes depreciation on AEC facilities and the cost of source and special nuclear materials consumed in research.

b/ Estimated.

c/ Detail not available in this and prior years.

d/ Plant projects authorized but not completed at June 30, 1959 totaled $16.4 million.

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LAWRENCE RADIATION LABORATORY - BERKELEY

Current Budget and Recent Costs by Categories of Work
(In thousands)

	F.Y. 1958 Costs	F.Y. 1959 Costs	F.Y. 1960 Budget
TOTAL	$13,263	$16,687	$19,660
Physical Research Program - Total	11,379	14,631	17,534
Physics Research - Total	7,698	10,023	12,200
High Energy Physics	7,266	9,471	11,810
Nuclear Structure and Neutron Physics	432	293	320
Design and Development of Devices for Physics Research	-	260	70
Chemistry Research - Total	2,887	3,538	4,034
Chemical Properties and Reactions - Total	2,887	3,538	4,034
Controlled Thermonuclear Research	794	1,070	1,300
Biology and Medicine Program - Total	1,855	2,040	2,126
Radiation Effects on Biological Systems - Total	204	400	575
Medical Research	130	150	435
Biological Research	37	121	140
Biophysics Research	37	129	-
Combating Radiation Detrimental Effects - Total	148	150	49
Medical Research	55	89	49
Biophysics Research	93	61	-
Beneficial Application of Atomic Energy - Total	1,447	1,392	1,217
Cancer Research	193	94	109
Medical Research	864	791	634
Biological Research	390	507	474
Biomedical Problems in Atomic Energy Operations - Total	-	-	206
Medical Research	-	-	130
Biophysics Research	-	-	76
Dosimetry and Instrumentation - Total	56	98	79
Instrumentation	56	98	79
Training, Education and Information - Total	2	16	-
International Conferences, Exhibits, Studies and Other Assistance - Total	2	16	-

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Future Plans

Current planning for the Lawrence Radiation Laboratory, Berkeley, envisions a personnel strength of about 3,300 of which approximately 50 percent will be directly associated with the scientific work of the laboratory. Laboratory strength as of the end of FY 1960 is expected to be somewhat greater than 2,300; thus, current plans based upon the research program, would call for an increase of somewhat more than 40 percent over the ten year period.

Manpower: The number of employees at Berkeley has increased from 1200 to 2200 in the last ten years. There are a number of reasons for projecting an increase similar in size, though at half the rate, during the next ten years. This is partly due to the fact that the experiments, especially in high energy physics, have become more complex. The simpler experiments have been done. The equipment requirements and support facilities and people have increased with the size of the accelerators. In addition, the number of experimental areas has increased, resulting in better utilization of the machines.

New or enlarged areas of research, such as the recently proposed Inorganic Materials Program, will add to the size of the laboratory. In ten years, this program would add 400 people to the staff. The size of the University of California at Berkeley is expected to increase from 20,000 to 40,000 in the next ten years. The number of graduate students and post doctorals who wish to work in and can contribute to the work of the laboratory will probably also double. Requirements for equipment and facilities must keep pace with the research program and the size of the staff.

Physics: The immediate program in the area of physics is based upon increasing the effectiveness and utilization of the Bevatron, 184-inch

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cyclotron, and related experimental equipment (such as the 72-inch liquid hydrogen bubble chamber) by increasing the experimental and support facilities and by accelerating the development of detection apparatus and data handling techniques. In the very near future, the electron synchrotron will be closed down and the high energy program will be concentrated on the major machines. A low-energy program of modest proportions will continue to utilize the 60-inch cyclotron (and its successor, the 88-inch cyclotron) and the Hilac.

For the next period of approximately two to five years, three programs must take place concurrently. These are: the continued utilization and improvement of techniques and apparatus, the development of accelerator improvements for the short range future, and the study of new accelerator possibilities. The accelerator development program, which is expected to open up higher energy and higher current ranges presently unavailable to high energy physics investigations, will take a period of five to seven years for development and construction.

Chemistry: The laboratory has a unique standing in the field of nuclear chemistry. The 60-inch cyclotron and the heavy ion linear accelerator are the principal machines being utilized. The 184-inch cyclotron and the Bevatron are also being used but to a somewhat lesser extent. The future chemistry program will utilize the accelerators to an increasing extent. The 88-inch cyclotron will replace the 60-inch cyclotron as the major tool. The Hilac and the 88-inch cyclotron will have a unique partnership arrangement. For example, the discovery and pioneering studies of some isotopes of particular interest are now being made at the Hilac. The 88-inch cyclotron will then produce the isotopes in sufficient quantity to permit intensive studies. The 184-inch cyclotron and the Bevatron, particularly after the beam intensity improvements, will find increased utilization for nuclear reaction studies.

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All of the chemistry programs depend on the continuous development of techniques and apparatus as a means of refining and extending the work. New techniques in chemistry, electronic instrumentation, radiation detection, the handling of radioactive materials (with special problems in the trans-uranium region), cryogenics, and in computer data processing and evaluation are under constant, vigorous development. Increasing applications of these techniques and apparatus are being made to problems far removed from those for which they were originally developed. These practical developments, as well as the basic research findings and training of scientists, constitute a major contribution by this laboratory to the nation's needs.

Biology and Medicine: In terms of size, this program will remain fairly stable during the next decade, though there will be a number of changes within it.

It is anticipated that greater emphasis will be placed on the use of the particle-accelerators available at LRL to study the effects of heavy-particle radiation on cells and cell components. These studies at first will be basic but, no doubt, will have practical therapeutic applications. There is the possibility that a particle accelerator specifically designed for deep X-ray therapy may be designed and built. Research on the biological effects of deuterium will also be expanded.

The experiments concerned with photosynthesis and basic molecular radiation chemistry will continue to provide the major stimulus for many of the ideas responsible for the progress in understanding the effects of radiation on living tissue. It would not be improper to anticipate within the next ten years a major breakthrough in this field on photosynthesis and energy accumulation in living tissues which would have major effects on the whole field of biochemistry.

The studies on the distribution of radioactive materials in the mammal will gradually be terminated as the laboratory animals involved die off. The space used for this program will be employed to develop a colony of pathogen-free animals which will be particularly useful for analyzing the role of stress from infectious diseases in the acute and chronic radiation syndrome. Other studies which may expand abruptly if a breakthrough develops are concerned with: the erythropoietic principle obtained from urine; the pinhole camera technique of scanning; the relation of fatty materials and foods to disease of the arteries and to the aging process; and the use of labeled hormones and biological compounds to study biological processes and diseases. The training effort at the Donner Research Laboratory should probably expand in a gradual, well-controlled fashion to about 50 percent greater than its present size and activities.

The role of the Lawrence Radiation Laboratory may also include increased attention and expansion of theoretical and laboratory studies of weapons effects, phenomenology of blast, thermal, prompt radiation, and fallout.

Inorganic Materials: Within the Chemical Division, there has been a continuing program of modest proportions concerned with the basic physical chemistry of matter, with some emphasis on high-temperature thermodynamics. A proposal for the establishment of a major Inorganic Materials Research Program is now being considered by the AEC. This work would be directed toward increasing the knowledge of the properties of materials, with special emphasis on the high temperature regions. The immediate plan, i.e., through the next five years, is to establish and to start the work in the four areas of primary interest: high temperature chemistry; physical chemistry of the solid state; metallurgy and ceramics; and general inorganic and physical chemistry. The longer range plan is to expand the areas of

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primary interest and to intensify the work on particular subjects which become of major importance.

This program is currently staffed by personnel within the chemistry program. It is possible that upwards of 400-500 persons might be engaged in it by the end of the ten year period.

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LAWRENCE RADIATION LABORATORY - LIVERMORE

Livermore was established in 1950 as a site for the classified MTA project being carried on jointly by the Radiation Laboratory and the California Research and Development Corporation. In 1952 a branch of the Radiation Laboratory, with the principal function of augmenting the nuclear weapons development program, was established there, and the MTA program was concluded in the next few years.

Livermore has approximately 3,600 employees. The main function of the Laboratory continues to be the development of nuclear weapons. More recently the laboratory has been assisting the Sandia Corporation in the engineering of proven nuclear weapons. The laboratory possesses extensive skills and equipment in the theoretical prediction of nuclear explosions, in experiments involving components of nuclear explosives, and in performing and observing nuclear tests. The major portion of this work proceeds in Livermore. Conventional high explosives facilities are located at Site 300 in the vicinity of Livermore. A small, permanent group, stationed in Nevada, is concerned with preparation of tests.

The interest in thermonuclear explosions has been extended to the study of controlled thermonuclear reactions. This work is carried on jointly with LRL - Berkeley, where a smaller fraction of the facilities are located. The Livermore's work in this field involves:

1. Exploration of containment of ionized gases in the mirror arrangement.
2. Exploration of the pinch effect.
3. Construction of equipment leading to the establishment of a circulating layer of electrons with the purpose of containing ionized gases.

The laboratory is also investigating high temperature, air cooled nuclear reactors with the ultimate purpose of achieving unmanned, nuclear-propelled flight. A part of this work consists of tests on unconventional reactors; these

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tests take place at the Nevada site. The scope of this project at Livermore encompasses:

1. Theoretical and systems study of a nuclear propelled ram-jet.

2. Materials investigation of possible components of a high temperature air-cooled reactor.

3. Assembly of critical masses of model reactors at various temperatures.

4. Running of an air-cooled full-scale reactor prototype on the ground.

In the last year increasing attention has been paid to the peaceful uses of nuclear explosives. The program as now visualized includes:

1. Theoretical investigation of possible peaceful uses.

2. Execution of excavation shots aimed at the establishment of harbors and other facilities.

3. Execution of shots aimed at novel methods of oil production.

4. Execution of shots in various media (salt, granite, limestone), aimed at the exploration of special effects and processes.

All these activities are supported by a modest program of basic research in nuclear physics and in related subjects.

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LAWRENCE RADIATION LABORATORY - LIVERMORE
Livermore, California

Eight Year Trend - Costs, Staff, and Facilities
(dollar amounts are in millions)

Fiscal Year	1960 b/	1959	1958	1957	1956	1955	1954	1953
Research and Development Costs:[a/]								
Weapons Program	$44.7	$40.6	$35.0	$26.3	$20.5	$13.5	$12.8	$ 6.0
Reactor Development Program:								
Missile propulsion	11.5	6.9	2.9	3.3	1.5	-	-	-
General reactor research and development	.1	-	-	-	-	2.5	1.5	1.2
Total Reactor Development	11.6	6.9	2.9	3.3	1.5	2.5	1.5	1.2
Physical Research Program:								
Controlled thermonuclear research	5.5	5.3	5.6	4.1	3.2	2.2	.7	.3
Civilian applications of nuclear explosives (Plowshare)	4.0	1.3	.3	-	-	-	-	-
Total Research and Development Costs	$65.8	$54.1	$43.8	$33.7	$25.2	$18.2	$15.0	$ 7.5
Personnel at June 30:								
Scientific and engineering		931	885	778	654	535	428	275
Other		2,711	2,141	1,883	1,418	969	611	350
Total Employees		3,642	3,026	2,661	2,072	1,504	1,039	625
Completed Plant and Equipment at June 30:[c/]								
Accelerators		$ 3.0	$ 4.1	$ 3.9	$ 3.8	$ .5	$ .2	$ -
Reactors		1.5	.8	.3	.3	.3	.3	-
Other		45.0	34.4	28.0	25.1	22.7	5.1	1.6
Total		$49.5	$39.3	$32.2	$29.2	$23.5	$ 5.6	$ 1.6

a/ Excludes depreciation on AEC facilities and the cost of source and special nuclear materials consumed in research.

b/ Estimated.

c/ Plant projects authorized but not completed at June 30, 1959 totaled $6.4 million.

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LAWRENCE RADIATION LABORATORY - LIVERMORE

Current Budget and Recent Costs by Categories of Work
(in thousands)

	F. Y. 1958 Costs	F. Y. 1959 Costs	F. Y. 1960 Budget
TOTAL	$43,750	$54,110	$65,800
Weapons Development - Total	34,955	40,540	44,700
Reactor Development - Total	2,867	6,939	11,600
Missile Propulsion Reactors	2,867	6,939	11,500
All other reactor research and development	-	-	100
Physical Research Program - Controlled Thermonuclear Research - Total	5,602	5,292	5,500
Civilian Application of Nuclear Explosives Program-Total	326	1,339	4,000
Design, Development and Test Direction	326	1,064	2,500
Demonstration Tasks	-	275	1,500

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Future Plans

The personnel strength of LRL - Livermore, as of the end of fiscal year 1960 is expected to be approximately 4,000, Livermore has expanded rapidly in recent years, with a large part of the effort going into weapon research. In the long run, however, greater effort will be devoted to the non-military fields. With or without a test moratorium, the laboratory should increase very gradually for two or three years (at about 200 per year). Thereafter, the overall strength should remain nearly constant unless weapons needs fall off significantly because of disarmament progress.

Weapons

There are currently slightly over 1600 technical personnel directly engaged in this activity. This may grow to the order of 2000 by 1963. Following that, it is expected that Livermore's weapons development activity will stabilize. In the absence of full-scale nuclear testing, a gradual manpower reduction among the weapons group might then begin. However, any shrinkage probably would be slow.

Nuclear Ramjet Propulsion: The present work is directed toward eventual groun tests of military high-temperature propulsion reactors, Project Pluto. Success at that stage may lead to laboratory participation in the development of a flying prototype. If the Pluto concept appears feasible, it is also likely that the laboratory will shift its emphasis somewhat from the military to broader civilian applications. The laboratory would, in this case, plan to construct and operate small prototype reactors to pursue feasibility of this system further. As foreseen now, the laboratory's level of effort, in this area, should increase slightly over the ten-year period.

Controlled Thermonuclear Research: This is another non-weapons research prog being pursued vigorously at the laboratory. Approximately 270 personnel, primaril technical, are directly involved. Considering the technical difficulties surrounding this project, it is difficult to foresee any general lessening of scientific

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effort in this area. Indeed, as Sherwood progress identifies new problems in the control of this type of energy release, we can expect it to lead into further studies of the behavior of hot ionized gases and to result in new techniques for the handling of electrical discharges and related phenomena.

Peaceful Uses of Nuclear Explosions: At present, some 100 professional personnel are assigned to the effort. This number will increase to approximately 150 by 1961 and should remain relatively constant thereafter.

Other Activities: In the event any cessation or limitation on nuclear testing affects the Livermore level of activity, consideration will be given to emphasizing one or more basic or applied scientific programs in which the laboratory has unusual competence and in which it is presently conducting a limited amount of research activity. Included among these might be: geophysics, particularly as related to meteorological prediction, seismology, and high atmosphere physics; low energy physics; stellar constitution; and behavior of elementary particles.

These basic research programs also would serve to broaden the scientific base of the laboratory, tend to maintain its standing in the scientific community, and thus, be of extreme importance in attracting and retaining outstanding people.

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LOS ALAMOS SCIENTIFIC LABORATORY

The Los Alamos Scientific Laboratory was established under a contract with the University of California in the early part of 1943 to provide a focal point for the previously diversified research directed towards the feasibility of an atomic bomb. Its initial staffing was partly military and partly civilian although the major technical direction was primarily the latter. It attained its wartime peak strength during the summer of 1945 with about 1500 civilians and 2000 military personnel more or less directly involved in laboratory activities.

The laboratory conducted the first nuclear weapons test at Almagordo on July 16, 1945, and provided the actual weapons and the technical crews associated with them for the bomb drops the following month.

By the time of the adoption of the Atomic Energy Act of 1946, the technical military staff of the laboratory had essentially vanished and the civilian staff had decreased to about 1300. Nevertheless, the laboratory successfully provided the nuclear devices for use in Operation Crossroads at Bikini in 1946 and participated in other technical aspects of this operation.

Following the decision by the AEC to continue the laboratory as a permanent institution, the laboratory began to increase in size, as shown on the accompanying chart.

During the first half dozen years after the war the laboratory concentrated almost all of its applied research and development on problems of atomic weapons development, climaxed by the successful development of the thermonuclear fusion principle for weapons in 1951. Since then the laboratory has broadened the base of its activities by applying to other areas of national interest various of the skills and technologies developed in connection with weapon activities.

The current missions of LASL include general conduct of basic and applied research in the fields of nuclear weapons, thermonuclear and fission power programs,

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DOE ARCHIVES

and nuclear rocket propulsion systems. The laboratory contains research facilities and equipment appropriate to fundamental research in nuclear physics, chemistry, metallurgy and cryogenics; computational techniques, biophysics, and diochemistry. Research is conducted in all these fields.

The primary mission of the laboratory is weapons development. In the weapons field the laboratory is specifically responsible for:

1. Experimental, theoretical, and applied research in the various sciences related to the use of atomic energy in weapon systems.

2. Design and development of all components for assigned weapon programs which specifically relate to the production of a nuclear explosion.

3. Participation in weapon system studies with other laboratories and/or military agencies.

4. Development of suitable production techniques, engineering evaluation, and maintenance of design intent in production, and assurance of quality of weapon nuclear components.

5. Participation in the scientific and diagnostic aspects of nuclear test operations including certain operational support activities.

Investigation of the feasibility of nuclear rocket propulsion is another important mission. In this field the laboratory is responsible for theoretical design and system studies of various types of potential uses of nuclear energy for rocket propulsion, materials, studies, construction and operational test of prototype and preliminary models, participation with National Aeronautics and Space Administration and other agencies in system studies potentially utilizing nuclear rocket propulsion, and participation in the nuclear aspects of full scale nuclear motor or nuclear flight tests in collaboration with NASA.

Another major mission of the laboratory is the study of the production of power from the fission process. In this field the laboratory primarily concerns itself with homogeneous or mobile fuels; systems which burn plutonium; very high temperature gas cooled systems whose character, in part, may be related to technologies developed in the nuclear rocket systems, and systems in which there is a direct conversion of thermal to electrical energy such as the plasma thermocouple.

Another mission of the laboratory is the study of the possible production of power from the thermonuclear fusion process. In this field the laboratory primarily concerns itself with the theory and experimental characteristics of the pinch effect and with the construction, study, and understanding of various laboratory-size devices exploring the containment, stability, temperature, and neutron production of differently generated and contained plasmas.

The biomedical activities grew up in recognition of the unique and difficult health problems that Los Alamos workers would face as a result of handling plutonium. Most of the biomedical work has continued to be directly related to weapons research, development, and testing, but many of the problems encountered have necessitated basic research on radiation biology, biochemistry, biophysics, radiochemistry, and instrumentation.

A final mission of the laboratory is participation in the scientific life of the United States through basic research and its publication in those areas which are peripheral to and stimulate the more specifically programmatic missions of the laboratory, and through cooperation with education and industrial research institutions.

LOS ALAMOS SCIENTIFIC LABORATORY
Los Alamos, New Mexico

Ten Year Trend - Costs, Staff, and Facilities
(dollar amounts are in millions)

Fiscal Year	1960 b/	1959	1958	1957	1956	1955	1954	1953	1952	1951
Research and Development Costs: a/										
Weapons Program	$35.6	$35.6	$36.9	$35.4	$35.7	$36.6	$39.9	$40.6	$38.2	$27.6
Reactor Development Program:										
Missile propulsion	15.8	12.1	7.9	5.9	2.8	-	-	-	-	-
General reactor research and development	5.5	3.3	3.0	2.2	1.6	-	-	-	-	-
Total Reactor Development	21.3	15.4	10.9	8.1	4.4	-	-	-	-	-
Physical Research Program:										
Controlled thermonuclear research	3.3	3.0	2.3	1.8	1.1	1.0	.3	.1	.1	.1
Biology and Medicine Program:										
Biomedical problems in atomic energy operations	1.0	1.0	.9	.9	.8	.7	.7	.7	.6	.7
Total Research and Development	$61.2	$55.0	$51.0	$46.2	$42.0	$38.3	$40.9	$41.4	$38.9	$28.4
Personnel at June 30:										
Scientific and engineering		979	934	857	778	725	679	602	529	464
Other		2,322	2,301	2,320	2,218	2,220	2,317	2,290	2,233	2,176
Total Employees		3,301	3,235	3,177	2,996	2,945	2,996	2,892	2,762	2,640
Completed Plant and Equipment at June 30: c/										
Accelerators		$ 2.0	$ 2.0	$ 2.0	$ 2.0	$	$	$	$	$
Reactors		.6	.6	.6	.6					
Other		138.0	125.2	120.4	119.4	117.4	119.9	95.3	63.4	49.4
Total		$140.6	$127.8	$123.0	$122.0	$117.4	$119.9	$95.3	$63.4	$49.4

a/ Excludes depreciation on AEC facilities and the cost of source and special nuclear materials consumed in research.

b/ Estimated.

c/ Plant projects authorized but not completed at June 30, 1959 totaled $22.8 million.

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LOS ALAMOS SCIENTIFIC LABORATORY

Current Budget and Recent Costs by Categories of Work
(In thousands)

	F.Y. 1958 Costs	F.Y. 1959 Costs	F.Y. 1960 Budget
TOTAL	$51,076	$54,940	$61,210
Weapons Development - Total	36,918	35,572	35,599
Reactor Development - Total	10,868	15,420	21,270
Nuclear Technology and General Support - Total	2,999	3,242	5,470
Engineering Physics and Advanced Reactor Development	2,999	3,242	5,450
Residue Disposal Development	-	-	20
Missile Propulsion Reactor - Rover - Total	7,869	12,178	15,800
Research and Development	6,791	7,956	-
Fuel Fabrication	97	600	-
Operations	446	3,177	-
Reactor Experiment	535	445	-
Controlled Thermonuclear Research	2,355	2,989	3,350
Biology and Medicine - Biomedical Problems in Atomic Energy Operations	935	959	991

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DOE ARCHIVES

Future Plans

Current plans for LASL contemplate continued operation of the laboratory at near its present strength of about 3,400 employees, including about 1,000 scientists and engineers. Over the decade, a slow growth (of the order of 10 or 15 percent of the present strength) may occur if the weapons development effort remains strong and other programs develop as anticipated.

The relative stability in size anticipated for the future is the result of two factors: (1) the desire to maintain the capabilities of the laboratory intact during any weapons testing moratorium, and (2) the limitation on growth imposed by the site and the dwelling space in the community.

The experience of LASL in the Rover project, in controlled thermonuclear research, and advanced reactor concepts indicates that staff can be transferred to other assignments if freed from weapons development. Such transfers would not be in the nature of make-work; to the extent that it can be made available, the Los Alamos staff can be expected to make first rate contributions in many of the research and development areas in which increased effort is required.

Weapons: For the next few years, the task of weaponizing newly-developed devices and continuing the development of new devices based upon present test data should absorb the major portion of LASL's manpower. However, unless nuclear testing on some basis occurs, this workload probably will decrease slowly but significantly, over the next ten years. Approximately two-thirds of the technical staff is presently engaged in LASL's weapons programs or on basic research related directly, or indirectly to the weapon effort. A long-term severe test limitation or ban would result in a very sizable reduction in this number by 1970.

Rover: A little over 300 persons (primarily technical) are now directly engaged in work on nuclear rocket propulsion, with employment expected to level off at 400-500 by 1963. Depending upon the success of the prototypes, by the

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mid-1960s, the effort will shift from feasibility demonstrations of the initial reactor concept to a greater emphasis upon advanced concepts and technical support for the rising agency or agencies. Additional related laboratory work is expected to be assigned as a result of NASA activities.

Civilian Reactors: The advanced concept work on mobile fuels, high temperature systems, and plutonium burners is expected to remain fairly stable in size unless weapons activity permits the assignment of additional staff.

Controlled thermonuclear research: No major change in the level of effort in this area is currently foreseen.

Direct Conversion: This program, the elimination of the thermal cycle in converting nuclear energy to electricity, engages about 40 people at present. It is expected to grow to a staff of 70 to 100 if weapons work permits. Considerably greater emphasis may be placed upon this activity in the event of a significant breakthrough.

Biomedical Research: The total program will remain quite stable in the coming years. Continued emphasis will be placed on scintillation counting techniques for monitoring and whole body counting purposes. Attempts to recreate under laboratory conditions the exposure rates of a fresh fallout gamma field will expand slightly along with measures of changes in recovery mechanisms and resistance to stress. Smaller studies in cell injury and metabolism will provide data pertinent to the whole body effects of radiation under investigation. Some expansion in studies on the toxicity of tritium and tritiated compounds is anticipated, offset by the completion of other studies of fission product metabolism and effects. The program on the long term effects of partial body and whole body irradiation will continue. The close adherence of the Los Alamos Scientific Laboratory program to the programmatic needs of the Commission will continue.

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SECTION SIX

PROJECT ENGINEERING LABORATORIES

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DOE ARCHIVES

BETTIS LABORATORY

The execution of a contract between the AEC and the Westinghouse Electric Corporation on December 29, 1948 for the development of a nuclear propulsion plant for submarine application marks the origin of the Bettis Plant. The Bettis Plant is wholly owned by the government and is operated for the AEC by the Westinghouse Electric Corporation.

The Submarine Thermal Reactor was the first large-scale development project assigned to the Bettis Plant. This project resulted in the development, construction, and test of the land prototype (S1W) of the water-cooled reactor plant for the USS Nautilus, followed by installation of the first submarine reactor plant in the Nautilus itself (S2W). The prototype was constructed at the National Reactor Testing Station; power operation began in May, 1953. The Nautilus went to sea in January, 1955.

In order to quickly exploit the Nautilus development and Bettis' experience in the field of water reactor technology, the AEC assigned the Bettis Plant the responsibility for the development of the USS Skate type of submarine nuclear propulsion plant; the development of the Pressurized Water Reactor(PWR) Plant for the nation's first full scale central station atomic power plant at Shippingport, Pennsylvania; the development of the nuclear propulsion plant for use in single screw, high speed, attack and Polaris missile launching submarines; and the development, construction, operation and test of a prototype nuclear propulsion plant for application to large naval surface ships such as aircraft carriers and guided missile cruisers.

The Bettis Plant has about 600,000 square feet of engineering offices, laboratories, fuel fabrication and test facilities and shop space, and leases an additional 300,000 square feet of offices and laboratory space in the Pittsburgh area.

DOE ARCHIVES

BETTIS LABORATORY
Pittsburgh, Pennsylvania

Ten Year Trend - Costs, Staff and Facilities
(dollar amounts are in millions)

Fiscal Year	1960	1959	1958	1957	1956	1955	1954	1953	1952	1951
Research and Development Costs:[a]										
Production Program	$ -	$ -	$ .1	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Reactor Development Program:										
Civilian power reactors	16.2	15.5	16.7	14.4	14.6	10.0	7.2	-	-	-
Merchant ship	-	-	-	-	-.1	-	-	-	-	-
Naval propulsion	37.1	39.7	47.2	40.9	18.8	8.4	8.4	19.3	11.9	7.1
Total Reactor Development	53.3	55.2	63.9	55.3	33.5	18.4	15.6	19.3	11.9	7.1
Total Research and Development	$ 53.3	$ 55.2	$ 64.0	$ 55.3	$ 33.5	$ 18.4	$ 15.6	$ 19.3	$ 11.9	$ 7.1
Personnel at June 30:										
By Types										
Scientific and Engineering		1036	1109	824					c/	
Other		2591	3630	3197						
Total Employees		3627	4739	4021					1366	1180
By Location										
Pittsburgh, Pennsylvania		2917	3940	3472					1366	1180
National Reactor Testing Station, Idaho		710	799	549					-	-
Completed Plant and Equipment at June 30:[d]										
By Type										
Reactors		$ 46.6	$ 17.2	$ 16.3	$ 15.8	$ 22.2	$ 22.2	$ -	$ -	$ -
All other		48.9	35.5	31.0	23.0	20.1	17.9	16.9	14.4	6.2
Total		$ 95.5	$ 52.7	$ 47.3	$ 38.8	$ 42.3	$ 40.1	$ 16.9	$ 14.4	$ 6.2
By Locations										
Pittsburgh, Pennsylvania		39.7	36.0	31.8	23.6	20.9	19.1	16.9	14.4	6.2
National Reactor Testing Station, Idaho		55.8	16.7	15.5	15.2	21.4	21.0	-	-	-

a/ Excludes depreciation on AEC facilities and the cost of source and nuclear materials consumed in research.
b/ Estimated.
c/ Detail not available in this and prior years.
d/ Plant projects authorized but not completed at June 30, 1959, totaled $18.9. Of this amount, $9.7 will be located at Pittsburgh and $9.2 at NRTS.

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BETTIS LABORATORY

Current Budget and Recent Costs by Categories of Work
(in thousands)

	F.Y. 1958 Costs	F.Y. 1959 Costs	F.Y. 1960 Budget
TOTAL	$ 64,022	$ 55,202	$ 53,275
Production Process Development - Total	75	15	-
Reactor Development Program - Total	63,947	55,185	53,275
Pressurized Water Reactor - Total	16,698	15,476	16,185
Research and Development	15,847	12,837	9,910
Fuel Fabrication	596	1,975	5,540
Test Operations	255	664	735
Naval Propulsion Reactors - Total	47,249	39,709	37,090
Attack Submarine Reactor	5,059	2,907	6,410
Natural Circulation Test Plant	-	-	780
Large Ship Reactor - Total	28,116	22,955	19,350
Research and Development	14,361	12,252	13,540
Fuel Fabrication	13,755	6,973	2,275
Operations	-	3,730	3,535
Guided Missile Cruiser Reactor	4,338	2,811	2,600
Submarine Thermal Reactor - Total	7,828	7,292	4,290
Research and Development	1,527	4,065	1,400
Fuel Fabrication	2,879	599	400
Operations	3,422	2,628	2,490
Expanded Core Facility	664	1,138	1,310
High Temperature Test Facility	-	1,148	1,700
Naval Reactor Design Studies	1,244	1,458	700
Training, Education and Information Programs - Total	-	2	-

0015041

Future Plans

To take care of the simultaneous development of the Submarine Fleet Reactor Project (S3W/S4W), the High Speed Submarine Reactor Project (S5W), Guided Missile Cruiser Project (CLW), Large Ship Reactor Project (A1W/A2W) and the Pressurized Water Reactor Project (PWR) power plants, the number of personnel at Bettis increased to nearly 5,000. This number of developmental projects could not have been carried out on schedule without such a buildup in personnel. This expansion also required additional facilities, and it was necessary to lease additional office and laboratory space in the Pittsburgh area.

Although this expansion was necessary, it has been concluded that, in the Naval reactor Development program, research and development laboratory of 5,000 people is too large to insure continued efficient operation and program control. With the completion of some phases of some of the naval reactors projects, the number of personnel, primarily non-technical personnel, is being reduced to permit more effective utilization of the development potential of Bettis. As the preceding chart shows, such a personnel cutback is already underway.

The use of leased facilities, requiring that Bettis' operations be carried on at two separate locations, complicates the operation of the laboratory. With a reduction in the number of personnel at Bettis, a consolidation of the laboratory at the main Bettis site becomes feasible. This will require the construction of an engineering building at Bettis.

It is now expected that the total level of employment at Bettis will drop somewhat below 3,000 early in the ten-year period and remain below this figure.

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DOE ARCHIVES

CONNECTICUT AIRCRAFT NUCLEAR ENGINE LABORATORY (CANEL)

CANEL is an Air Force owned facility, specifically designed to provide for the development of an indirect cycle nuclear powerplant for aircraft propulsion. The facility is operated by the Pratt & Whitney Aircraft Division of United Aircraft Corporation, under contract with the Air Force. The major effort at CANEL at the present time is being sponsored by the Atomic Energy Commission. This effort consists of research and development leading to high performance, liquid metal cooled, aircraft propulsion reactors. A less extensive research and development effort, on propulsion components external to a reactor-shield assembly, is being sponsored by the Air Force and the Navy.

The CANEL facility is located on the west bank of the Connecticut River, approximately 18 miles south of Hartford. The facility site is roughly circular with an exclusion radius of approximately 4000 feet. Construction was initiated by the Air Force during calendar year 1955. The site was chosen because of its proximity to the Pratt & Whitney main plant at East Hartford, Connecticut, because it is relatively remote from cities and towns, and because of the availability of large quantities of cooling water, a navigable river, and adequate electric power.

The CANEL facility provides about 680,000 square feet of laboratory, shop, and administrative space which currently houses approximately 1,600 people, including about 375 technical employees. The facilities either presently in place, now under construction or planned for the immediate future represents an Air Force investment of about $60,000,000. These facilities provide for the design,

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development, fabrication, test and post-test inspection of experimental aircraft reactors and components external to the reactor-shield assembly. The present work at CANEL is directed primarily towards solving materials problems associated with high temperature reactor fuel elements and other components such as heat exchangers, valves and pumps peculiar to liquid reactor systems.

The upward trend in activity is expected to continue through fiscal year 1961, after which a fairly stable level should be maintained until the mid-60's. An increase will be required during the major hardware phase of the program leading to a ground test prototype, and assuming successful completion of ground tests, a further step-up of activity would be required in preparation for flight tests.

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CONNECTICUT AIRCRAFT NUCLEAR ENGINE LABORATORY
Hartford, Connecticut

Nine Year Trend - Costs, Staff, and Facilities
(dollar amounts are in millions)

Fiscal Year	1960 b/	1959	1958	1957	1956	1955	1954	1953	1952
Research and Development Costs: a/									
Reactor Development Program:									
Manned aircraft propulsion	$17.5	$16.0	$14.2	$14.8	$10.0	$ 3.8	$ 1.6	$ -	$ -
Total Research and Development	$17.5	$16.0	$14.2	$14.8	$10.0	$ 3.8	$ 1.6	$ -	$ -
Personnel at June 30:									
Scientific and engineering		401	391	388	270	135	62	40	45
Other		1,193	1,067	741	264	57	13	8	5
Total Employees		1,594	1,458	1,129	534	192	75	48	50
Completed Plant and Equipment at June 30: c/		$ 4.3	$ 2.8	$ 2.3	$ 1.9	$ 1.1	$ .2	$ -	$ -

a/ Excludes depreciation on AEC facilities and the cost of source and special nuclear materials consumed in research.

b/ Estimated.

c/ Principally equipment; the buildings are owned by the Air Force.

0015045

CONNECTICUT AIRCRAFT NUCLEAR ENGINE LABORATORY

Current Budget and Recent Costs by Categories of Work
(In Thousands)

TOTAL	F.Y. 1958 Costs	F.Y. 1959 Costs	F. Y. 1960 Budget
TOTAL	$14,186	$15,977	$17,500
Reactor Development - Aircraft Propulsion Indirect Cycle - Total	14,186	15,977	17,500
Low Power Reactor Experiment	-	-	9,700
Advanced Research and Development	14,186	15,977	7,800

0015046

KNOLLS ATOMIC POWER LABORATORY

The Knolls Atomic Power Laboratory had its inception in 1946 when the AEC signed a contract with the General Electric Company for the operation of a laboratory for research and development in atomic energy.

The primary effort during the early histroy of the Laboratory was the sodium-cooled breeder reactor. Supporting work for Hanford also was carried on. When work on the sodium breeder reactor stopped, the effort of the Laboratory was reoriented to the Submarine Intermediate Reactor project. This was the first large scale development effort for navel ship application to be undertaken at the Knolls Atomic Power Laboratory. This project resulted in the development, construction, and test of the land prototype (S1G) of the sodium-cooled reactor plant for the USS Seawolf. This prototype was constructed at West Milton, New York; it achieved criticality in March, 1955, and was operated for test and evaluation until it was shut down in February, 1957. The sodium reactor plant (S2G) installed in the USS Seawolf achieved criticality in June, 1956. This plant operated for two years during which the ship steamed over 71,000 miles. However, the Submarine Intermediate Reactor project was discontinued at Knolls because sodium proved less suitable than pressurized water as a coolant for naval reactors, and the Seawolf's reactor is now being replaced by a water-cooled reactor plant similar to that of the USS Nautilus.

Knolls is currently assigned three major reactor development projects for naval application; the Submarine Advanced Reactor project (S3G/S4G), the Destroyer Reactor project (D1G/D2G), and, most recently, a natural

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DOE ARCHIVES

circulation pressurized water plant for submarine application. The Submarine Advanced Reactor project provides for the design, construction, development and test of a two-reactor pressurized water nuclear propulsion plant for the radar picket submarine Triton. A land prototype of one reactor of this plant was constructed at West Milton, New York and is now undergoing test and evaluation. The Destroyer Reactor project (D1G/D2G) was assigned to Knolls in fiscal year 1957. This project covers the development of a pressurized water nuclear propulsion plant for installation in a large destroyer-type naval ship. Because of the developmental nature of this plant a land prototype is being constructed at West Milton, New York in the 225-foot diameter sphere which previously housed the land prototype of the Seawolf sodium-cooled propulsion plant.

The Knolls Atomic Power Laboratory has about 580,000 square feet of engineering offices, laboratories and shop space and employs about 2,200 people, about 700 of whom are engineers and scientists.

The size of the staff at Knolls has been relatively stable since 1952, and no significant changes are expected in the foreseeable future.

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DOE ARCHIVES

KNOLLS ATOMIC POWER LABORATORY
Schenectady, New York

Ten Year Trend - Costs, Staff, and Facilities
(dollar amounts are in millions)

Fiscal Year	1960 b/	1959	1958	1957	1956	1955	1954	1953	1952	1951
Research and Development Costs: a/										
Production Program	$ -	$ -	$ .1	$ .3	$ .5	$ .9	$ 1.4	$ 2.6	$ 2.7	$ 2.8
Weapons Program	-	-	-	-	-	-	-	.3	.1	-
Reactor Development Program:										
Naval propulsion	32.6	31.3	32.2	24.2	20.0	18.1	16.0	13.4	9.3	7.7
General reactor research and development	-	-	.3	1.3	1.1	1.1	1.1	.8	1.1	.8
Total Reactor Development	32.6	31.3	32.5	25.5	21.1	19.2	17.1	14.2	10.4	8.5
Physical Research Program	.5	.3	.4	.8	.9	.3	.1	-	-	.2
Biology and Medicine Program	-	.1	.1	.1	.1	.1	.1	.1	-	-
Total Research and Development Costs	$33.1	$31.7	$33.1	$26.7	$22.6	$20.5	$18.7	$17.2	$13.2	$11.5
Personnel at June 30:										
Scientific and engineering		670	606	484	473	440	353	375	307	238
Other		1,508	1,553	1,633	1,670	1,757	1,717	1,802	1,610	1,408
Total Employees		2,178	2,159	2,117	2,143	2,197	2,070	2,177	1,917	1,646
Completed Plant and Equipment at June 30: c/										
Reactors		$34.7	$12.2	$11.3	$32.4	$30.7	$ -	$ -	$ -	$ -
Other		38.7	38.1	35.1	34.1	34.4	34.1	33.4	32.0	30.5
Total		$73.4	$50.3	$46.4	$66.5	$65.1	$34.1	$33.4	$32.0	$30.5

a/ Excludes depreciation on AEC facilities and the cost of source and special nuclear materials consumed in research.

b/ Estimated.

c/ Plant projects authorized but not completed at June 30, 1959 totaled $38.0 million.

0015049

KNOLLS ATOMIC POWER LABORATORY

Current Budget and Recent Costs by Categories of Work
(in thousands)

	F.Y. 1958 Costs	F.Y. 1959 Costs	F.Y. 1960 Budget
TOTAL	$ 33,068	$ 31,655	$ 33,051
Production Process Development - Total	65	-	-
Reactor Development Program - Total	32,526	31,255	32,598
Reactor Systems	329	-	-
Nuclear Technology	14	23	13
Naval Propulsion Reactors - Total	32,183	31,232	32,585
Submarine Advanced Reactor - Total	24,216	18,901	13,290
Research and Development	17,503	14,915	10,790
Fuel Fabrication	5,792	1,043	-
Operations	921	2,943	2,500
Natural Circulation Test Plant	-	-	3,200
Destroyer Reactor - Total	7,717	12,166	16,095
Research and Development	7,717	12,166	15,520
Fuel Fabrication	-	-	75
Operations	-	-	500
Naval Reactor Design Studies	250	165	-
Physical Research Program - Total	395	341	453
Special Projects	365	341	453
Metallurgy and Materials Research - Total	30	-	-
Alloy Theory and the Nature of Solids	8	-	-
Effects of Irradiations on Materials	22	-	-
Biomedical Problems in Atomic Energy Operations	82	59	-

0015050

LOCKLAND AIRCRAFT NUCLEAR PROPULSION LABORATORY

Although the Lockland facility is owned by the Air Force, it is included in this discussion because it is a major government-owned institution carrying on an AEC development program. Performance of the work by the General Electric Company has been supported jointly by the Air Force and the Commission since 1951. The project as a whole is aimed at the development of a direct cycle, nuclear propelled aircraft engine.

The Air Force is responsible for the propulsion machinery, other than the reactor itself, and the AEC sponsors the work on the reactor.

The major problems toward which the work is directed include the development of fuel elements and structural material capable of withstanding the high temperatures which must be reached in order to achieve the necessary performance, and the shield problems which result from the weight limitations within which the machine must be designed. Facilities for testing reactors developed at Lockland have been constructed at the National Reactor Testing Station in Idaho where a substantial supporting facility is operated by the General Electric Company as a part of its AEC contract.

The facilities at Lockland used in the AEC work represent an Air Force investment of approximately $38,000,000, about 3,000 people are currently employed on the AEC work, of whom 625 are scientific and engineering personnel.

0015051

The Lockland facilities include metallurgy, physics and chemical laboratories, critical experiment cells, and fabrication shops. The fabrication capability is approximately two reactor-shield assemblies per year.

The current level of effort appears appropriate for the next few years, with some increase during the major hardware phase of the program leading to a ground test prototype. Assuming successful completion of ground tests, a higher level of activity will be required as the work is directed toward flight tests.

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LOCKLAND AIRCRAFT NUCLEAR PROPULSION LABORATORY
Lockland, Ohio

Nine Year Trend - Costs, Staff and Facilities
(dollar amounts are in millions)

Fiscal Year	1960 b/	1959	1958	1957	1956	1955	1954	1953	1952	1951
Research and Development Costs: a/										
Manned aircraft propulsion	$41.3	$45.7	$40.0	$32.2	$17.9	$ 8.1	$ 5.8	$ 9.6	$ 3.5	
Total Research and Development Costs	$41.3	$45.7	$40.0	$32.2	$17.9	$ 8.1	$ 5.8	$ 9.6	$ 3.5	
Personnel at June 30:										
By Type:										
Scientific and Engineering		625	487	435	328	187	127	179	156	
Other		2356	1948	1981	1233	701	451	681	420	
Total Employees		2981	2435	2416	1561	888	578	860	576	
By Location:										
Lockland, Ohio		2490	2000	2006	1228	695	535	860	576	
National Reactor Testing Station, Idaho		491	435	410	333	193	43	-	-	
Completed Plant and Equipment at June 30: c/										
By Type:										
Reactors		$ 1.5	$ .1	$ -	$ -	$ -	$ -	$ -	$ -	
All other		39.4	28.2	19.1	15.3	1.5	1.0	.6	.1	
Total		$40.9	$28.3	$19.1	$15.3	$1.5	$ 1.0	$ .6	$ .1	
By location:										
Lockland, Ohio d/		$ 7.6	$ 5.9	$ 3.6	$ 2.0	$ 1.5	$ 1.0	$ .6	$ .1	
National Reactor Testing Station, Idaho		33.3	22.4	15.5	13.3	-	-	-	-	

a/ Excludes depreciation on AEC facilities and the cost of source and nuclear materials consumed in research.

b/ Estimated.

c/ Plant projects authorized but not completed at June 30, 1959, totaled $23.0, of which $21.8 is to be located at NRTS.

d/ Principally equipment; the buildings are owned by the Air Force.

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DOE ARCHIVES

LOCKLAND AIRCRAFT NUCLEAR PROPULSION LABORATORY

Current Budget and Recent Costs by Categories of Work
(In Thousands)

	F.Y. 1958 Costs	F.Y. 1959 Costs	F.Y. 1960 Budget
TOTAL	$39,961	$45,681	$41,332
Reactor Development - Aircraft			
Propulsion Direct Cycle - Total	39,961	45,681	41,332
Heat Transfer Reactor Experiment No. 2	-	3,035	2,300
Research and Development	-	809	70
Fuel Fabrication		406	1,200
Operations	-	719	1,000
Reactor Experiment Fabrication	-	1,101	30
Heat Transfer Reactor Experiment No. 3	-	5,043	1,100
Research and Development	-	22	60
Fuel Fabrication	-	1,974	40
Operations	-	931	900
Reactor Experiment Fabrication	-	2,116	100
Propulsion System Ground Test	-	17,292	5,100
Research and Development	-	13,856	2,100
Fuel Fabrication	--	168	-
Operations	-	102	-
Reactor Experiment Fabrication	-	3,166	3,000
Advanced Core Test	-	-	5,000
Advanced Research and Development	-	20,311	27,832

0015054

SANDIA LABORATORY

The wartime mechanical work of assembling atomic weapons was performed at Sandia Base, near Albuquerque, by scientists of the Los Alamos Laboratory working with personnel of the Armed Forces. After the war, the facilities at Sandia Base were expanded somewhat and were operated for several years by the University of California as an extension of the Los Alamos Laboratory.

In order to relieve Los Alamos of production problems, the operation of the Sandia Laboratory was transferred on November 1, 1949, to the Sandia Corporation, a wholly-owned subsidiary of Western Electric Company, formed specifically to take over this contract. The Sandia Laboratory has been expanded to keep pace with the number of different weapon types. The present strength of the Sandia Corporation as a whole is 8000, of whom about 6,900 are employed in the Albuquerque facilities.

In 1956, when the decision was made to "weaponize" designs of LRL - Livermore, a branch of the Sandia Corporation was established at Livermore, California, to support directly the efforts of the Laboratory. At present, its facilities are being completed, and it is near its planned strength of 850. The Livermore installation provides such support as must be located close to Lawrence Radiation Laboratory, but leans heavily on the Albuquerque facility for work that can effectively be accomplished there. In addition to the Albuquerque and Livermore locations, some 100 employees of the Corporation operate range-test facilities at Salton Sea, California, Tonopah, Nevada, and the ballistic ranges and approximately 125 carry out manufacturing-related and inspection tasks at vendors' plants and related locations.

0015055

The basic mission of the Sandia Laboratory is the development of those portions of atomic weapons for which the AEC is responsible, exclusive of the high explosive and nuclear components which are developed by LASL and LRL - Livermore. For free-fall bombs, AEC responsibility includes the complete weapon; for missile applications, AEC normally provides a warhead including a firing set only.

In the exercise of this development responsibility, Sandia Laboratory also conducts component development, quality control, reliability engineering, tool and test equipment development, military liaison, and manufacturing relations.

0015056

SANDIA LABORATORY
Albuquerque, New Mexico

Ten Year Trend - Costs, Staff and Facilities
(dollar amounts are in millions)

Fiscal Year	1960	1959	1958	1957	1956	1955	1954	1953	1952	1951
Research and Development Costs:[a]										
Weapons Program (Includes production costs)	$121.8	$ 96.4	$101.6	$ 90.3	$ 56.5	$ 60.8	$ 59.6	$ 69.3	$ 58.1	$ 37.1
Total Research and Development Costs	$121.8	$ 96.4	$101.6	$ 90.3	$ 56.5	$ 60.8	$ 59.6	$ 69.3	$ 58.1	$ 37.1
Personnel at June 30:										
Scientific and engineering		1907	1753	1521	1296	1289	1258	1155	c/	
Other		6034	5698	5361	4613	4417	4162	4251		
Total Employees		7941	7451	6882	5909	5706	5420	5406		
Completed Plant and Equipment at June 30:[d]										
By Type:										
Accelerators		$ .2	$ .2	$ -	$	$	$ -	$ -	$ -	$
All other		82.8	70.0	61.3	59.2	57.0	53.8	47.2	39.1	30.8
Total		$ 83.0	$ 70.2	$61.3	$59.2	$57.0	$53.8	$47.2	$39.1	$30.8
By Location:										
Albuquerque, New Mexico		75.3	68.7	61.1	59.2	57.0	53.8	47.2	39.1	30.8
Livermore, California		7.7	1.5	.2	-	-	-	-	-	-

a/ Excludes depreciation on AEC facilities and the cost of source and nuclear materials consumed in research.

b/ Estimated.

c/ Detail not available for this and prior year.

d/ Plant projects authorized but not completed at June 20, 1959, totaled $16.5, of which $15.7 will be located at Albuquerque.

0015057

Under test moratorium conditions, it is intended to continue the Sandia Laboratory at near its present strength permitting only a gradual reduction through 1970 for the following reasons:

1. It represents an invaluable collection of outstanding people and superior technical facilities which can make a distinct contribution to technical programs of importance to the nation.

2. It is necessary to retain, as a going organization, able individuals of varied qualifications who would be available as needed to work on weapons requirements as they arise.

3. Since weapon technology has so fully exploited the existing art of electronics, materials, and related fields, there is considerable need for concentrated research in those fields to prepare for the more sophisticated weapon needs of tomorrow. Weapon improvement in the mechanical-electrical field is less dependent upon nuclear test than similar improvements in the nuclear field.

With time, and if Sandia's weapon load decreases, other activities such as the following will be initiated or increased within the technical capacity and facilities available.

1. Increased effort in basic research and exploratory development.

This work is expected to provide better components, materials, and non-nuclear systems which can be employed without test; and to add greatly to the weapons technology available if and when testing is reopened. Major fields of investigation include: hydromagnetics, high temperature phenomena, solid-state physics, physical electronics, and combustion processes.

0015058

2. Study of Radiation Effects:

This work is concerned with the problem of the effects of the radiation environment created by a nuclear explosion on a ballistic missile warhead. Sandia Laboratory, with its new SERF reactor now under construction, can play a significant role in such studies and developmental work.

3. Development of Detection Systems.

Sandia Laboratory is well qualified to assist the DOD in developing a seismic system for detection of underground explosions and can also contribute to programs for the development of instrumentation and auxiliary equipment for sensing outer space detonations.

4. Support of Project Plowshare.

For Project Plowshare, Sandia Laboratory is currently conducting studies in cratering phenomena and containment of radioactive products. In addition, Sandia will support with effects instrumentation actual Plowshare shots, as it has done in previous development test series. Also, they will participate, as for their normal mission, in the product engineering of any devices developed specifically for Plowshare use.

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DOE ARCHIVES

SECTION SEVEN

PRODUCTION PLANT LABORATORIES

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During the approximately 15 years of operation of the Hanford Works, laboratory and semi-works facilities valued at more than $44,000,000 have been installed at that site; additional facilities are now under construction, at a cost of about $25,000,000. Of the total Hanford technically trained staff of about 1,400, approximately 700 are currently engaged in research and development programs. This organization was created to provide technical support for the production of plutonium and plutonium weapons components at Hanford. The scope of the research and development effort emphasizes applied research, process and equipment development, design development, prototype testing, and engineering evaluation of new and improved processes. These activities are carried on by the General Electric Company, operator of the entire Hanford complex.

Since Hanford was the first major reactor site, the research and development program to support the production activities was established on a relatively broad base, encompassing not only reactor design and operation, but also the study of nuclear and chemical safety, plutonium and uranium metallurgy, chemical separations technology, waste disposal, and environmental effects. The staff, in carrying out these varied activities in support of the production program, acquired skill and experience which could be applied beneficially to other atomic energy programs. Upon completion of the major efforts in connection with the expansion of the plutonium production facilities, the opportunity was taken to utilize these skills to advantage in other programs. The research and development program has thus been broadened to include important peaceful aspects of atomic energy.

The biology program originated with the need to insure an adequate radiation protection program, and to determine the possible effects of the

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reactor cooling water on aquatic life in the Columbia River. In recent years, the character of the research program has gradually changed towards a more basic approach to the problems being studied. In addition, a closer liaison between the northwestern universities and Hanford is developing which promises to be beneficial both to the university community and to the AEC.

Other non-production activities currently utilizing Hanford laboratory staff and facilities are the plutonium recycle program, power reactor fuel processing development, and fission product recovery and utilization studies.

Of these, the plutonium recycle program, involving development, design, and construction of the Plutonium Recycle Test Reactor and associated fuel fabrication facilities, is by far the largest; it engages about 20 percent of the effort of the laboratory.

0015062

HANFORD LABORATORY
Richland, Washington

Ten Year Trend - Costs, Staff, and Facilities
(dollar amounts are in millions)

Fiscal Year	1960 b/	1959	1958	1957	1956	1955	1954	1953	1952	1951
Research and Development Costs:[a/]										
Production Program	$12.4	$12.6	$10.4	$ 8.3	$ 9.0	$ 8.8	$ 8.7	$ 8.1	$ 6.3	$ 4.9
Weapons Program	.9	.7	.3	.2	.2	.1	.2	.8	.4	-
Reactor Development Program:										
Civilian power reactors	6.3	5.4	3.6	1.2	-	-	-	-	-	-
Merchant ship	.2	.6	.3	.1	-	-	-	-	-	-
General reactor research and development	.5	.3	-	-	-	-	-	-	-	-
Total Reactor Development	7.0	6.3	3.9	1.3	-	-	-	-	-	-
Physical Research	.6	.3	.3	.2	.2	.1	.1	-	-	-
Biology and Medicine Program:										
Biomedical problems in atomic energy operations	1.8	1.7	1.6	1.4	1.2	1.1	c/			
Dosimetry and instrumentation	.4	.3	.3	.3	.2	.2				
Total Biology and Medicine	2.2	2.0	1.9	1.7	1.4	1.3	1.3	1.3	1.1	.9
Total Research and Development	$23.1	$21.9	$16.8	$11.7	$10.8	$10.3	$10.3	$10.2	$ 7.8	$ 5.8
Personnel at June 30:										
Scientific and engineering		722	688	677	672	667	662	658	587	456
Other		958	912	559	563	549	532	518	491	482
Total Employees		1,680	1,600[d/]	1,236	1,235	1,216	1,194	1,176	1,078	938
Completed Plant and Equipment at June 30:[e/]										
Accelerators		$ .3	$ .3	$ .3	$ .3	$ .3	$ -	$ -	$ -	$ -
Reactors		.1	.1	-	-	-	-	-	-	-
Other		45.3	41.5	36.7	33.2	31.4	21.7	15.0	6.5	6.0
Total		$45.7	$41.9	$37.0	$33.5	$31.7	$21.7	$15.0	$ 6.5	$ 6.0

a/ Excludes depreciation on AEC facilities and the cost of source and special nuclear materials consumed in research.

b/ Estimated.

c/ Detail not available in this and prior years.

d/ Allocation of full personnel overhead was not made until July 1, 1957.

e/ Plant projects authorized but not completed at June 30, 1959 totaled $24.5 million.

0015063

HANFORD LABORATORY

Current Budget and Recent Costs by Categories of Work

(In Thousands)

	F.Y. 1958 Costs	F.Y. 1959 Costs	F.Y. 1960 Budget
TOTAL	$16,808	$21,890	$23,096
Production Process Development - Total	10,391	12,606	12,400
Weapons Development - Total	277	644	900
Reactor Development Program - Total	3,945	6,294	6,975
Civilian Power Reactors - Total	3,601	5,417	6,350
Plutonium Recycle Reactor	3,470	5,215	5,000
Gas Cooled Reactor	131	202	1,350
Nuclear Technology - Total	-	307	450
Maritime Gas Cooled Reactor	344	570	175
Physical Research Program - Total	279	334	574
Chemistry Research - Total	228	270	504
Chemical Properties and Reactions	-	-	100
Special Projects	228	270	404
Metallurgy and Materials Research - Total	51	64	70
Biology and Medicine Program			
Biochemical Problems in Atomic Energy - Total	1,603	1,664	1,857
Biological Research	1,067	974	1,086
Biophysics Research	536	445	476
Environmental Research	-	245	295
Dosimetry and Instrumentation - Total	310	311	341
Dosimetry	188	192	209
Instrumentation	122	119	132
Training, Education and Information - Total	3	37	49
Assistance to Schools	3	25	39
International Conferences, Exhibits, Studies and other assistance	-	12	10

0015064

Future Plans

Production Process Improvement: Opportunities continue to exist for significant improvement in the production processes employed at Hanford and in the economics and safety of plant operations. However, barring major changes in production activities, the needs for support of production will decrease in the future, making possible the progressive reassignment of technical personnel to other programs.

Reactor Development: The plutonium recycle program is expected to continue at about the same level.

Nuclear technology development programs have only recently been initiated at HAPO in the areas of Fuels and Materials and Sanitary and Environmental Engineering, and the scope of the programs was necessarily modest at the outset. The HAPO staff is extremely competent in these areas, and the level of support will be increased substantially during the ten-year period as personnel presently engaged in production process development become available.

Biology: Research endeavors concerning the hazard evaluation of internally deposited radioisotopes on organs and organ systems in small and large animals will be maintained and expanded where necessary, since little valid information is currently available to delineate dose-effect relationships and to permit acceptable extrapolation of effects and hazards to man. Chronic feeding experiments employing various fission products and reactor effluent radioisotopes have been emphasized. Particular attention is directed toward radiation effects on nucleic acid metabolism of the gastrointestinal tract. Projected studies over the next ten years will be expanded to include comprehensive metabolic and biologic response studies concerning Pu-239, Sr-90, Ca-45, Ra-226, Zn-65, P-32 and Ru-106.

Development of the use of miniature swine as an experimental animal will be emphasized. Studies concerning removal of internally deposited isotopes,

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such as plutonium will be expanded. The addition of studies on the factors affecting the permeability and absorptive properties of cells toward radionuclides is urgently needed.

In total, the level of effort in the biology program is expected to be increased by about fifteen percent over the decade.

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DOE ARCHIVES

SAVANNAH RIVER LABORATORY

The first reactor at the Savannah River Plant began operation six years ago. Process development work at the site, however, had begun two years earlier and, from the beginning, the results of that work made possible economies in design and operation of the production facilities. The last of the production reactors went critical in early 1955 and, until that time, research and development activities were directed almost exclusively toward the primary production mission of the plant. For that purpose, laboratory, semi-works and support facilities valued at $45,000,000 have been provided at the plant site. The laboratory is operated by the E.I. du Pont de Nemours Co., which also operates the production facilities.

The experience gained in the design, construction, and operation of the heavy water moderated and cooled production reactors by the Savannah River Laboratory staff is now being utilized in the development of power reactors. In November, 1957, the laboratory was assigned responsibility for engineering studies and development work on natural uranium fueled, heavy water moderated power reactors. Design studies of plants having capacities in the range of 100 MWE to 425 MWE have been completed, and the work is being carried forward. In addition, a Heavy Water Component Test Reactor, now under construction, will be completed early in 1961 at a cost estimated to be $9,300,000. This reactor will be a useful tool for obtaining power reactor design data and for testing various types of fuel elements.

Other Savannah River Laboratory capabilities include fission product recovery, techniques of fuel fabrication, chemical separation and tritium technology, in some of which its experience and equipment are unique.

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DOE ARCHIVES

SAVANNAH RIVER LABORATORY
Aiken, South Carolina

Ten Year Trend - Costs, Staff and Facilities
(dollar amounts are in millions)

Fiscal Year	1960 b/	1959	1958	1957	1956	1955	1954	1953	1952	1951
Research and Development Costs: a/										
Production Program	$ 9.6	$ 8.7	$10.0	$ 9.8	$ 9.4	$ 8.5	$ 6.4	$ 9.3	$14.2	$ 2.5
Weapons Program	.1	.1	.1	.2	-	-	.1	.2	-	-
Reactor Development Program:										
Civilian power reactors	7.0	2.6	1.1	.3	-	-	-	-	-	-
Total Research and Development Costs	$16.7	$11.4	$11.2	$10.3	$ 9.4	$ 8.5	$ 6.5	$ 9.5	$14.2	$ 2.5
Personnel at June 30:										
Scientific and engineering	-	300	300	296	291	292	265	162	31	c/
Other	-	335	330	315	299	299	204	89	23	
Total Employees		635	630	611	590	591	469	251	54	
Completed Plant and Equipment at June 30:										
Reactors		$16.2	$16.1	$16.1	$16.1	$ 8.6	-	-	-	-
Other		28.4	25.2	24.8	21.3	-	-	-	-	-
Total		$44.6	$41.3	$40.9	$37.4	$ 8.6				

a/ Excludes depreciation on AEC facilities and the cost of source and nuclear materials consumed in research.

b/ Estimated.

c/ Detail not available.

d/ Plant projects authorized but not completed at June 30, 1959 totaled $45.0.

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DOE ARCHIVES

Future Plans

It is expected that numerous opportunities will exist for significant though perhaps less major improvements in the productivity, economy, and safety of nearly all of the current plant processes. Increasing emphasis will be placed upon development of production reactors of improved design, as the present reactors reach the limit of economic exploitation. Other assignments will include the problems associated with variable quality of "natural" uranium, corrosion problems from aluminum reactor materials, recycling natural and enriched uranium, and adaption of separations processes to different types of fuel elements.

Over the decade a stable staff size is visualized. The present distribution of effort, as shown on the preceding chart and tables, will shift somewhat toward civilian reactor work, barring major changes in production activities.

DOE ARCHIVES

SECTION EIGHT

UNIVERSITY LABORATORIES

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DOE ARCHIVES

UNIVERSITY LABORATORIES

In the discussions making up this section, only those AEC activities that are carried on in facilities meeting the criteria of "AEC Laboratories" stated in Section Four are included. In addition to these activities each of the universities carries on contract research for the AEC in its own facilities, using varying types and amounts of government owned equipment.

0015071

ARCHIVES

ARGONNE CANCER RESEARCH HOSPITAL

The Argonne Cancer Research Hospital began its clinical and laboratory experimental program in the spring of 1953. Its purpose and program are directed toward the exploitation of high energy radiation sources for the treatment of malignancies; utilization of radioisotopes in the diagnosis and therapy of disease states; and basic research in oncology and hematology; as well as to the elucidation of certain biologic effects of ionizing radiations.

The physical facilities comprise 56 patient beds available for clinical research, radiochemical laboratories, animal quarters, and three sources of high energy radiations. These latter are a 50-Mev linear electron accelerator, a 2-Mev Van de Graaff accelerator, and a 2200-curie Co 60 unit designed for rotational therapy. The radiation sources are available for biological experimentation as well as the therapy of tumors in the human being.

The scientific program of the Argonne Cancer Research Hospital is correlated in general with the broad scientific program of the University of Chicago's Division of the Biological Sciences and the University Clinic of which it is a part. In addition, close liaison is maintained with the scientific program of the Argonne National Laboratory. As, for example, in joint studies of radium dial painters to determine the effects of the body burden of radium they carry.

Future Plans

With the recently completed 50 Mev linear accelerator now in operation and being used in the treatment of patients, this cancer research facility has reached a stable operational level. The main mission of the Hospital will continue to be that of conducting extensive studies on hospitalized patients using radioisotopes therapeutically, diagnostically, and as tracers in metabolic experiments.

0015072

ARGONNE CANCER RESEARCH HOSPITAL
Chicago, Illinois

Nine Year Trend - Costs, Staff, and Facilities
(dollar amounts are in millions)

Fiscal Year	1960 b/	1959	1958	1957	1956	1955	1954	1953	1952
Research and Development Costs: a/									
Biology and Medicine Program									
Beneficial applications of atomic energy	$ 2.0	$ 1.9	$ 1.7	$ 1.6	$ 1.4	$ 1.1	$ .8	$ .5	$ .2
Total Research and Development Costs	$ 2.0	$ 1.9	$ 1.7	$ 1.6	$ 1.4	$ 1.1	$ .8	$ .5	$ .2
Personnel at June 30:									
Scientific and engineering		50	51	53	52	52	37 b/	37 b/	20 b/
Other		142	140	132	131	140	117 b/	112 b/	60 b/
Total employees		192	191	185	183	192	154	149	80
Completed Plant and Equipment at June 30: c/		$ 4.6	$ 4.5	$ 4.2	$ 4.2	$ 4.2	$ 4.1	$ 3.7	$ -

a/ Excludes depreciation on AEC facilities and the cost of source and special nuclear materials consumed in research.

b/ Estimated.

c/ Plant projects authorized but not completed at June 30, 1959 totaled $0.1 million.

0015073

DOE ARCHIVES

CAMBRIDGE ELECTRON ACCELERATOR

New discoveries in high energy physics and extemely heavy operating schedules demanded of the Cosmotron at Brookhaven and the Bevatron at Berkeley clearly demonstrated the need for additional high energy accelerators. Consequently, in 1955, the Commission approved a program to construct and operate two additional multi-Bev accelerators at university sites. In March 1956, the Commission selected the joint proposal of Harvard University and the Massachusetts Institute of Technology to construct and operate one of the two machines.

Following authorization by the Congress, work on this facility started in April 1956. The accelerator consists of six major components, magnet, magnet power supply, radio-frequency power supply, electron source and injector, vacuum system, and controls and special equipment. The project buildings, located on the Harvard campus, include a laboratory, and experimental area, a power house, magnet ring housing, housing for the electron injector, and a cryogenics area. These are interconnected by tunnels and passageways since the working level of the machine is below ground for reasons of shielding. The orbit radius of the synchrotron will be 118 feet and the frequency of operation is designed to be 60 cycles per second.

The buildings for the accelerator, laboratory, offices and experimental areas are essentially complete. Fabrication of several of the major components

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is underway. According to the present schedule, all major components will be in procurement by mid-1960 and will be installed by early 1961. Testing and tune-up is scheduled for the Spring of 1961, and construction will be considered complete when acceleration of injected electrons is demonstrable. It is estimated that construction costs will be $11.6 million.

The machine will provide an intense beam of six billion electron volts energy; it will be the most powerful electron synchrotron presently known to be operating or building anywhere in the world.

The Cambridge Electron Accelerator will be used by one of the largest concentrations of high energy physicists in the world, and it will be an important facility for the education and training of future scientists. The Physics faculties at Harvard, M.I.T., Yale, and other universities are planning experiments to be conducted on the machine.

The scale of operation envisaged includes 30 to 40 senior scientists involved in about 12 major experimental setups. To utilize the accelerator most effectively, future plans of the laboratory call for shielding the different beams in the experimental area from one another, so that work on the assembly of one apparatus can proceed while another experiment is in progress. The shielding would be partly movable to provide the necessary flexibility.

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DOE ARCHIVES

PRINCETON-PENNSYLVANIA PROTON ACCELERATOR

One of the two high energy particle accelerators authorized by the Congress for fiscal year 1956 is being built at Princeton University as a joint project of Princeton and the University of Pennsylvania. Located at Princeton University's Forrestal Research Center, this project is known as the Princeton-Pennsylvania Proton Accelerator (PPA).

This three billion electron volt proton synchrotron is scheduled to be completed in mid-1960. It will be similar to the Cosmotron at Brookhaven, but is designed to provide a much higher number of protons per second in its beam, largely because of its higher pulse rate. It is hoped to achieve a beam current that is at least one hundred times as great as that of the Cosmotron. This feature will make possible experiments involving events that occur too rarely for successful study with lower intensity machines.

This project is expected to cost nearly $12 million. Work was undertaken in April 1956. Princeton and Pennsylvania are contributing some $500,000. Component parts of the accelerator will be magnet, magnet power supply, injection system, radio-frequency power system, vacuum system, and controls, and necessary buildings, laboratories and other supporting facilities.

Certain classes of experiments can not be performed with the presently planned internal proton beam; full extraction of external proton beams will be necessary if the full research and utility potential of high energy machines are to be realized. Experiments such as proton scattering, study of direct proton interactions using bubble chambers, and detection of very short lived particles would be practicable only with a well-shielded external beam. Therefore it is anticipated that, during the period under review, full external beam facilities will be provided for the PPA.

0015076

PRINCETON STELLARATOR

Princeton University operates one of the four major laboratories doing research to determine the feasibility of controlling thermonuclear reactions. A research program based on the so-called stellarator concept was initiated in 1951 at Princeton's Forrestal Research Center. A stellarator is a device in which ionized gas is confined in an endless tube by means of a very strong externally applied magnetic field.

A number of small stellarators have been constructed in succession, beginning in 1952. Stellarators, with their novel magnetic field configurations and plasma heating schemes, are inherently complex devices requiring a great deal of careful design and fabrication.

Because the small ones have limited capabilities, a facility, known as the Model C complex, is under construction, for completion in calendar 1961. This facility should open the way for new and more meaningful studies of plasma behavior using a succession of devices. The first of these, called Model C, will have a "racetrack" tube about 40 feet in circumference and 8 inches in diameter, equipped with helical stabilizing windings. It will be strictly a research facility, designed to yield information, and is not intended to be a net power producer. The initial cost of Model C, including buildings, supporting facilities, and experimental apparatus, is expected to be about $35 million, of which the plant facilities will be $9.9 million.

It is not anticipated that the Model C device will supersede or replace all of the smaller devices under study at Princeton. It is likely that for several years there will be areas of research on plasma confinement, stability and heating, which can be carried out more

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economically and quickly on the smaller devices than on Model C. Furthermore, the Princeton theoretical group has made excellent contributions to plasma theory, especially to the study of instabilities. It can be expected that Model C, and any succeeding device would each require a period of experimentation lasting at least two years.

It is difficult to make predictions for this program beyond 1965. Instability phenomena have come to light that make it doubtful that the original plan for ohmic heating of the plasma up to energy levels of 100 volts will be sufficiently successful in Model C. If this proves to be the case, another method -- ion cyclotron resonance heating -- is available. If this method in turn experiences serious difficulties, it is to be presumed that Model C, or its immediate successor, would make use of injection methods. In that case, a joint effort with ORNL, LRL, or with both, would seem desirable from the standpoint of saving time and funds, because of the costs that would otherwise be involved in developing a group of injection experts independently at Princeton, the construction of apparatus for them, and the standby costs for Model C whenever it is not fully used.

The design, construction and utilization of one or two injection stellarators, of the same general size as the Model C device, might well be expected to occupy a five year period, say from 1965 to 1970. Any other alternative dictated by future developments would probably require a similar period of time.

0015078

PRINCETON STELLARATOR
Princeton, New Jersey

Nine Year Trend - Costs, Staff and Facilities
(dollar amounts are in millions)

Fiscal Year	1960 b/	1959	1958	1957	1956	1955	1954	1953	1952	1951
Research and Development Costs: a/										
Physical Research Program:										
Controlled thermonuclear research	$19.4	$12.0	$ 4.9	$ 2.6	$ 1.5	$ 1.0	$ .6	$ .4	$ .1	$ -
Total Research and Development Costs	$19.4	$12.0	$ 4.9	$ 2.6	$ 1.5	$ 1.0	$ .6	$ .4	$ .1	$ -
Personnel at June 30:										
Scientific and engineering	-	89	77	70	54	34	18	13	7	-
Other	-	194	130	114	70	28	9	3	1	
Total	-	283	207	184	124	62	27	16	8	-
Plant projects authorized but not completed at June 30, 1959		$ 9.9								

a/ Excludes depreciation on AEC facilities and the cost of source and nuclear materials consumed in research.

b/ Estimated.

0015079

DOE ARCHIVES

PRINCETON STELLARATOR

Current Budget and Recent Costs by Categories of Work
(In thousands)

	F.Y. 1958 Costs	F.Y. 1959 Costs	F.Y. 1960 Budget
Physical Research Program - Total	$4,897	$11,975	$19,364
Controlled Thermonuclear Research - Total	4,897	11,975	19,364
General Research and Development	-	330	629
C Stellarator Series - Fabrication	-	8,470	14,697
C Stellarator Series - Operation and Modification	-	-	460
Stellarator - Research and Development	-	3,175	3,578

0015080

DOE ARCHIVES

UNIVERSITY OF ROCHESTER BIOMEDICAL PROJECT

The University of Rochester Biomedical Project had its beginning in 1943 under the Manhattan Engineering District. Its mission was to develop experimental data that would enable the establishment of safe levels of exposure to various chemicals and radioactive substances used in the development of the atomic bomb.

After the establishment of the Atomic Energy Commission, the biological and medical program at the University of Rochester was placed on a more permanent basis, and more closely associated with the University. The physical proximity of the AEC facilities to the Medical School has contributed to close association and integration with the parent university. The Project is administered by the Department of Radiation Biology in the Medical School. Nine members of the Project staff hold the rank of full professor, and there are many more in the other faculty grades. The total scientific staff numbers about forty-five.

An important educational and training program is operated by the Project. In addition to AEC-supported courses in Radiological Physics and Industrial Medicine, which supply many of the health physicists for AEC and contractor facilities, more than half of the graduats students enrolled in the life sciences in the University Graduate School are under the Department of Radiation Biology. These students may major in biophysics, radiation biology, pharmacology, or biochemistry. The graduates of these courses have filled many responsible positions in AEC installations, both in research and in operations.

0015081

DOE ARCHIVES

Although the Rochester Project now has strong training and basic research programs, the AEC continues to rely on this laboratory for much of its toxicological data. The Division of Pharmacology and Toxicology cooperates in studying the toxicity, retention, excretion, and movement within the body of materials in the atomic energy industry suspected of chemical or radiological toxicity or other detrimental effects. Uranium, thorium, radium, radon, beryllium, polonium, thallium, indium, and mercury are examples. The alpha-inhalation laboratory is well equipped to study the relation of various particle sizes to the inhalation, retention and distribution of aerosols. The studies are expected to continue for many years and will be increased by the addition of strong programs in aerosol physics, pulmonary physiology, and instrumentation. Other programs in this division are devoted to bone metabolism and the study of the transport of ions across cellular membranes.

The Radiology and Biophysics Division is oriented primarily toward the study of biological processes by physical techniques and of certain aspects of chronic radiation damage and recovery. These programs are expected to continue for a number of years at the present level of effort. Arrangements are expected to be made in the near future for transfer of a relatively small program concerned with amino acid metabolism to other University departments.

The Medical Division carries out metabolic studies in irradiated animals, and devises and tests various clinical procedures for promoting recovery from acute radiation damage. This program is expected to decrease in activity unless radically new anti-radiation drugs are developed.

0015082

It is anticipated that the Medical Division will decrease the level of its experimental program with animals and pay increased attention to long-term effects as they may be observed in human populations occupationally exposed to radiation and radioactive materials.

A small but significant program, both basic and applied, on the production of burns by short, intense flashes of thermal radiation has supplied the AEC with most of its knowledge of the processes involved and possible methods for protection from burns caused by nuclear weapons. This work is essentially complete and will be phased out during the next two years. The basic program in physical measurements will probably be transferred to the Institute of Optics.

During the past few years the staff of the Project has paid increasing attention to the programs dealing with long-term, low-level effects of radiation in several species of laboratory animals. These studies are expected to continue for a number of years and may be further increased to meet specific AEC needs. However, no significant increase in the number of scientific personnel is planned, and it is expected that the level of operations will remain essentially constant during the next ten years.

0015083

UNIVERSITY OF ROCHESTER BIOMEDICAL PROJECT
Rochester, New York

Ten Year Trend - Costs, Staff and Facilities
(dollar amounts are in millions)

Fiscal Year	1960 b/	1959	1958	1957	1956	1955	1954	1953	1952	1951
Research and Development Costs: a/										
Biology and Medicine Program:										
Radiation effects on biological systems	$ .3	$ .3	$ .3	$ .3	$ .3	$ .3	$ -c/	$ -	$ -	$ -
Combating radiation detrimental effects	.1	.1	.1	.1	.1	-	-	-	-	-
Beneficial applications of atomic energy	.2	.1	.1	.1	.1	.1	-	-	-	-
Biomedical problems in Atomic Energy operations	1.0	1.0	1.0	.8	.8	.8	-	-	-	-
Dosimetry and instrumentation	.1	.1	-	.1	-	-	-	-	-	-
Civil effects	-	-	-	-	-	-	-	-	-	-
Total Biology and Medicine	1.7	1.6	1.5	1.4	1.3	1.2	1.2	1.1	1.1	1.1
Training, Education and Information	.1	.1	.1	-	-	.1	.1	.1	-	-
Total Research and Development Costs	$ 1.8	$ 1.7	$ 1.6	$ 1.4	$ 1.3	$ 1.3	$ 1.3	$ 1.2	$ 1.1	$ 1.1
Personnel at June 30:										
Scientific and engineering	-	45	46	77	95	94	88	105	101	69
Other	-	133	140	106	92	87	82	82	78	103
Total employees	-	178	186	183	187	181	170	187	179	172
Completed Plant and Equipment at June 30: d/										
All other	$	$ 5.0	$ 2.5	$ 2.4	$ 2.4	$ 2.4	$ 2.4	$ 2.3	$ 2.3	$ 1.1
Total	$	$ 5.0	$ 2.5	$ 2.4	$ 2.4	$ 2.4	$ 2.4	$ 2.3	$ 2.3	$ 1.1

a/ Excludes depreciation on AEC facilities and the cost of source and special nuclear materials consumed in research.

b/ Estimated.

c/ Detail not available in this and prior years.

d/ Plant projects authorized but not completed at June 30, 1959, totaled $0.5.

0015084

UNIVERSITY OF ROCHESTER BIOMEDICAL PROJECT

Current Budget and Recent Costs by Categories of Work
(In thousands)

	F.Y. 1958 Costs	F.Y. 1959 Costs	F.Y. 1960 Budget
TOTAL	$1,618	$1,708	$1,812
Biology and Medicine Program - Total	1,510	1,576	1,672
Radiation Effects on Biological System - Total	291	314	321
Medical Research	89	111	113
Biological Research	202	203	208
Combating radiation Detrimental Effects - Total	84	114	90
Medical Research	84	-	-
Biological Research	-	114	90
Beneficial Applications of Atomic Energy - Total	103	137	150
Cancer Research	60	96	104
Medical Research	43	41	46
Biomedical Problems in Atomic Energy Operations - Total	960	954	1,050
Medical Research	387	954	1,050
Biophysics Research	573	-	-
Dosimetry and Instrumentation	56	57	61
Instrumentation	56	57	61
Civil Effects Program - Total	16	-	-
Training, Education and Information Program - Total	108	132	140
Fellowships	86	99	100
Other Training, Education and Information Activities	22	33	40

0015085

SECTION NINE

NATIONAL REACTOR TESTING STATION

0015086

DOE ARCHIVES

NATIONAL REACTOR TESTING STATION

The National Reactor Testing Station was established in mid-1949 as a site for the testing and operation of various nuclear reactors and their associated auxiliary processing, administrative, and development facilities. The site area presently covers almost 900 square miles on the Snake River plain about 40 miles west of Idaho Falls in southeastern Idaho. In the ten years of its existence, the station has grown to become a major establishment of the Atomic Energy Commission; completed and authorized plant investment exceeds $300 million. It has a permanent operating force of about 3,400 (excluding about 650 Navy and Navy contractor employees). As of mid-1959 there were 18 operating reactors or critical facilities and six more under construction. (Update)

Seven major research and development contractors have responsibilities at the NRTS: Aerojet-General Corporation, Atomics International, Combustion Engineering Company, General Electric Company, Phillips Petroeum Company, University of Chicago (ANL), and Westinghouse Electric Corporation. This multiplicity of operating contractors at a single site represents a unique aspect of the NRTS operations.

The AEC's Idaho Operations Office maintains a complex, on-and off-site radiation monitoring network and furnishes personnel metering, analytical, instrument, inspection, and other services essential to a comprehensive health and safety program. It also coordinates the activities of U. S. Weather Bureau and U. S. Geological Survey offices at the station.

In addition to managing the NRTS as a whole, the Idaho Operations Office also administers the research and development activities assigned to the Phillips Petroleum Company.

0015087

DOE ARCHIVES

Phillips has the largest single operating force at the NRTS, with a staff of over 1800 of whom more than 400 are professional scientists and engineers. It is responsible for an engineering development laboratory consisting of six major facilities: the Materials Testing Reactor (MTR), the Engineering Test Reactor (ETR), the Chemical Processing Plant (CPP), and the series of reactors used in the reactor safety program (SPERT-I, SPERT-II, and SPERT III). Auxiliary supporting facilities include: an ETR critical facility; the Reactivity Measurement Facility (RMF), a unique and highly sensitive development tool; hot cells and assembly areas; a hot pilot plant and a chemical engineering laboratory; computer equipment and a variety of service, maintenance and engineering facilities. The scope of projects performed in these facilities extend over the entire development field from the gathering of basic nuclear data (the cross sections program) through various phases of nuclear technology, both reactor and chemical, to nuclear engineering and plant operation.

The Materials Testing Reactor and Engineering Test Reactor, operating at power levels of 40 MW and 175 MW respectively, are the AEC major radiation testing facilities. They contain complex, multi-million dollar loop experiments and capsule tests from every major AEC site and operating contractor. Commercial irradiations are also performed to the extent facilities are available. In addition, research and development work is conducted in the fields of nuclear physics, reactor physics, reactor materials, and component engineering, making use of the special facilities provided by the high flux testing reactors and the technical staff which is essential to their operation.

0015088

The SPERT reactors, of which there are presently three with a SPERT-IV planned for 1961, are an essential part of the AEC's reactor safety program; since 1955, several hundred planned excurisons in the SPERT-I facility have provided a wealth of information on reactor stability and behavior under varying conditions. SPERT-II and III will extend reactor parameters into high temperature and high pressure areas and permit study of several moderator and coolant conditions.

The Idaho Chemical Processing Plant is the AEC's only multipurpose production facility for the recovery of enriched spent reactor fuels. A $2 million per year chemical and engineering development program is integrated with this major facility and has produced significant contributions and advancements in the processing field including the demonstration of continuous dissolution and the separation of highly radioactive isotopes by the "Rala" process.

In addition to Phillips, Combustion Engineering Company and Aerojet-General Corporation also conduct research and development programs at NRTS for the Idaho Operations Office. These latter two organizations are engaged in the Army Reactors program -- Combustion Engineering as operator of the Stationary Low Power Reactor #1 and Aerojet-General as developer and operator of the Army Gas Cooled Reactor Experiment. Aerojet-General is also at work on design of a small, trailer-mounted, gas-cooled nuclear power plant scheduled for completion in April, 1961.

The NRTS activities of ANL, Bettis and Lockland are referred to in previous sections, and the work of Atomics International is dealt with in Appendix A.

0015089

NATIONAL REACTOR TESTING STATION
Idaho Falls, Idaho

Ten Year Trend - Costs, Staff and Facilities
(dollar amounts are in millions)

Fiscal Year	1960	1959	1958	1957	1956	1955	1954	1953	1952	1951
Research and Development Costs:[a/] [b/]										
Production Program	$ 2.3	$ 1.0	$ .6	$ .1	$ -	$ -	$ -	$ -	$ -	$ -
Weapons Program	.5	.4	.4	.5	.1	.1	.1	-	-	-
Reactor Development Program:										
Civilian power reactors	2.1	4.2	3.3	.9	.1	-	-	-	-	-
Army power	6.9	6.2	2.7	.7	-	-	-	-	-	-
Naval propulsion	2.6	1.9	1.5	1.3	.2	-	-	-	-	-
Manned aircraft propulsion	3.5	1.0	.8	.7	.2	-	-	-	-	-
General reactor research and development	9.9	7.3	10.7	6.1	7.3	5.5	7.4	7.2	5.7	2.0
Total Reactor Development	25.0	20.6	19.0	9.7	7.8	5.5	7.4	7.2	5.7	2.0
Physical Research:										
Other physical research	.1	.6	.2	.2	-	-	-	-	-	-
Biology and Medicine:										
Beneficial applications of atomic energy	.1	-	.1	-	-	-	-	-	-	-
Total Research and Development Costs	$28.0	$22.6	$20.3	$10.5	$ 7.9	$ 5.6	$ 7.5	$7.2	$5.7	$ 2.0
Personnel at June 30:[b/]										
Scientific and Engineering		412	378	318	251	223	203	96	90	45
Other		1426	1302	1158	954	819	717	181	157	11
Total Employees		1838	1680	1476	1205	1042	920	277	247	56
Completed Plant and Equipment at June 30:[d/]										
By type:										
Reactors										
Idaho Operations Office		$24.8	$24.1	$14.6	$13.5	$22.9	$11.9	$11.0	$ 1.5	$ -
Argonne National Laboratory		3.2	1.4	1.4	.8	.8	.8	.8	.8	.8
Atomics International		1.8	.3	-	-	-	-	-	-	-
Bettis Laboratory		46.6	13.4	12.5	12.0	18.4	18.4	-	-	-
Lockland ANP Laboratory		1.5	.1	-	-	-	-	-	-	-
Total reactors		77.9	39.3	28.5	26.3	42.1	31.1	11.8	2.3	.8
All Other										
Idaho Operations Office		80.8	75.7	61.8	61.2	45.6	44.6	40.9	8.2	4.1
Argonne National Laboratory		.7	.3	.3	.3	.3	.3	.3	.3	.3
Atomics International		.3	.1	-	-	-	-	-	-	-
Bettis Laboratory		9.2	3.3	3.0	3.2	3.0	2.6	-	-	-
Lockland ANP Laboratory		31.8	22.3	15.5	13.3	-	-	-	-	-
Total all other		122.8	101.7	80.6	78.0	48.9	47.5	41.2	8.5	4.4
Total Completed		$200.7	$141.0	$109.1	$104.3	$91.0	$78.6	$53.0	$10.8	$ 5.2
By management:										
Idaho Operations Office		105.6	99.8	76.4	74.7	68.5	56.5	51.9	9.7	4.1
Other		95.1	41.2	32.7	29.6	22.5	22.1	1.1	1.1	1.1

a/ Excludes depreciation on AEC facilities and the cost of source and nuclear materials consumed in research.

b/ Does not include Argonne, Atomics International, Bettis, or Lockland ANP Laboratory data.

c/ Estimated.

d/ Plant projects authorized but not completed at June 30, 1959, totaled $114.9, as follows:

Idaho Operations Office	$39.5
Argonne National Laboratory	31.8
Atomics International	.3
Bettis Laboratory	21.2
Lockland ANP Laboratory	21.9

0015090

NATIONAL REACTOR TESTING STATION

Current Budget and Recent Costs by Categories of Work
(In Thousands)

	F. Y. 1958 Costs	F.Y. 1959 Costs	F.Y. 1960 Budget
TOTAL	$20,234	$22,605	$27,960
Production Process Improvement - Total	596	965	2,300
Weapons Development - Total	431	371	470
Reactor Development - Total	18,957	20,671	25,032
Civilian Power Reactors - Total	3,321	4,230	2,130
Water Cooled Reactors - Total	519	778	640
Pressurized Water Reactor Res. & Dev.	314	508	500
Boiling Water Reactor Res. & Dev.	205	249	140
Heavy Water Reactor Res. & Dev.	-	21	-
Organic Moderated Reactor Res. & Dev.	88	109	620
Sodium Cooled Reactors - Total	272	332	420
Fast Breeder Reactor	253	272	400
Research and Development	51	25	400
Operations-NRTS Services Allocated to EBR	202	247	-
Sodium Graphite Reactor Res. & Dev.	19	60	20
Gas Cooled Reactor Res. & Dev.	2,308	2,851	350
Fluid Fuel Reactors - Total	134	160	100
Homogeneous Reactor Res. & Dev.	129	40	100
Liquid Metal Fuel Reactor Res. & Dev.	5	120	-
Nuclear Technology & Gen. Support - Total	7,518	5,562	9,440
Engineering Physics and Advanced Reactor Dev.	777	951	1,065
Reactor Fuels & Materials Dev.	1,107	772	775
Reactor Components	65	-	-
Separations and Development - Aqueous Chemical Proc. Dev.	400	462	885
Radioactive Residue Processing and Controls	806	748	1,000
Residue Treatment Development	733	685	900
Residue Disposal Development	73	62	100
Thermal Reactor Safety - Total	4,363	2,629	5,715
Research and Development	-	47	-
Fuel Fabrication	-	205	-
Operations	-	1,465	-
Reactor Experiment Fabrication	-	912	-

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DOE ARCHIVES

NRTS Cont'd

	F.Y. 1958 Costs	F.Y. 1959 Costs	F.Y. 1960 Budget
Army Power Reactors - Total	2,664	6,190	6,910
Pressurized Water Reactors	55	-	50
Stationary Low Power Plant No. 1 - Total	1	259	600
Army Gas Cooled Reactor Systems - Total(GCRE)	2,608	5,906	5,940
Research and Development	1,568	2,467	4,365
Fuel Fabrication	44	586	950
Operations	-	-	575
Reactor Experiment Fabrication	996	2,853	50
General Support	-	-	320
Advanced Reactor Studies	-	25	-
Naval Propulsion Reactors	1,505	1,945	2,600
Submarine Intermediate Reactor(S1G & S2G) Research & Development	32	22	-
Submarine Advanced Reactor Res. & Dev.(S3G)	542	534	500
Small Submarine Reactor (S1C) Res. & Dev.	76	69	50
Attack Submarine Reactor (S5W) Res. & Dev.	144	114	130
Natural Circulation Test	-	-	20
Large Ship Reactor (A1W) - Total	31	497	900
Research and Development	16	138	-
NRTS Services Allocated to A1W	15	359	-
Destroyer Reactor (D1G) Res. & Dev.	46	273	450
Naval Reactor Operational Dev.S1W Reactor Fac.	634	320	360
Research & Development	415		-
NRTS Services Allocated to NRF	219	320	-
Expended Core Facility - Cost of Operations	-	97	190
High Temperature Test Facility Res. & Dev.	-	15	-
Naval Reactor Design Studies	-	4	-
Airplane Propulsion Reactors - Total	786	971	3,500
Indirect Cycle Reactors - Total	91	75	-
Low Power Reactor Experiment Res. & Dev.	1/	65	-
Intermediate Propulsion Reactor Res.&Dev.	1/	10	-

1/ Detail not available

0015092

DOE ARCHIVES

NRTS - Cont'd	F.Y. 1958 Costs	F.Y. 1959 Costs	F.Y. 1960 Budget
Direct Cycle Reactors - Total	675	888	3,500
Heat Transfer Reactor Experiment No. 2 (HTRE 2) - Total	1/	670	1/
Research and Development	1/	94	-
NRTS Services Allocated to ANP	-	576	-
Propulsion Sys. Ground Test (XMA) Res. & Dev.	1/	218	1/
General Support	20	8	-
Missile Propulsion Reactors Tory II Res. & Dev.	-	2	-
Auxiliary Power Sources SNAPP II Res. & Dev.	2	1	-
Operational Services - Total	3,099	1,770	452
Materials Testing Reactor	-	-	-
Cost of Operations - Gross	4,299	3,958	1/
Dist. Credits - AEC Users	(4,029)	(3,786)	1/
Dist. Credits - NON-AEC Users	(270)	(172)	1/
Engineering Test Reactor - Net	2,634	1,555	1/
ETR - Cost of Operations - Gross	2,708	4,273	1/
ETR - Dist. Credits - AEC Users	(74)	(2,715)	1/
ETR - Dist. Credits - NON-AEC Users		(3)	
National Reactor Testing Sta. - Net	465	215	1/
NRTS - Cost of Operations - Gross	5,446	5,845	1/
Advanced General Site Planning	169	215	1/
Cost of Operations - Other	5,277	5,630	1/
NRTS - Distribution Credits	(4,981)	(5,630)	1/
Transportation & Security Shipments	62	45	1/
Physical Research - Total	153	579	100
Physics Research - Total	13	257	20
Nuclear Structure and Neutron Physics	2	23	10
Extra Nuclear Properties of Matter	11	99	10
Physical Methods of Isotope Separation	-	135	-
Chemistry Research - Total	134	322	70
Process Chemistry	2	51	10
Chemical Properties and Reactions	126	219	50
Special Projects	6	52	10

1/ Detail not available

0015093

NRTS - Cont'd	F.Y. 1958 Costs	F.Y. 1959 Costs	F.Y. 1960 Budget
Metallurgy and Materials Research			
Effect of Irradiation on Materials	6	-	10
Biology and Medicine - Beneficial Application			
Cancer Research	95	18	60
Training, Education and Information - Total	2	1	-

0015094

Future Plans

With the primary mission of the NRTS one of support for the reactor development program, the future trend of activity there is necessarily dependent on future trends of the individual development programs which are discussed elsewhere. However, with the completion of facilities now authorized, and the probable construction of additional facilities which will require the remote location and unique facilities of the NRTS, an increase in total permanent employment for the station as a whole to about the 4,400 level over the next few years (excluding Navy and Navy contract employees), and possibly beyond that by the end of ten years, is anticipated.

The only major activity which may be expected to be transferred out within the next ten years is the recovery of enriched uranium spent fuel presently performed at the ICPP. The present process development and improvement programs and the work in the areas of waste disposal are all directed toward providing industry the information and background essential to their entering this field, and the AEC is committed to performing this recovery operation at the ICPP only until industrial plants are able to assume the load. The present target schedule for such transfer is within ten years.

The continuing need for research in reactor safety would indicate a relatively constant level of work in this field.

An expanding need for irradiation facilities in test reactors will require support of the MTR-ETR complex at or above the present level. Additional test reactor requirements not yet met will require construction of a test reactor of advanced design. If this requirement is not met by private industry, construction by AEC wouldprobably be at an eastern location.

0015095

In the nuclear technology field, a modest program of heat transfer studies is planned for the near future. In nuclear technology as a whole, a program expansion of approximately 80 percent is anticipated for the ten year period with increasing emphasis on fuels and materials, reactor physics, reactor components, and sanitary and environmental engineering programs. However, the increase on work of this nature would have only a minor effect on total NRTS employment.

0015096

ARCHIVES

PART III

SUMMARY AND CONCLUSIONS

0015097

(This part will be developed following staff discussions of Parts I and II)

0015098