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REPORT TO THE 71-0096

JOINT COMMITTEE ON ATOMIC ENERGY
CONGRESS OF THE UNITED STATES

Use And Operating Costs Of The Atomic Energy Commission's High Energy Accelerators

B-159687

BY THE COMPTROLLER GENERAL OF THE UNITED STATES

FEB. 8, 1971

COMPTROLLER GENERAL OF THE UNITED STATES
WASHINGTON, D.C. 20548

B-159687

Dear Mr. Chairman:

The General Accounting Office has reviewed the use and operating costs of the Atomic Energy Commission's high energy physics research accelerators. The review was made in accordance with a request dated October 22, 1969, from the Chairman, Joint Committee on Atomic Energy.

A copy of this report is being sent today to the Vice Chairman of your Committee. Copies are also being sent to the Atomic Energy Commission.

We believe that the contents of this report would be of interest to other committees and members of Congress. Therefore, as agreed to by the Committee, we are making distribution of this report to such other committees and members of Congress.

Sincerely yours,

Elmer B. Staats

Comptroller General
of the United States

The Honorable John O. Pastore, Chairman
Joint Committee on Atomic Energy
Congress of the United States

COMPTROLLER GENERAL'S REPORT TO THE JOINT COMMITTEE ON ATOMIC ENERGY CONGRESS OF THE UNITED STATES

USE AND OPERATING COSTS OF THE ATOMIC ENERGY COMMISSION'S HIGH ENERGY ACCELERATORS B-159687

D I G E S T

WHY THE REVIEW WAS MADE

The Atomic Energy Commission (AEC) provides more than 90 percent of the Federal Government's financial support for high energy physics research. AEC supports the design, development, construction, and operation of accelerators and associated facilities and research conducted at Government-owned accelerator laboratories and at universities. A high energy accelerator is a machine which provides a primary beam of protons or electrons having an energy of 1 billion electron volts or greater. (See p. 7.)

Annual operating costs for AEC's high energy physics program currently total about $118 million. The costs of constructing accelerators and related facilities have varied from a few million dollars to $250 million, the estimated cost of the 200-billion-electron-volt accelerator currently under construction at Batavia, Illinois.

The Joint Committee on Atomic Energy requested the General Accounting Office (GAO) to review aspects of AEC's high energy physics program. GAO reviewed

--the methods used by AEC and five of its contractor-operated accelerator laboratories for allocating funds to various program activities and

--other matters relating to accelerator utilization and operating costs.

FINDINGS AND CONCLUSIONS

The questions raised by the Joint Committee and GAO's findings and conclusions follow.

Who decides that interest in research conducted at a given accelerator has declined to the point at which support from the high energy physics budget should be curtailed or stopped?

These decisions are made by AEC, with the advice of its High Energy Physics Advisory Panel, on the basis of their collective judgment concerning the relative priorities and needs of various program activities and in the context of overall funding limitations. For example,

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Tear Sheet

substantial reductions in AEC's fiscal year 1970 operating budget and anticipation of continued restrictions resulted in a decision to reduce operating funds for the Princeton-Pennsylvania Accelerator. Further reductions in the fiscal year 1971 budget led to a decision to shut down the accelerator by the end of that year. (See pp. 23 to 26.)

Is it more appropriate for all contractors operating high energy accelerators to accept somewhat curtailed productivity or for the operation of one or more to be substantially curtailed so that those remaining can operate at relatively full utilization?

This question cannot be answered categorically because consideration must be given to scientific and technical factors, such as the unique capabilities of individual accelerators and the quality and significance of the research performed. GAO believes, however, that more information should be available on the costs of operating the accelerators at various levels than is routinely provided to AEC by the laboratories. This would enable AEC to evaluate more fully the effects of alternative funding decisions. (See pp. 15 to 26.)

Are there standards against which actual performance and potential performance are gauged? If standards do not exist or are tenuous, could AEC develop, through management cost analysis or other techniques, standards which might provide for a more efficient allocation of funds and improved overall quality of research within the budgets provided by the Congress?

In the final analysis, overall performance of the accelerator laboratories is gauged by the quality of the research performed. There are specific criteria for evaluating new proposals as well as past performance. There is no clearly defined formula, however, for weighting these criteria so as to give each proposal or experiment a quantitative grade. Whether or not a project has scientific merit is decided by scientists who are considered by AEC to be experts in their respective fields. (See p. 27 and pp. 48 to 51.)

Because of the scientific and technical factors involved, GAO could not determine whether more quantitative standards could be developed to assist laboratory and AEC personnel in evaluating research quality. Laboratory officials were generally of the opinion that development of a quantitative formula for evaluating proposed and completed experiments was not feasible. (See pp. 52 and 53.)

With respect to accelerator operations, no formal standards have been established relating accelerator performance to operating costs at various operating levels. Some cost data being reported to AEC by the laboratories were not on a uniform basis. This was caused, in part, by different interpretations by the laboratories of AEC's reporting requirements. Also the laboratories did not have detailed written descriptions of the accounts used in their internal accounting systems. (See pp. 27 to 30.)

GAO adjusted the laboratories' cost data for greater uniformity and, with the assistance of laboratory personnel, developed information about the cost of operating accelerators at various levels of beam output. (See pp. 30 to 37.)

GAO believes that such information could be useful to AEC in considering alternative allocations of available funds. The information could be considered in conjunction with such factors as (1) the effects on the research efforts of individual scientists and on ongoing research programs and (2) the possible need for shifts in other research funds among the laboratories. The information also could be used in comparing expected operating costs and output with those actually achieved. Variances could be analyzed and corrective action taken, if needed. (See pp. 38 to 42.)

Who would decide to change the support category of an accelerator from high energy physics to some other field like biology and medicine, chemistry, or various combinations?

Only one of the laboratories had proposed a major shift of its program to some other research discipline. The decision to sponsor the proposed shift rested with AEC and would have involved a commitment of funds from programs other than high energy physics for the construction of major facilities as well as for a share of the accelerator operating costs.

Technical reviews of the proposal were made by AEC and by scientists in other research disciplines. The proposal, however, was not approved by AEC, and it does not appear that the proposed shift will be carried out in view of AEC's decision to shut down the accelerator in fiscal year 1971. AEC said that its decision had been made after considering the scientific merits of the proposal and its increasingly tighter budgets. (See pp. 43, 46, and 47.)

Experiments involving other research disciplines have been run on some of the accelerators. At all but one laboratory, the high energy physics program was bearing the cost of these experiments. GAO believes that such costs should be charged to the programs benefiting in order to accurately show the costs of the various programs involved. (See pp. 43 to 45.)

RECOMMENDATIONS OR SUGGESTIONS

AEC should

--implement procedures to achieve greater uniformity in the cost data reported by the accelerator laboratories (see pp. 40 and 41.)

--require the laboratories to provide estimates of accelerator operating costs and related beam output at various operating levels (see pp. 41 and 42), and

--require laboratories to charge the costs of providing services to other research disciplines to the programs benefiting (see p. 45.)

AGENCY ACTIONS AND UNRESOLVED ISSUES

AEC has agreed:

--To implement procedures to achieve greater uniformity in the cost data reported by the accelerator laboratories. (See p. 41.)

--To require the laboratories to provide, on a trial basis, data relating to estimated accelerator operating costs and related beam output at various operating levels. AEC will subsequently assess the overall value of such information in program administration in relation to the time and effort required by the laboratories to develop the information. (See p. 42.)

--To charge the incremental costs of providing services to other research disciplines to those programs benefiting when the costs are significant and when adequate mutuality of interest does not exist. (See p. 45.)

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ABBREVIATIONS

AEC	Atomic Energy Commission
Bev	billion electron volts
GAO	General Accounting Office
HEP	high energy physics
LRL	Lawrence Radiation Laboratory, Berkeley, California
OMB	Office of Management and Budget
SLAC	Stanford Linear Accelerator Center, California

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- --the methods used by AEC and five of its contractor-operated accelerator laboratories for allocating funds to various program activities and
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FINDINGS AND CONCLUSIONS

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Who decides that interest in research conducted at a given accelerator has declined to the point at which support from the high energy physics budget should be curtailed or stopped?

These decisions are made by AEC, with the advice of its High Energy Physics Advisory Panel, on the basis of their collective judgment concerning the relative priorities and needs of various program activities and in the context of overall funding limitations. For example, substantial reductions in AEC's fiscal year 1970 operating budget and anticipation of continued restrictions resulted in a decision to reduce operating funds for the Princeton-Pennsylvania Accelerator. Further reductions in the fiscal year 1971 budget led to a decision to shut down the accelerator by the end of that year. (See pp. 23 to 26.)

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--To charge the incremental costs of providing services to other research disciplines to those programs benefiting when the costs are significant and when adequate mutuality of interest does not exist. (See p. 45.)

CHAPTER 1

INTRODUCTION

The General Accounting Office has reviewed selected aspects of the Atomic Energy Commission's high energy physics (HEP) program in accordance with a request of October 22, 1969, from the Chairman, Joint Committee on Atomic Energy, Congress of the United States. A copy of the request is included as appendix I.

Our review was directed primarily toward (1) evaluating the methods used by AEC and five of its contractor-operated accelerator laboratories for allocating funds to the various HEP program activities and (2) developing information concerning accelerator utilization and operating costs. The scope of our review is described in chapter 6.

Following is a list of the five accelerator laboratories included in our review and the accelerator names. The multiprogram laboratories conduct research in several different scientific fields. The two single-purpose laboratories conduct only HEP research.

Multiprogram laboratories:
- Argonne National Laboratory (Argonne), Argonne, Illinois--Zero Gradient Synchrotron
- Brookhaven National Laboratory (Brookhaven), Upton, New York--Alternating Gradient Synchrotron
- Lawrence Radiation Laboratory (LRL), Berkeley, California--Bevatron

Single-purpose laboratories:
- Princeton-Pennsylvania Accelerator (Princeton-Penn), Princeton, New Jersey--Princeton-Pennsylvania Accelerator
- Stanford Linear Accelerator Center (SLAC), Stanford, California--Stanford Linear Accelerator

In addition to supporting the five accelerator laboratories, AEC provides all the financial support for (1) the 200-billion-electron-volt accelerator currently being constructed at the National Accelerator Laboratory at Batavia, Illinois, and (2) the Cambridge Electron Accelerator

(Cambridge) operated by Harvard University at Cambridge, Massachusetts.

Under its statutory authority, AEC supports basic research in the physical sciences. The objectives of this research are to further man's understanding of the natural laws and phenomena related to atomic energy and to increase the body of knowledge in each of the disciplines involved.

AEC's Division of Research has primary responsibility for directing the physical research program. The Office of the Assistant Director for the High Energy Physics Program is responsible, within that division, for the technical administration of the HEP program. AEC's field operations offices provide contract administration; however, they do not have responsibility for management of the technical aspects of the program. The responsibility for managing the day-to-day research activities at the accelerator laboratories rests with the laboratory directors and associate directors, who are considered by AEC to be experts in their respective fields.

Certain of the controls exercised by AEC and its contractors were commented on in our report dated May 13, 1970, to the Chairman, Atomic Energy Commission, on selected aspects of the management of the HEP program (B-159687). Pertinent sections of that report are included in appendix II.

NATURE OF HIGH ENERGY PHYSICS

HEP is a basic science which studies and investigates the nature of subnuclear, or "elementary," particles and their interaction with one another and with matter. Its goals are to determine the fundamental and unifying laws which govern the behavior of the material universe. Physicists believe that such knowledge will greatly enhance man's understanding of nature and will have a profound influence on man's ability to utilize his resources in controlling the environment.

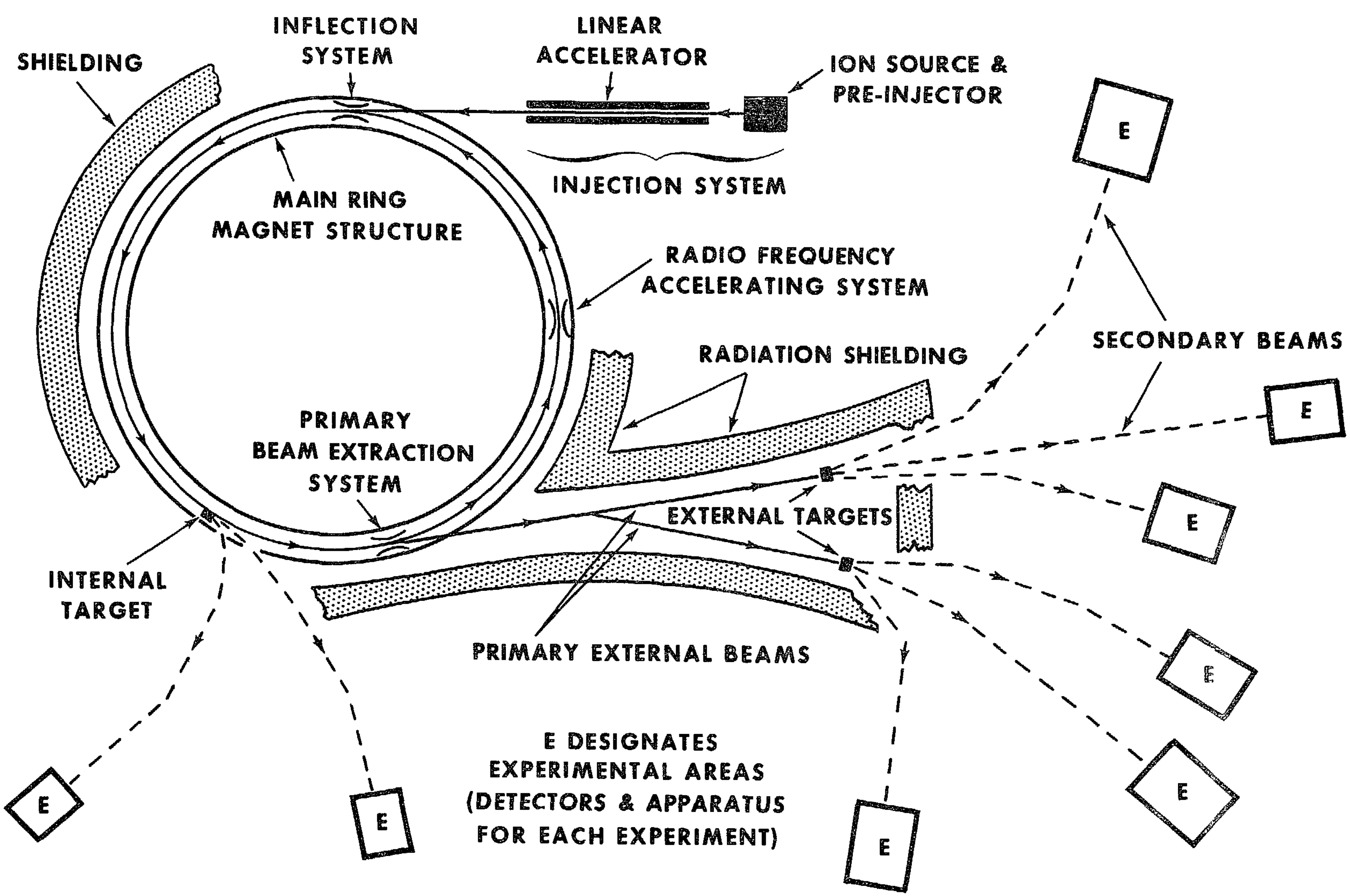
A high energy accelerator is a machine which provides a primary beam of protons or electrons having an energy of 1 billion electron volts (Bev) or greater. The term "electron volt" refers to the amount of energy gained by an electron when it is accelerated through an electrical potential difference of 1 volt.

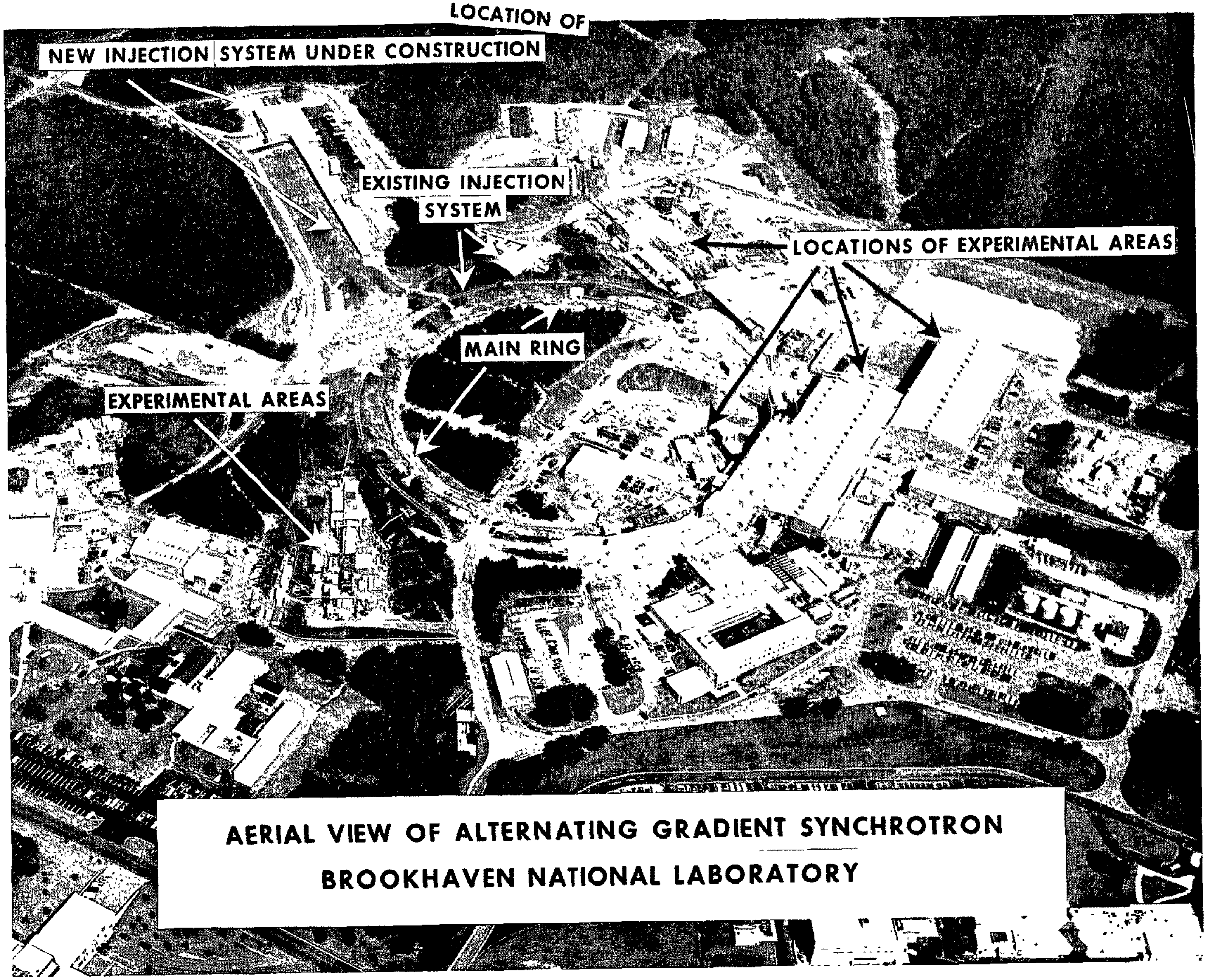
The beams of particles produced by an accelerator, in effect, provide a "light" for the physicist to "see" the inner nature of protons, electrons, and other subnuclear particles. In this sense the accelerator is analogous to a super microscope that enables man to study the substructure of nuclear particles that have dimensions billions of times smaller than the smallest object that he can see with an optical microscope.

Accelerators can be used to create other particles by accelerating the primary beam particles to a desired energy level and colliding them with targets either within, or external to, the accelerator. In the latter case the primary beam is extracted and transported by a system of magnets from the accelerator to the targets.

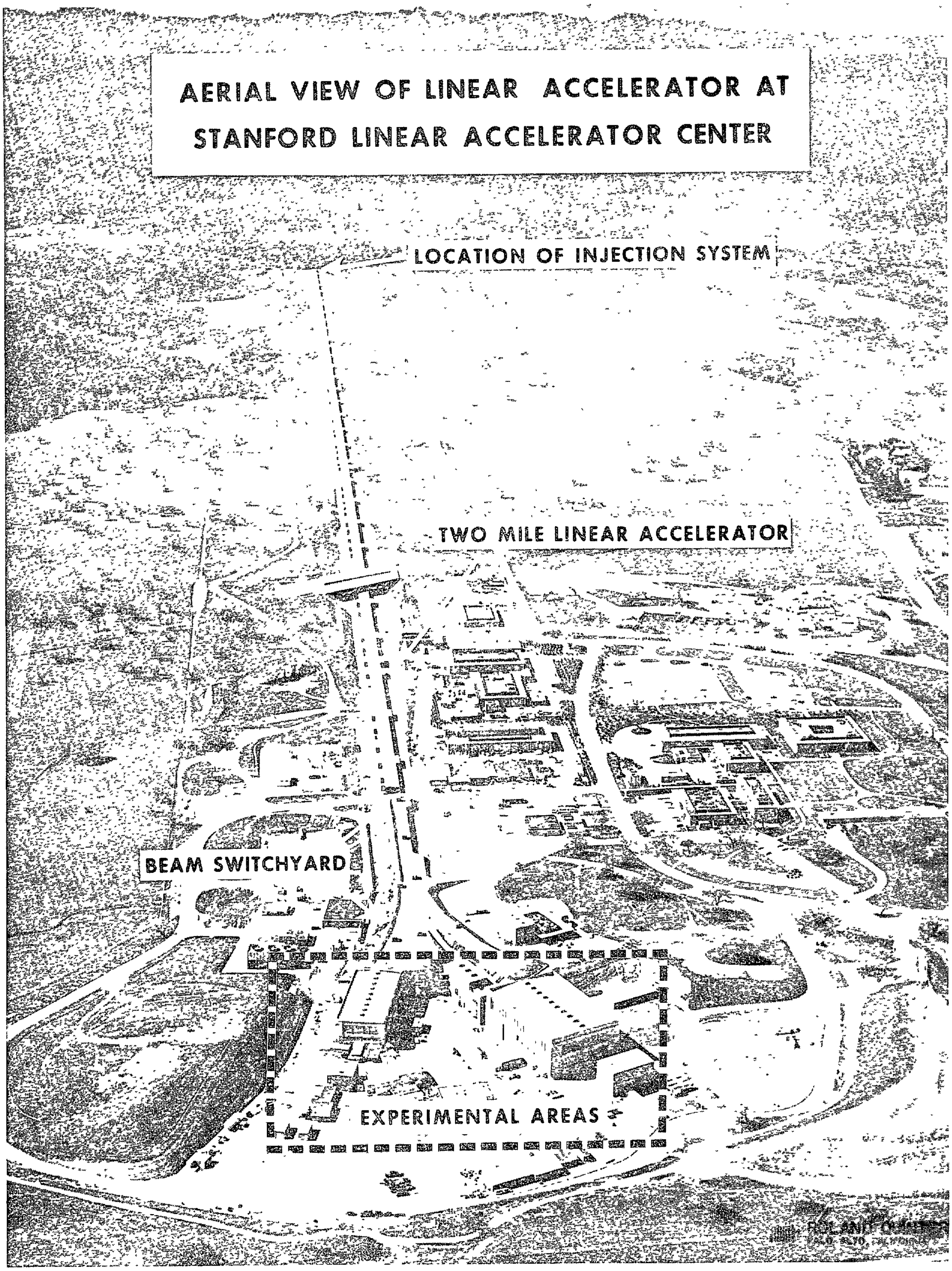
A large variety of secondary particles are produced at each target as a result of the collisions. Another system of magnets and particle separators selects the appropriate secondary particles from all those emanating from the target and transports them as a beam to an experimental area. The drawing and photographs on the following pages, which were provided by AEC, show the relative size and location of the major accelerator components and experimental areas.

TYPICAL PARTICLE ACCELERATOR & EXPERIMENTAL AREAS





AERIAL VIEW OF ALTERNATING GRADIENT SYNCHROTRON
BROOKHAVEN NATIONAL LABORATORY



AERIAL VIEW OF LINEAR ACCELERATOR AT
STANFORD LINEAR ACCELERATOR CENTER
LOCATION OF INJECTION SYSTEM
TWO MILE LINEAR ACCELERATOR
BEAM SWITCHYARD
EXPERIMENTAL AREAS

At the experimental area such devices as spark chambers and bubble chambers are used for detection and study of elementary particles and their interactions. In the bubble chamber, particles pass through a superheated liquid and trails of bubbles form along the paths followed by the charged particles. The trails are photographed for subsequent analysis.

Spark chambers are similar in purpose to bubble chambers in that they are used for detecting and measuring paths of charged elementary particles. Charged particles pass through a parallel array of electrically charged metal plates located in the chamber. The spaces between the plates are filled with an inert gas. Events occurring within the chamber are revealed by sparks which jump between the plates at the points traversed by the charged particles. These events are recorded optically or electronically.

After an experiment has been completed, the resulting data are analyzed by using a wide variety of complex equipment. When the experimental results have been evaluated, related findings are generally published in scientific journals.

With respect to the accomplishments resulting from the field of high energy physics, AEC advised us that:

> "Within the last twenty years a phenomenal new world of subnuclear particles has been discovered including many of the anti-world counterparts. This new world within the proton and the neutron manifests itself when particles from proton and electron accelerators collide with protons or neutrons. The fundamental properties of many of these particles as well as the manner in which they mutually interact have been successfully investigated. A scheme of classifying types of particles and their excited states has developed in a manner analogous to the classification of atomic spectra which ultimately revealed the electronic structure of the atom. The importance of that achievement cannot be overexaggerated since it has affected every aspect of modern man's life.

"The new world within the proton when fully understood may also provide a wealth of undreamed phenomena. In concert with the past experimental discoveries, advances in the understanding of the elementary particle interactions have not only clarified the subnuclear phenomena of nature, but have also given new insights into all aspects of nature.

"These many discoveries have been made possible because of the outstanding advances in accelerator technology together with the development of many new detection devices such as the bubble chamber and the spark chamber. Advances in fast electronics, computer techniques, and superconducting magnets have provided for efficient utilization of the new devices.

"The accomplishments of high energy physics have been outstanding and revealing. It is significant also that while Western Europe and the USSR maintain competitive programs in HEP, the dominant research results have originated with the US program. As an indication of the significance of the accomplishments, it is noteworthy that 13 individuals associated with US elementary particle physics programs have received the Nobel Prize Awards since 1957. These as well as other awards attest to the world-wide recognition of the high quality research and the leadership of the US high energy physics effort."

COSTS OF HIGH ENERGY PHYSICS

The following table shows the construction costs of the original accelerator facilities (excluding subsequent conversion and improvement costs) at AEC's six operating accelerator laboratories and the estimated cost of the 200-Bev accelerator.

Accelerator	Construction costs of original accelerator facilities (000 omitted)	Year full beam energy obtained
Alternating Gradient Synchrotron (Brookhaven)	$ 30,600	1960
Bevatron (LRL)	9,900	1954
Cambridge Electron Accelerator	10,200	1962
Princeton-Pennsylvania Accelerator	11,600	1963
Stanford Linear Accelerator	113,600[a]	1966
Zero Gradient Synchrotron (Argonne)	51,400	1963
200-Bev Accelerator (AEC estimates)	250,000[a]	1971

[a]Construction costs included costs associated with the establishment of completely new laboratories.

AEC provides more than 90 percent of the Federal Government's financial support for the national HEP program. The National Science Foundation, the Department of Defense, and the National Aeronautics and Space Administration provide the remaining support.

The annual operating costs of AEC's HEP program have increased substantially over the past decade from about $51 million in fiscal year 1962 to about $118 million estimated for fiscal year 1971. As shown in the above table, four new accelerators came into operation during this period.

Of the estimated costs of $118 million for fiscal year 1971, about $93 million will be used for HEP at AEC-supported accelerator laboratories and about $25 million will be used to support theoretical and experimental research conducted by groups of scientists resident at universities. These university research groups generally perform their experiments at AEC's accelerator laboratories but plan the experiments and analyze the experimental results at their home institutions.

The following table shows the actual operating costs for fiscal years 1969 and 1970 and the estimated costs for fiscal year 1971 at the five accelerator laboratories included in our review.

	Fiscal year 1969	Fiscal year 1970	Fiscal year 1971
	(000 omitted)		
Argonne	$17,411	$17,250	$16,700
LRL	18,219	17,738	16,585
Brookhaven	21,153	21,473	22,050
Princeton-Penn	4,974	4,129	2,000
SLAC	23,465	23,819	24,300
Total	$85,222	$84,409	$81,635

Total capital equipment and construction costs for such items as computers, experimental facilities, and accelerator improvements incurred by the five laboratories in fiscal years 1969 and 1970 and estimated costs for fiscal year 1971 are shown below.

	Fiscal year 1969	Fiscal year 1970	Fiscal year 1971
	(000 omitted)		
Argonne	$12,518	$ 5,412	$ 3,231
LRL	3,171	1,960	10,002
Brookhaven	20,076	16,914	10,670
Princeton-Penn	1,378	880	128
SLAC	7,156	2,786	3,425
Total	$44,299	$27,952	$27,456

CHAPTER 2

PROCEDURES FOR ALLOCATING HIGH ENERGY PHYSICS FUNDS AMONG PROGRAM ACTIVITIES

In its request the Joint Committee on Atomic Energy raised a question concerning whether it was more appropriate for all contractors operating high energy accelerators to accept somewhat curtailed productivity or for the operation of one or more of the accelerators to be substantially curtailed so that the remaining facilities could be operated at relatively full utilization. In consideration of this question, we examined into the procedures used and factors considered in allocating HEP funds among the various program activities.

CURRENT BUDGET DEVELOPMENT PROCEDURES

The process of planning and developing AEC's operating budget for the HEP program requires input from the Congress, Office of Management and Budget (OMB), officials at AEC Headquarters and field offices, contractor-operated accelerator laboratories, and university research contractors. In addition, the High Energy Physics Advisory Panel, composed of a group of scientists--primarily physicists involved in HEP at accelerator laboratories and universities--provides assistance to AEC through its review of program plans and budgets and through advice on matters relating to priorities, plans, and the allocation of funds among the accelerator laboratories and other research contractors.

The budget classifications used by AEC for formulating the operating budget estimates and for allocating funds are shown below.

- Category--high energy physics:
  - Activity--each of the seven AEC contractor-operated accelerator laboratories
    - Subactivity:
      - Research
      - Design and development of devices
      - Operations

Activity--general research and development
Subactivity:
Research
Design and development of devices
Advanced accelerator research and development

AEC's Assistant Director for the High Energy Physics Program stated that generally all costs of operating the accelerators should be included in the operations subactivity and that those costs incurred by research groups and in operating general research devices, such as bubble chambers, should be included in the research subactivity.

The design and development of devices subactivity includes costs related to the design, development, and improvement of accelerator components and associated experimental apparatus. The general research and development activity includes research and development costs which cannot be specifically identified with one of the seven accelerators. The university research program is the major part of this activity.

The annual high energy physics operating budgets for the laboratories involve the preparation and consideration of the following documents.

Budget assumptions

Laboratory officials develop budget assumptions on the basis of their judgment of the projected needs of the overall HEP program as related to their laboratory. The budget assumptions are submitted to AEC 18 months before the start of the budget year for which funds are being requested and are intended as long-range forecasts of laboratory needs for use in planning future fund allocations for each laboratory. The budget assumptions show funding requirements for the budget year and projected needs for the following 4 years. They are not based upon the requirements of specific experiments because, at the time that they are submitted, such information is not completely available; instead, the projections are based upon avenues of research which are considered to be important and within the capability of the laboratory.

Program assumptions

AEC develops program assumptions for use by each laboratory as general guidelines for the preparation of the laboratories' annual budget requests. The assumptions are provided to the laboratories about 15 months before the start of the budget year and show the total HEP funds which AEC estimates will become available to the laboratories for the budget year and the following 4 years. The projections contained in budget and program assumptions are helpful in the long-range planning for the HEP program.

AEC officials advised us that long-range planning for the HEP program was particularly important because of the relatively long period of time required for experiments; a typical HEP experiment takes about 3 years from conception to completion. They also stated that the importance of long-range planning had been recognized in all countries engaged in HEP research. For example, the HEP facility at the European Organization for Nuclear Research is set up so that it has firm budget plans for 2 years in advance, plus a tentative budget for the third year, with provision for cost escalation.

AEC develops the program assumptions on the basis of the laboratories' budget assumptions, AEC and OMB estimates of funding availability, and the knowledge and experience of AEC officials, as well as their personal familiarity with the funding and programmatic needs of each laboratory.

As shown below, for fiscal year 1969 the amounts included in the program assumptions were significantly less than the amounts included in the budget assumptions submitted by each of AEC's six operating accelerator laboratories.

	Assumptions for fiscal year 1969	
Laboratory	Laboratory budget assumptions	AEC program assumptions
	(000 omitted)	
Argonne	$ 22,220	$ 19,700
LRL	22,000	19,200
Brookhaven	24,140	23,300
Cambridge	11,090	9,250
Princeton-Penn	9,765	9,250
SLAC	34,000	27,500
Total	$123,215	$108,200

AEC officials explained that the projected funding estimates appearing in the program assumptions were rough estimates of the future needs of the laboratories matched to a rough estimate of funding to be available to the overall HEP program.

Annual budget requests

The laboratories submit their annual budget requests to AEC about 13 months before the start of the budget year for which funds are being requested. They contain estimates which are of assistance to AEC in its preparation of the annual President's budget which is submitted to the Congress about 5 to 6 months before the start of the budget year.

Preparation of the budget requests involves a detailed process during which each laboratory considers factors such as manpower needs of accelerator and supporting organizations; materials, services, and subcontract requirements; needs of experimental groups; and other factors.

The requests generally show the laboratories' projections of accelerator operations and research needs rather than a level of operations and research consistent with AEC's estimates of available funds as shown in the program assumptions.

For example, the program assumptions furnished to SLAC and LRL for fiscal year 1969 clearly indicated that the probability of sustaining the amounts included in the assumptions was negligible. In a letter dated March 23, 1967, transmitting the SLAC program assumption, AEC stated in part:

> "The FY 1969 estimates shown above are intended to be preliminary guideline amounts; it should be recognized that there is no assurance that they will survive the budget cycle. Realistically, in view of the many fiscal demands confronting the Administration, the prospects for successful support of the estimates are not overly optimistic."

Similar comments were expressed by AEC in a letter dated March 21, 1967, transmitting the LRL program assumptions.

Notwithstanding this advice, the SLAC and LRL budget requests submitted to AEC exceeded the assumption guidelines by $4.7 million and $2.3 million respectively. The SLAC request provided for funds sufficient to enable it to achieve an average of twenty-one 8-hour accelerator operating shifts a week even though the program assumption issued by AEC stated that SLAC was expected to achieve only an average 15-shifts-a-week operation with the estimated funds available.

Other accelerator laboratories also submitted budget estimates which exceeded AEC program assumption guidelines, as shown below.

	Amount over assumptions (millions)
Cambridge	$2.9
Brookhaven	1.2
Argonne	.9
Princeton-Penn	.3

AEC officials advised us that it was consistent with their desires and needs that the laboratories indicate the funding needed to carry out their recommended programs and not limit their requests to the amounts given by AEC as guidelines concerning the availability of funds. AEC added that it considered the indications of the laboratories' needs as important input during its process of continually refining the budget allocations throughout the budget formulation cycle.

The annual budget requests furnished by the laboratories also show revised estimates for the fiscal year beginning about a month after their submission to AEC. The revised estimates are based on the laboratories' reconsideration of funding needs as well as amounts included in the President's budget which provide additional guidance to the laboratories with respect to funding availability.

Financial plans

The revised budget estimates are of assistance to AEC in its preparation of financial plans which provide for an allocation of HEP funds for each of the activities and subactivities assigned by AEC. The plans, which take into consideration amounts authorized or expected to be authorized by the Congress, are sent to the laboratories at the start of the budget year; however, they are usually revised several times during the year on the basis of changes in the availability of funds following congressional appropriation and OMB apportionment and of changes in the needs and levels of financial support required by the laboratories and for other activities and subactivities.

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We attempted to make a detailed analysis of the manner in which the above documents were developed and utilized for fiscal year 1969. Considerable documentation was prepared and maintained in support of the laboratories' annual budget requests, much of which was included in the budget documents furnished to AEC. The documentation, however, did not show all the various alternatives considered by the laboratories in determining their programmatic and related funding needs but supported primarily those needs as finally agreed upon by the laboratories' officials during budgetary meetings and related discussions.

The decisions regarding the specific amounts included in the various AEC budget documents were reached by AEC officials on the basis of the input from the laboratories, and their scientific judgment, knowledge of program needs and priorities, and personal experience. Alternatives considered in arriving at specific allocations of funds generally were not documented.

The following section describes the manner in which fund allocation decisions are arrived at by AEC.

METHOD OF ALLOCATING FUNDS AMONG LABORATORIES

During the budget formulation cycle the expected overall level of financial support for physical research undergoes numerous revisions resulting from internal budget reviews by the AEC Commissioners, the General Manager, and the AEC Budget Review Committee and from external reviews by OMB and various congressional committees. The Director, Division of Research, with the assistance of his staff generally allocates the total funds for physical research among the various program categories, including HEP.

Decisions concerning the amounts to be allocated to each activity and subactivity of the HEP program generally are made on the basis of recommendations by AEC's Assistant Director for the High Energy Physics Program and his staff.

The Assistant Director advised us that each staff member is responsible for maintaining a detailed knowledge of certain accelerator laboratories or university research contractors and for maintaining a general knowledge of all phases of the HEP program. Each staff member participates in formulating the recommended allocations of HEP funds to the various activities and subactivities of the program during staff meetings with the Assistant Director.

During the meetings, tentative allocations are discussed in consideration of needs and priorities and a decision is reached regarding recommended levels of financial support for each laboratory and contractor on the basis of the judgment, knowledge, and experience of the HEP staff.

The following statement by AEC contained in the hearings on AEC's fiscal year 1971 authorization bill conducted by the Joint Committee on Atomic Energy provides some insight into the manner in which each member acquires his knowledge of laboratory activities.

> "*** In establishing funding levels each year *** a great deal of effort is expended in keeping up to date in assessing and understanding the various requirements at the different labs. A large part of this effort takes the form of studying budget

documents, having conversations with lab officials, lab staff, and users, conducting program reviews, meeting with High Energy Physics Advisory Panel and studying the periodic reports from the lab. ***"

Many factors are considered in determining the specific funding levels for the various accelerators and the final budget amounts have, in the past, been determined by making selective but widespread allocations of any increases or decreases in available funds.

DECISIONS TO REDUCE OR DISCONTINUE SUPPORT OF SPECIFIC ACCELERATORS

In its request, the Joint Committee on Atomic Energy raised a question concerning who makes the decision that interest in the research to be conducted at a given accelerator has declined to the point when support from the high energy physics budget should be curtailed or stopped.

As a result of substantial reductions in AEC's fiscal year 1970 operating budget and in anticipation of continued funding restrictions, AEC decided to explore the possible consequences of significant reductions in the financial support for Princeton-Penn.

On July 8, 1969, AEC requested Princeton-Penn to make a detailed analysis of the impact on its operations at annual funding levels of $2.5, $3.5, and $4.75 million, compared with a $4.95-million level of funding in fiscal year 1969. The study was completed by Princeton-Penn and a reply was submitted to AEC on September 19, 1969.

AEC advised us that it met with the High Energy Physics Advisory Panel in October 1969, at which time the alternative levels of financial support for Princeton-Penn, among other topics, were discussed. Following this meeting, the Chairman of the Panel reported its reaction in a letter dated October 15, 1969, to the Director, Division of Research:

> "I would like to report to you the reaction of the High Energy Physics Advisory Panel (HEPAP) to the present FY 1971 budget figures. Up to now the response to increasingly tight budgets has been a more or less uniform sharing of the burden among the different institutions. This has been a wise policy but the cumulative effect of several years of reduced budgets and the unlikelihood of an early improvement of the situation now brings this policy into question. The cuts have caused serious damage to all centers of research and this is why selective cutting is necessary in order to allow the more

vital centers to survive without the gravest damage.

"Under these unfortunate circumstances we come to the conclusion that, because of the low beam energy and because many--but not all--of PPA's [Princeton-Penn] capabilities can be matched elsewhere, it is logical to reduce the PPA program. We regret to be forced to such a step because we consider the work at PPA to be of scientific and educational importance. We therefore believe that such selective reduction of support should not be equivalent to a shutdown. We quote from our Report (page 39): 'At this time (1969) <u>all</u> of the high energy accelerators in the United States are performing important work (within funding limitations) and are of great educational value with programs of considerable scientific interest and significance. None should be shut down in the immediate future.'

"The decrease of support for PPA is suggested in order to support the most urgent programs at other institutions, and we recommend that this decrease be limited so that the program will not be eliminated but will continue at a reduced rate. It is still an important part of the high energy effort in the U.S. and should remain so for a long time."

AEC subsequently reduced financial support for Princeton-Penn to $4 million for fiscal year 1970, corresponding to an effective annual support level of about $3.5 million for the latter half of the fiscal year.

Because of sizable reductions in AEC's budget for fiscal year 1971 made midway during the budget process, the HEP staff considered two different approaches to allocating the reduction in program funds. Under the first approach, percentage reductions would have been made in the existing planned levels of fiscal year 1971 financial support for each contractor.

Under the second approach, the higher energy accelerators (those capable of performing the more forefront research) would have received sufficient funds to conduct a constant level of research with modest cost-of-living increases. This alternative would have had the effect of assigning priority to the higher energy accelerators and reducing the financial support for the lower energy machines

The consensus of AEC and the High Energy Physics Advisory Panel was to follow a policy of protecting those facilities capable of performing the more forefront research. AEC decided, with the Panel's concurrence, to shut down the Princeton-Penn accelerator by the end of fiscal year 1971. The operating budget for Princeton-Penn was reduced to $2 million for fiscal year 1971 to enable an orderly closing of the laboratory, including completion of the most important experiments under way.

The following table compares the fiscal year 1970 funding level, as shown in the President's budget for fiscal year 1971, with the amount requested for fiscal year 1971, as shown in that budget. The table shows that the three highest energy accelerators were allocated increases in operating funds whereas the financial support for the other accelerators was reduced. Funding levels for the general research and development activity, which is shown separately in the table, were also reduced.

Accelerators at the following laboratories (and Bev)	Funding levels		Increase or decrease(-)
	Fiscal year 1970	Fiscal year 1971	
	(millions)		
National Accelerator Laboratory (200)	$ 6.6	$ 9.4	$2.8[a]
Brookhaven (33)	21.3	22.0	.7
SLAC (21)	23.9	24.5	.6
Argonne (12.5)	17.2	16.9	-.3
LRL (6.2)	14.1	13.5	-.6
Cambridge (6)	3.5	2.4	-1.1
Princeton-Penn (3)	4.0	2.0	-2.0
Total	90.6	90.7	.1
General research and development	29.9	28.8	-1.1
Total	$120.5	$119.5	-$1.0

[a]The annual funding level for the 200-Bev accelerator is expected to increase to more than $40 million by fiscal year 1975 following completion of construction of the accelerator and associated research facilities.

In summary decisions concerning the reduction or discontinuance of support for specific accelerators generally are made by AEC, with the advice of the High Energy Physics Advisory Panel, on the basis of their collective judgment as to the relative priorities and needs of the various activities within the HEP program and in the context of overall funding limitations.

CONCLUSION

As noted on page 15, the Joint Committee on Atomic Energy raised a question as to whether it would be more appropriate for all contractors operating high energy accelerators to accept somewhat curtailed productivity or for the operation of one or more to be substantially curtailed, so that those remaining could be operated at relatively full utilization.

On the basis of our review, we do not believe that the above question can be answered categorically because, in any given situation, consideration must be given to factors such as the unique capabilities of the various accelerators and the quality and significance of the research output. We do believe, however, that, in exercising the judgments involved, more information should be available as to the costs of operating the accelerators at various levels to enable AEC to more fully evaluate the effects of alternative funding decisions, as discussed in the following chapter.

CHAPTER 3

DEVELOPMENT OF IMPROVED COST AND OPERATING DATA FOR USE IN ALLOCATING FUNDS

In its letter of October 22, 1969, the Joint Committee on Atomic Energy raised a question as to whether there were standards against which actual performance and potential performance of the AEC accelerator laboratories were gauged. The Joint Committee requested that, if standards did not exist or were tenuous, we determine whether AEC could develop, through management cost analysis or other techniques, standards which might provide for a more efficient allocation of funds and for improved overall quality of HEP research within the budgets provided by the Congress.

In the final analysis, the overall performance of the accelerator laboratories is gauged by the quality of the research performed. Our comments regarding the standards used for evaluating research quality are contained in chapter 5.

With respect to accelerator operations, AEC has not established formal standards for relating accelerator performance to operating costs at various operating levels. Therefore, we examined into the feasibility of having individual accelerator laboratories submit their proposed budgets in a manner that would disclose the cost of accelerator operations at various operating levels.

We directed our study primarily to the operations subactivity since the costs of this subactivity are directly related to the operating level of the accelerator. Costs related to research and the design and development of devices at various operating levels were not developed because such factors as the mix of in-house and outside users, size and complexity of experiments, and the size of the laboratory's scientific staff affect these costs and do not necessarily vary directly with accelerator operating levels. As such, although decisions as to amounts to be expended in these areas should be influenced by the amount of accelerator operating time available, such decisions must be based to a large extent on scientific and technical judgment of laboratory and AEC officials.

NONUNIFORM COST DATA REPORTED BY LABORATORIES

According to the AEC Manual, the operations and research subactivities are defined as follows:

Operations - "Includes all costs incurred for the operation of this machine (and facility) for such items as salaries and wages of the operating staff, power, supplies, and equipment not meeting capitalization criteria, maintenance and repairs, costs of getting ready to operate, including salaries and wages of personnel hired in advance of operation in order to have them available at the start of operations unless they are used in construction or fabrication of the machine, and test costs exclusive of tests during construction or fabrication designed to prove out the facility and assure compliance with design."

Research - "Includes all costs of physics, including the operation of the machines, carried out with (a) accelerators or other devices whose primary radiation exceeds 1,000 Mev per nucleon or electron accelerated and (b) cosmic rays."

Our examination into the types of costs that were being reported by the five laboratories in the above subactivities showed that none of the laboratories had detailed written descriptions of the types of costs included in their internal accounts. Because of the importance of written account descriptions in facilitating our examination of operations costs, we inquired into the possibility of laboratory officials preparing such descriptions.

LRL and SLAC officials advised us that the preparation of account descriptions would require a detailed, time-consuming study and that, in many instances, the information needed would have to be obtained from the individual researchers who charge their costs to the accounts. Officials at Argonne similarly told us that the development of written account descriptions would require a major effort. Princeton-Penn and Brookhaven officials prepared and furnished account descriptions to us for use in making our review.

Our discussions with the laboratories' officials, analyses of the laboratories' accounts, and reviews of account descriptions where available indicated that cost data reported to AEC by the laboratories in the operations and other budget subactivity accounts were not reported on a uniform basis. We noted that the nonuniformities in cost data reported in the research and operations subactivities were caused, in part, by differences in the laboratories' interpretations of the AEC definitions of those subactivities and the types of costs which should be included therein.

For example, at LRL certain costs of operating and maintaining beam lines and costs associated with setting up experiments, which amounted to about $1.2 million in fiscal year 1969, were included in LRL's internal account designated as "Bevatron Operations." In accordance with LRL's interpretation of the AEC reporting requirements, these costs were reclassified and reported to AEC as research subactivity costs. Brookhaven also reported such costs as research costs. Similar-type costs incurred by SLAC and Princeton-Penn, however, were reported to AEC as operations costs. At Argonne, similar costs were reported as either research or operations costs, depending upon the organizational unit which incurred them.

Brookhaven, in fiscal year 1969, included electric power costs of about $131,000 for operating the 80-inch bubble chamber in amounts reported as research costs and included all other power costs, which amounted to about $759,000, including an estimated $34,000 for operating the 30- and 31-inch bubble chambers, in amounts reported as operations costs. Brookhaven officials advised us that, because of the significance of electric power used in operating the 80-inch chamber, the group responsible for operating and maintaining all of Brookhaven's bubble chambers decided to separately meter the power used in operating the 80-inch chamber and to monitor the power costs incurred in its operation.

At Argonne, power used in operations and research is separately metered. Power costs during fiscal year 1969 amounted to about $1.7 million of which about $923,000 was reported as operations costs and $742,000 as research costs.

Princeton-Penn, SLAC, and LRL do not separately meter power and the related costs are included in their entirety in amounts reported as operations costs.

Because of the lack of a uniform interpretation of the definition of the operations subactivity and consequent lack of uniformity among the laboratories in the classification and reporting of costs to AEC, we found it necessary to redefine operations costs to obtain more uniform data for our study at each of the five laboratories. We redefined operations costs as including all those incurred in obtaining, accelerating, and directing beams of subnuclear particles into the various experimental areas existing at the accelerators including the costs of setting up and shielding such areas. Also, we considered all power costs to be operations costs because the lack of separate metering at some locations made it infeasible to limit the inclusion of such costs to those applicable to operating the accelerators.

Although another definition might be considered appropriate by AEC, the one which we adopted appeared reasonable and was similar to that used by SLAC and by Princeton-Penn, with certain relatively minor exceptions.

On the basis of our definition of operations costs, we recomputed fiscal year 1969 operations costs with the assistance of laboratory personnel. The following table compares the operations costs reported by the laboratories, in accordance with their interpretations of AEC reporting requirements, with the costs as computed in accordance with our definition.

Accelerator laboratory	Actual operations costs in fiscal year 1969: As reported by the laboratories	Actual operations costs in fiscal year 1969: As recomputed by GAO	Difference
	(000 omitted)		
Argonne	$ 4,561	$ 8,156	$3,595
LRL	3,789	5,040	1,251
Brookhaven	3,878	7,630	3,752
Princeton-Penn	4,754	4,680	-74
SLAC	11,332	11,063	-269

We also obtained information as to the number of accelerator beam hours used for HEP research during fiscal year 1969. We computed, as shown below, the cost per beam hour in fiscal year 1969 on the basis of (1) operations costs as reported by the laboratories and (2) operations costs as recomputed by us in accordance with our definition.

Laboratory	Number of beam hours achieved	Cost per beam hour: Based on operations costs as reported by the laboratories	Cost per beam hour: Based on operations costs as defined by GAO
Argonne	6,045	$ 755	$1,349
LRL	6,159	615	818
Brookhaven	4,890	793	1,560
Princeton-Penn	3,791	1,254	1,235
SLAC	4,627	2,449	2,391

The above table shows that the cost per beam hour varies considerably among the accelerators. It should be noted, however, that there are substantial differences in the operations, ancillary beams and facilities, and basic characteristics of each accelerator, which result in considerable differences in the types of equipment, shielding, experimental facilities, and related costs associated with operating the various accelerators.

As discussed previously, the development of accelerator operating costs for each of the laboratories on a more uniform basis involved a reclassification of various types of costs, primarily those charged to the research and operations subactivities. In this regard, the laboratories' research subactivities included, in addition to the costs relating to a wide variety of functions involving the support of in-house research groups, costs of operating and maintaining various types of equipment and facilities used in the performance of experiments at the accelerator laboratories.

The types and complexity of such equipment and facilities and the related operation and maintenance costs at each of the laboratories varied widely. We considered some of these costs as operations in accordance with our definition.

On the basis of our review, we believe that there is a need for AEC to redefine the operations subactivity in a more precise manner so as to provide for more uniform cost reporting by the accelerator laboratories. In addition, we believe that the usefulness to AEC of the cost data currently reported as research and operations could be increased if the costs of operating and maintaining those facilities and major equipment not considered by AEC to be part of accelerator operations were reported separately. Such a change would result in greater uniformity in reporting the costs of the various functions included in the subactivities of the HEP program. In our opinion, the availability of more uniform cost information could be of assistance to AEC in evaluating the operations of the accelerators and in determining the relative funding needs of the laboratories.

COST OF OPERATIONS AT ALTERNATIVE OPERATING LEVELS

The laboratories' officials advised us that fiscal year 1969 costs and utilization were generally not typical of normal operating conditions. They stated that, in some cases, severe restrictions on fiscal year 1969 funding were met by instituting short-term economies in the laboratories' programs and that the operating modes in effect during fiscal year 1969 could not have been sustained over the long run.

For example, although LRL's output (6,159 beam hours) was near optimum, the officials advised us that this level could not be sustained in the long run under the 1969 funding level and that significantly greater funding would have been required to achieve this output under normal operating conditions. They stated also that the high level of productivity was achieved, in part, by deferring a scheduled 4-week shutdown for maintenance, machine modification, and development work and by instituting other short-term economies.

SLAC officials stated that funding restrictions were largely met by curtailing planned accelerator shifts, support to research groups, maintenance, and development work. According to SLAC officials, such cuts have resulted in delayed startup and completion of experiments and in lesser productivity than could have been achieved under normal funding conditions.

Princeton-Penn, on the other hand, did not achieve the number of beam hours during fiscal year 1969 which it would have expected to achieve under more normal operating conditions. Princeton-Penn officials explained that a greater number of beam hours was not achieved largely because of a major shutdown of the accelerator during fiscal year 1969 for maintenance and modification work which had been deferred in the prior fiscal year. They stated that the work which would normally have been performed during fiscal year 1968 was deferred because the experimental program dictated a continual operation of the accelerator in fiscal year 1968 and into fiscal year 1969.

At Brookhaven, the number of beam hours achieved during fiscal year 1969 was similarly affected by an unscheduled shutdown of the accelerator for motor generator repairs and a scheduled shutdown for major modification and improvements.

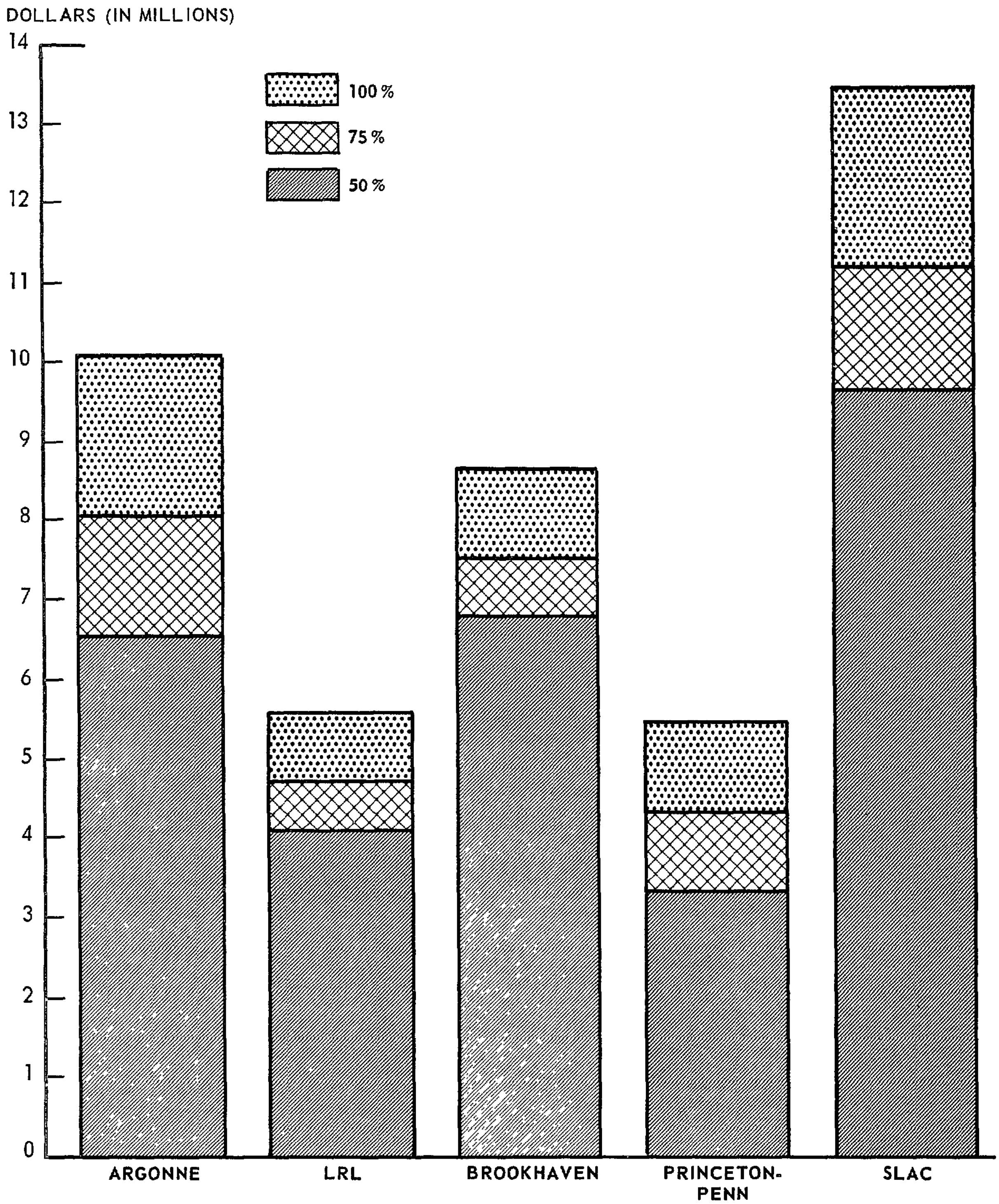
As part of our review, we developed estimates of accelerator operations costs and beam output which would have been expected to be achieved if the laboratories had been funded at a level that would have permitted them to optimize their fiscal year 1969 operations under normal operating conditions. We also developed similar information on operations costs and beam output at levels of 50 percent and 75 percent of optimum. Our estimates were developed with the assistance of laboratory personnel who provided us with most of the operating data relative to the mode of accelerator operations and beam output at the various levels.

The charts on pages 35 and 36 show total estimated operations costs and accelerator beam hours for each laboratory at the selected levels of operation. Additional details on costs and beam hours are presented in appendix III.

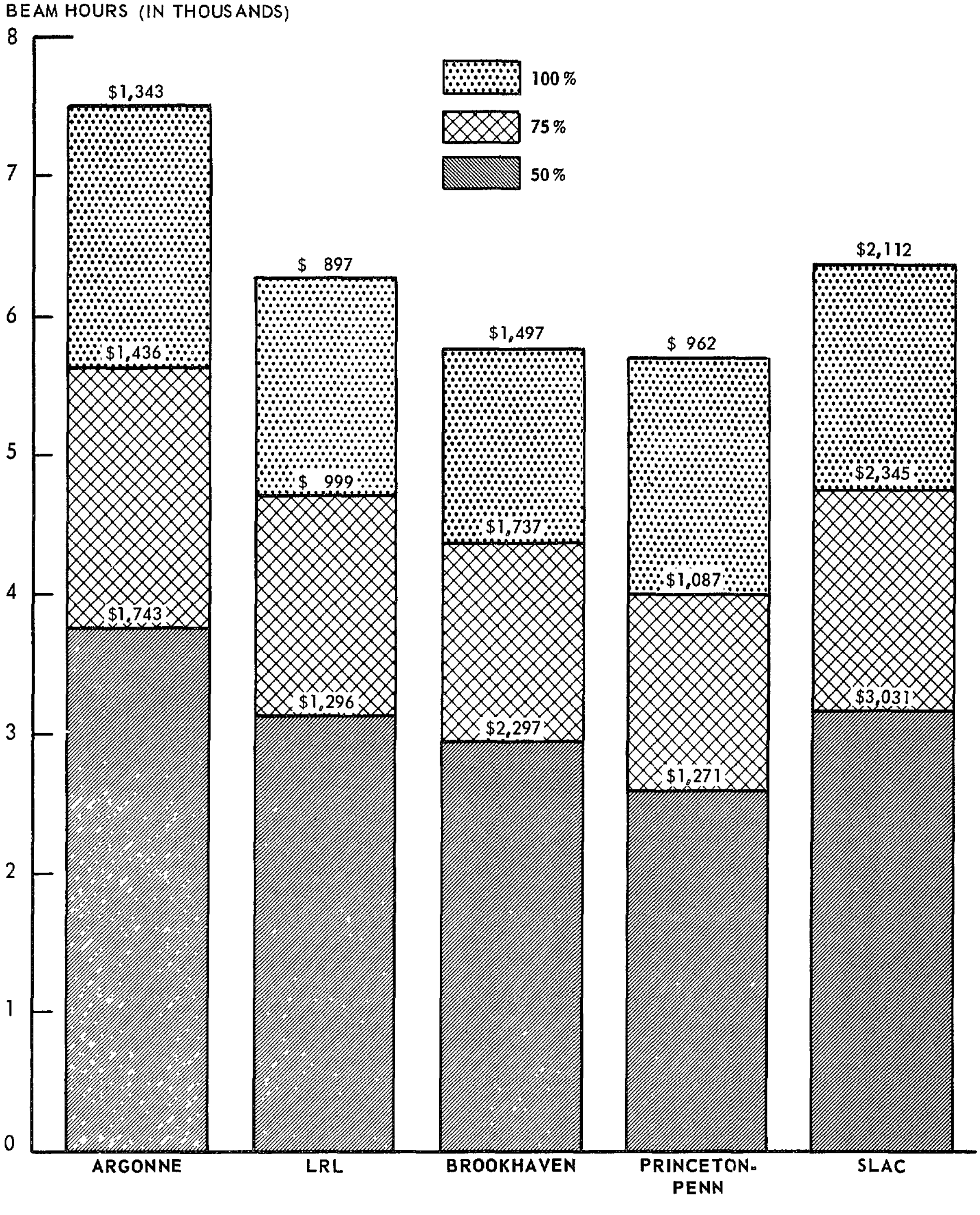
As shown in the first chart, the costs of achieving an operating level of 50 percent of optimum are substantially greater than those required to increase operations from 50 percent of optimum to 100 percent, thus indicating the magnitude of the fixed costs involved in operating the accelerators.

The second chart shows the amounts by which the average costs per beam hour decrease as operating levels increase. The difference in the number of beam hours estimated by the laboratories at the optimum level results from differing expectations and judgments with regard to accelerator shutdown requirements for maintenance, repairs, machine modification, improvements, and development work. The number of beam hours corresponded either directly to the selected operating level or to a level nearest to the selected level which the laboratories considered necessary in order to achieve peak efficiency.

ESTIMATED OPERATIONS COSTS AT SELECTED ACCELERATOR OPERATING LEVELS



ESTIMATED BEAM HOURS AND COSTS PER BEAM HOUR AT SELECTED ACCELERATOR OPERATING LEVELS



Although the cost per beam hour achieved is lower when the five accelerators are operated at their optimum levels, four of the five accelerators were operated at considerably below optimum during fiscal year 1969, as shown below. AEC advised us that this situation resulted from overall limitations on program funding.

Accelerator laboratory	Beam hours		Actual as a percent of optimum
	Actual 1969	At optimum	
Argonne	6,045	7,503	80.6
LRL	6,159	6,277	98.1
Brookhaven	4,890	5,770	84.7
Princeton-Penn	3,791	5,700	66.5
SLAC	4,627	6,360	72.8
Total	25,512	31,610	80.7

USE OF ADDITIONAL COST DATA IN EVALUATING ALTERNATIVE FUND ALLOCATIONS

In recent years, funds available for the HEP program have not been sufficient to enable each of AEC's accelerators to be fully utilized. It appears likely that program funds will continue to be limited in the future, especially in view of the estimated operating funds of $40 million a year that will be required in connection with the operation of the 200-Bev accelerator, an amount that is about 33 percent of the current HEP budget.

It is apparent that, under such circumstances in the future, AEC would be required to make extremely difficult decisions as to the allocation of available funds among the various accelerator laboratories.

We believe that information showing accelerator operating costs at various operating levels could be useful to AEC in assessing the effects of shifting operating funds from one accelerator to another.

For example, on the basis of the estimated fiscal year 1969 costs, as developed by us (see pp. 34 to 36), the following allocation of fiscal year 1969 funds for the accelerator operations subactivity would have resulted in providing the funds for the operation, at the optimum level, of the Brookhaven and SLAC accelerators, AEC's two highest priority operating accelerators.

Laboratory	Operating level	Number of beam hours	Total operations costs (000 omitted)
Argonne	50%	3,751	$ 6,539
LRL	75	4,708	4,704
Brookhaven	100	5,770	8,635
Princeton-Penn	50	2,600	3,304
SLAC	100	6,360	13,431
Total		23,189	$36,613

Under the above allocation, total costs for accelerator operations at the five laboratories would have been about the same as those actually incurred in fiscal year 1969.[1] Total accelerator beam hours would have been reduced by about 2,300 or 9 percent, but beam hours available on the Brookhaven and SLAC accelerators would have increased by a total of about 2,600 hours or about 27 percent.

We are not suggesting that an actual allocation of funds, as shown above, would have represented a more desirable and appropriate action under fiscal year 1969 operating conditions. Instead, our purpose is to illustrate that information of the type developed in our review, together with management's knowledge as to the priorities of the different accelerators, would be useful in evaluating alternative funding decisions.

We recognize that, in assessing the desirability of a fund allocation similar to that shown above, AEC would have to consider such factors as (1) the effects on the research efforts of individual scientists and on ongoing research programs, and (2) the possible need for shifts in research funds among the laboratories.

Also, our above allocation of funds was limited to a consideration of three operating levels--50, 75, and 100 percent. In developing cost and operating data at various levels, however, AEC might wish to consider smaller operating increments so that it could evaluate the desirability of alternatives involving smaller shifts in funding.

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[1] Actual accelerator operations costs (according to the GAO definition) incurred by the five laboratories in fiscal year 1969 amounted to about $36,569,000.

CONCLUSIONS AND RECOMMENDATIONS

We believe that the opportunity exists for AEC to obtain improved information concerning estimated and actual costs which would be useful in allocating available program funds and in evaluating the operations of the accelerators. Our specific conclusions and recommendations are discussed below.

Need for uniform cost reporting for high energy physics subactivities

Our review has shown that the laboratories have not reported operations and research subactivity cost data to AEC on a uniform basis. The laboratories' nonuniformities in reporting costs for the subactivities were caused, in part, by the different interpretations placed on AEC's definitions of operations and research. We adopted a definition of operations costs similar to the interpretation of AEC's definition by Princeton-Penn and SLAC and applied it uniformly in classfying the fiscal year 1969 costs at each of the five laboratories. We found that there were significant differences among the laboratories in distributing costs to the various subactivities.

We believe that the availability of more uniform cost information would be of assistance to AEC in evaluating the operations of the accelerators and in determining the relative funding needs of the laboratories. We believe also that the development by the laboratories of written account descriptions would tend to ensure that the cost data are reported on a uniform basis and in accordance with AEC requirements.

Recommendations

We therefore recommend that AEC:

1. Redefine the operations subactivity in a more precise manner so as to provide for more uniform cost reporting by the accelerator laboratories.

2. Require the laboratories to report separately the costs of operating and maintaining facilities and

major equipment relating to the performance of experiments at the laboratories which are not considered by AEC to be part of the operations subactivity.

3. Require the laboratories to develop written account descriptions as part of their formal accounting systems.

AEC agreed that greater uniformity in reporting cost data could be obtained and could be helpful in the administration of the HEP program. AEC stated that it plans to formulate new definitions of the research and operations subactivities, which will include the segregation of the costs of operating and maintaining facilities and major equipment relating to the performance of experiments.

AEC agreed also to work with the laboratories to develop written account descriptions and to ensure greater uniformity in cost reporting.

Need for cost and operating data at various operating levels

As previously noted (see p. 27), AEC has not established formal standards for relating accelerator performance to operating costs at various operating levels. In our opinion, additional information, similar to that which we developed showing the cost of operating accelerators and accelerator beam output at various operating levels, would be helpful to AEC in considering alternative allocations of available funds to the accelerator laboratories.

In this regard, we noted that Cambridge recently submitted budget requests to AEC, which included estimates for both a 10-shift weekly operation and a 14-shift weekly operation. Cambridge had been operating on a 10-shift basis due to budget reductions, and its experimental program apparently had been significantly reduced by the fund limitations. Cambridge submitted the two estimates to provide AEC with information showing the effect that different levels of funding would have on its operations.

We also believe that such information could be useful to AEC in comparing expected accelerator operating levels at the time funds are allocated with the actual levels that are achieved during the year. We recognize that there may be large variations between expected and actual operating levels due to unscheduled downtimes for maintenance, setup, repairs, and improvements, as well as continuous changes in the experimental schedule which would explain some of these variances. The variances could be analyzed by AEC to determine their causes and possible need for corrective action.

Recommendation

We therefore recommend that AEC require the laboratories to provide, during the budget formulation cycle, data relating to estimated accelerator operations costs and related beam output at various operating levels. Although for the purpose of our study we selected operating levels of 50, 75, and 100 percent and made various assumptions regarding related costs and beam output, the levels selected and assumptions made in implementing our recommendation would be for AEC's determination.

In commenting on our recommendation, AEC stated that additional data concerning operations subactivity costs and beam output at various levels of accelerator operation might be useful in program administration. AEC pointed out, however, that considerable information relating to this topic was already available for the laboratories, although not on a uniform basis, and that supplementary information could be obtained when required. According to AEC, any additional benefit that could be derived from such a requirement for more data of this type must be carefully weighed in terms of the expenditures of time and effort the laboratories would have to make in developing the additional data at the expense of research effort. AEC agreed, therefore, to implement this recommendation on a trial basis and to follow-up with an assessment of its overall value in program administration.

CHAPTER 4

USE OF ACCELERATORS IN PROGRAMS

OTHER THAN HIGH ENERGY PHYSICS

The Joint Committee on Atomic Energy requested that we examine into the costs and/or savings involved in shifting the program of an accelerator to some other research discipline. The Joint Committee also raised the question as to who would or could decide that the support category of an accelerator might be changed from HEP to some other research discipline. We therefore examined into the extent that the accelerators at the five laboratories included in our review were being used, or were planned to be used, in non-HEP research programs.

We found that some experiments related to nuclear physics or nuclear chemistry research had been conducted at four of the five laboratories. Except at one laboratory, the HEP program was charged for the cost of providing the beam and other services for the experiments.

Of the five laboratories, only Princeton-Penn had proposed shifting a major part of its program to some other research discipline. The proposal, however, was not approved by AEC, and it does not appear that the shift will be made in view of AEC's decision to shut down the Princeton-Penn accelerator in fiscal year 1971.

POTENTIAL COST SHARING BY PROGRAMS OTHER THAN HIGH ENERGY PHYSICS

We noted that nuclear chemistry experiments were being carried out on the Brookhaven accelerator by scientists from the laboratory's chemistry department. Brookhaven allocated the estimated costs incurred in providing accelerator operating time for such experiments to the benefiting program. During the 3-year period ended June 30, 1969, costs of about $590,000 were allocated by Brookhaven to its chemistry program for the use of the accelerator for the nuclear chemistry experiments. We noted, however, that the other laboratories were not requiring reimbursement for non-HEP research use of their accelerators.

During the period 1964 through 1969, Princeton-Penn ran a total of 19 experiments which, according to Princeton-Penn officials, were either in the nuclear physics field or in the nuclear chemistry field. Two additional non-HEP experiments were run during the first half of fiscal year 1970, and three additional experiments were scheduled to be started in the spring and summer of 1970. Of the 19 non-HEP experiments, nine were completed during fiscal year 1969 or were running at the year-end. Of these, six were nuclear physics experiments and three were nuclear chemistry experiments. A total of 1,704 prime research hours was charged to these experiments during fiscal year 1969.

During fiscal year 1969 the Princeton-Penn accelerator was used for a total of 17,602 research hours (hours charged to experiments run on the accelerator plus hours used for machine physics). Based on the number of research hours achieved and total operations costs incurred in fiscal year 1969 ($4,680,000), the average cost for each research hour was about $266. Using this average, we estimated that the costs charged to the HEP program in setting up and running non-HEP experiments during fiscal year 1969 amounted to about $453,000.

Princeton-Penn officials stated that they had never considered the possibility of charging non-HEP research users for the cost of using the accelerator and facilities. They said that they considered the laboratory to be a Government-financed institution available to any person or group wishing to conduct research, as long as it was good research.

At LRL the accelerator was being used periodically for nuclear chemistry research. During the period January 1968 through June 30, 1969, a total of 2,868 research hours was charged to nuclear chemistry experiments performed on the accelerator by researchers in LRL's Nuclear Chemistry Department. LRL officials advised us that the nuclear chemistry experiments did not interfere with other ongoing HEP experiments and that the costs relating to such experiments were mainly setup costs which were relatively minor--$6,890. They stated that, as a matter of policy, LRL did not require that these costs be allocated to the programs benefiting because the additional expense of separately accounting for the costs would not be warranted.

At Argonne we were advised that, since the inception of accelerator operations in 1963, a group of nuclear chemists has conducted a continuing series of nuclear chemistry experiments using the internal beam of the accelerator. We were told that the experiments required the exclusive use of the accelerator for about 2 hours a week. We estimated that the average annual cost (in fiscal year 1969 dollars) to the HEP research program for providing chemistry experiments on the Argonne accelerator was about $30,560. Argonne officials advised us that they had no requirement that such costs be allocated to the chemistry program.

Recommendation

We recommend that AEC require the accelerator laboratories to charge to non-HEP programs the costs of providing services to such programs in order to accurately show the costs of the various research programs involved.

In commenting on our recommendation, AEC noted that the non-HEP experiments conducted at the accelerators were a small part of the program and that the incremental cost to the program for each experiment was often small since the non-HEP experiments often did not interfere with other ongoing HEP experiments. Furthermore, a substantial proportion of these were of mutual interest to HEP and non-HEP users, so the HEP program benefited in these instances. AEC agreed that, when the incremental costs are significant and when it has been determined that adequate mutuality of interest does not exist, such costs will be charged to the benefiting program.

POSSIBILITY OF SHIFTING ACCELERATOR SUPPORT TO OTHER RESEARCH DISCIPLINE

Our review at the five accelerator laboratories indicated that only Princeton-Penn had proposed to shift a part of its program to another research discipline. In September 1969 Princeton-Penn submitted a proposal to AEC for a heavy ion improvement program, a major construction project for the modification of the accelerator. The program was designed to permit the acceleration of heavy ions--including uranium--up to 800 million electron volts per nucleon.

According to the proposal the project would cost between $4.5 million and $5.725 million and would be completed in four phases over a period of about 3-1/2 to 4 years.

In a letter submitted for the record during the fiscal year 1971 authorization hearings before the Joint Committee on Atomic Energy, the laboratory director stated that the program would cost about $2.5 million. The director subsequently advised us, however, that the $2.5 million cost related to phases I and II only. These two phases could provide some of the heavy ion capability stated in the proposal without proceeding to phases III and IV. According to the proposal full capability would have required the completion of phases III and IV and would have cost an additional $2 million. AEC officials advised us that its technical reviews of the proposal indicated that the cost estimates submitted by Princeton-Penn were too low. They stated that the proposal also did not contain estimates of the additional funding that would be needed to provide laboratory facilities required for utilizing the proposed heavy ion accelerator's capabilities.

We were advised by Princeton-Penn officials that the impact of a heavy ion capability on operating costs had not been studied but that they believed that there would be little or no effect on such costs. They stated that the heavy ion experiments would require shorter secondary beam lines and less shielding materials than those required for proton experiments; therefore certain costs, such as secondary beam power and setup costs incurred in supporting the heavy ion experiments, would be expected to be less. On the other hand, they advised us that it would be more difficult to operate the machine for heavy ion experiments and that additional personnel would be required so that any savings in power and setup costs would be offset.

According to the director of the laboratory and correspondence furnished to us by the director, there was considerable interest in the project by scientists in the nuclear physics, chemistry, and biomedical fields. Princeton-Penn officials advised us that, if the project were completed, the accelerator would probably be used for HEP research about half the time and for heavy ion--nuclear physics, chemistry, or biomedical--experiments the other half.

The decision to sponsor the project rested with AEC and would have involved a commitment of program funds, other than HEP program funds, for the construction of the project and for a share of the accelerator operating costs. The support category would have been dependent on which of AEC's programs would benefit from the project and on whether there was sufficient scientific or program interest, need and priority for the project, in relation to other competing projects within the programs.

Princeton-Penn's proposal was reviewed by various AEC officials within the Division of Research, who were responsible for the nuclear chemistry and physics programs. Also, the Division solicited the views of scientists in other laboratories and institutions regarding the scientific merits of the proposal. AEC advised us that, after considering the scientific merits of the proposal and after being faced with increasingly tighter budgets and competition for available research funds, it had decided not to provide financial support for the heavy ion project.

AEC's Assistant Director for Chemistry Programs stated that the chemistry programs' immediate needs for experiments involving the acceleration of heavy ions were expected to be satisfied by the new, super HILAC (heavy ion linear accelerator) which is under construction at LRL and by the heavy ion linear accelerator at Yale University. He pointed out, however, that there was an increasing interest by nuclear chemists and physicists in Princeton-Penn's adaptability to accelerate heavy ions.

CHAPTER 5

STANDARDS USED FOR EVALUATING RESEARCH QUALITY

The Joint Committee on Atomic Energy requested that we examine into the ground rules or standards used by AEC and the High Energy Physics Advisory Panel to decide what was good proposed research and into whether there were standards for evaluating actual performance in relation to potential performance.

USE OF STANDARDS IN EVALUATING RESEARCH

AEC and the High Energy Physics Advisory Panel generally are not involved in evaluating the quality of individual proposed experiments; however, they are involved in assessing the quality of the overall research program. AEC, in addition, becomes involved with the details of research proposed by university research groups as part of its annual review of contracts.

The final evaluation and approval of all experiments at each accelerator are made by the laboratory directorate upon the recommendations of the scheduling or program advisory committees which are charged with the responsibility for reviewing the scientific merit of proposed experiments. Our report to the Chairman of AEC (B-159687, May 13, 1970) included comments on program committee procedures. (See app. II.)

To perform an experiment using one of the accelerators, a research group must submit a proposal outlining the objectives, methods, and requirements of the proposed investigation. The program advisory committee evaluates the proposal on the basis of its scientific merit (i.e., if it is "good physics") and in the light of the existing accelerator experimental schedule and other proposed experiments.

Laboratory officials advised us that a clearly defined quantitative formula for determining whether a proposed experiment was good physics did not exist. We were advised that such decisions were made on the basis of the recommendations of each laboratory's program committee, the recommendations being based on the judgment of and scientific evaluations made by committee members. AEC advised us that the evaluations by the program committees were based on a range of both quantitative and qualitative criteria, some of which are listed below.

1. Will the proposed experiment obtain information on specific parameters that describe elementary particle reactions?

2. Will the experiment discover new particles, uncover new concepts or principles, or stimulate new ideas?

3. Will the probable results answer a fundamental theoretical question?

4. If the experiment is highly speculative, will the potential benefits or gains merit the undertaking?

5. Will the proposed experimental apparatus be capable of obtaining the results?

6. Is the available manpower and competence of the experimental group adequate for performing the experiment?

7. Will the experiment establish or test new experimental techniques?

8. Have adequate steps been taken to ensure that undesirable particle reactions will be minimized and that the data resulting from the experiment will be valid?

AEC advised us that the quality and performance of the research programs at the laboratories were continually evaluated by the program advisory committees, other laboratory advisory groups, and the laboratory senior staffs.

The program committees at SLAC and Princeton-Penn, for example, make a review of the results of ongoing experiments if and when the experimenter requests accelerator running hours or pictures in addition to the hours or pictures allotted at the time that the experiments were approved. LRL requires that experimenters give an oral presentation of the status of their ongoing experiments during regular meetings of the program committee. We were advised by officials at each of the five laboratories that the program committees reviewed the past performance of those scientists submitting new proposals for experiments.

Laboratory officials generally stated that they believed that HEP research was being adequately evaluated on an informal basis by the laboratory staffs and by the scientific community as a whole and that the evaluations were based on scientific opinions and judgment.

AEC advised us that, in developing scientific opinions and in making judgments with respect to evaluations of completed experiments, the laboratories considered such criteria as those listed below.

1. Did the experiment achieve its fundamental purpose and obtain the expected result?

2. Was the accuracy of the results as good as that projected or better?

3. Did the group recognize new phenomena in the investigation and take appropriate action? Were any important steps overlooked?

4. Were the results obtained within the projected time and cost estimate?

5. Were the results received favorably by the physics community?

6. Were the experimental results published, and were many theoretical papers published by others dealing with these results?

We were advised that there were specific quantitative and qualitative criteria for evaluating new proposals as well as completed experiments but that there was no clearly defined quantitative formula for weighting these criteria so as to give each proposal or experiment a quantitative grade. The assessment of the scientific merit of experiments in meeting the above criteria was based on the judgment of scientists who were considered by AEC to be experts in their respective fields.

LRL advised us that some other approaches to quantitative evaluation of research had been discussed in the past but that each approach had been found to have certain significant flaws. One approach was related to the number of scientific publications emanating from various experiments; however, because individual publications may vary in scope and quality, they were considered unreliable for making quantitative comparisons. LRL advised us that consideration also had been given to using the number of times that different publications had been referred to by scientists in connection with their own published results but that publications which reflected questionable results sometimes had been referred to more often. AEC advised us, however, that these methods were helpful in the qualitative evaluations of the research.

The AEC Assistant Director of the High Energy Physics Program stated that he and his staff evaluated the quality of research performed at laboratories through various means, such as program reviews made during periodic visits to the laboratories, participation in conferences and other meetings, and discussions with members of the scientific community. The Assistant Director said that the assessments and evaluations made by the scientific community and conveyed to AEC were a significant mechanism that was used by his office in evaluating the quality of research performed at the laboratories.

COMMENTS CONCERNING DEVELOPMENT OF QUANTITATIVE STANDARDS FOR SELECTING EXPERIMENTS

Because of the scientific and technical factors involved, we could not determine whether more quantitative standards could be developed to assist laboratory and AEC personnel in evaluating the quality of research.

We did, however, inquire into the feasibility of developing more quantitative standards for evaluating the quality of proposed HEP experiments. We also inquired into the possiblity that such standards could be developed by a central group of scientists, such as the High Energy Physics Advisory Panel, which would also become involved in the selection of experiments to be run on the accelerators. The following discussion relates to comments obtained during our inquiries.

Argonne, Brookhaven, and LRL officials stated that the possibility of developing a clearly defined quantitative formula for evaluating the quality of proposed research was questionable because such a formula would be based on many factors not applicable to all experiments. Also the relative weighting of these factors would be based on value judgments which would differ among scientists. Brookhaven explained that, although a clearly defined formula could be helpful in determining the priority for selection of proposed experiments, the state of the art--high energy physics--had not advanced to the point at which such a definition would be possible.

SLAC officials asserted that the use of clearly defined criteria and other formalized procedures for selecting experiments would amount to only a recordkeeping exercise. Princeton-Penn officials stated that it was not necessary to develop specific criteria or procedures because its program committee considered the most vital questions, including the question of whether the proposed experiment was good physics. They also stated that a determination of what was good physics was a matter of scientific judgment.

The laboratories generally were not in favor of using a central review committee for the selection of experiments.

SLAC pointed out that it would be difficult to attract qualified and creative scientists because of the time that would be required to serve on such a committee. Both SLAC and Princeton-Penn expressed some concern that, under a centralized selection process, proposed experiments which were considered highly exploratory would not be approved over the more conservative, classical-type experiments. Various laboratory officials explained that the probability of success of exploratory experiments was somewhat doubtful but that the payoff was usually greater if they were successful.

Each of the laboratories thus felt that the initiative for selecting experiments should remain with the laboratories. The laboratories also were generally of the opinion that development of precise quantitative standards for evaluating research results was not feasible because of the many judgmental factors involved.

CHAPTER 6

SCOPE OF REVIEW

We conducted our review at AEC Headquarters in Germantown, Maryland, and at five of the AEC contractor-operated accelerator laboratories at the following locations.

- Argonne National Laboratory, Argonne, Illinois
- Brookhaven National Laboratory, Upton, New York
- Lawrence Radiation Laboratory, Berkeley, California
- Princeton-Pennsylvania Accelerator, Princeton, New Jersey
- Stanford Linear Accelerator Center, Stanford, California

We directed our review toward obtaining an understanding of the manner in which operating funds were allocated to the various activities and subactivities of the HEP program. We examined into the laboratories' procedures used in arriving at amounts included in requests for operating funds submitted to AEC and into the AEC policies, practices, and procedures employed in determining the amount of funds for allocation to the laboratories and to other activities and subactivities of the HEP program.

We examined into certain aspects of the laboratories' accounting systems to evaluate their adequacy for providing useful cost and other information to AEC for program planning and budgeting. With the assistance of laboratory personnel, we developed pertinent data regarding accelerator operating costs and utilization for fiscal year 1969.

We also examined into the scheduling and use of accelerator operating time and into the criteria used by AEC and the laboratories in evaluating the quality of HEP research. Our review did not, however, include an evaluation of the quality of the research work conducted under the HEP program.

We reviewed applicable legislative history and records available at the laboratories and AEC Headquarters and obtained the views of various AEC and laboratory personnel knowledgeable of, and responsible for, the administration and conduct of the HEP program.

APPENDIXES

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Congress of the United States

JOINT COMMITTEE ON ATOMIC ENERGY

WASHINGTON, D.C. 20510

October 22, 1969

Honorable Elmer B. Staats
Comptroller General of the United States
U. S. General Accounting Office
Washington, D. C.

Dear Mr. Staats:

The purpose of this letter is to formally request the assistance of your office in connection with a selective review of certain aspects of the Atomic Energy Commission's high energy physics research program. In particular the Committee is interested in the AEC's method of allocating resources among the various activities of this program, including the bases for determining where to apply budget reductions to the operation of high energy accelerators. Often in the past, when proposed budgets were reduced as a result of the authorization and appropriation process, the AEC has imposed essentially a pro rata or equitable reduction among all its operating contractors.

The central question seems to be whether it is more appropriate for all contractors operating high energy accelerators to accept somewhat curtailed productivity or for the operation of one or more of the accelerators to be substantially curtailed so that the remaining facilities can be operated at relatively full utilization. An effort should be made to determine the "ground rules" or standards used by the AEC and the High Energy Physics Advisory Panel (HEPAP) to decide what is "good" proposed research. This request stems from a statement in the HEPAP report of June 1969 to the AEC, namely, in the fifth paragraph on page 20 where it is stated that:

> "During the next decade several of the existing accelerators will be operated at a reduced level or shut down when interest declines in the research that can be accomplished there."

Several questions are raised by this statement:

1. Who makes the decision that "interest" in the research to be conducted at a given accelerator has declined to the point where support from the high energy physics budget should be curtailed or stopped?

2. Who would or could decide that the support category of an accelerator might be changed from high energy physics to some other field like biology and medicine or chemistry, or various combinations?

3. Are there standards against which actual performance and potential performance are gauged?

If standards do not exist or are tenuous, you should determine if the AEC could develop, through management cost analysis or other techniques, standards which might provide for a more efficient allocation of funds and improved over-all quality of high energy research within the budgets provided by the Congress.

It is expected that GAO will wish to examine (1) the on-line time for experiments of each of the major high energy accelerators, (2) the program of operation of accelerators to determine whether fiscal economies could be realized through more efficient scheduling of accelerator use time, (3) the costs of operating and maintaining such facilities in order to provide reasonable estimates of funds required for various levels of accelerator operations, and (4) the costs and/or savings involved in shifting part of, or the entire program of an accelerator like the Princeton-Pennsylvania accelerator, from high energy physics to research in biology and medicine, chemistry, nuclear physics or some other recognized discipline.

It would be particularly appreciated if your staff could advise the Committee of any significant findings developed which might assist the Committee during its review of AEC's fiscal year 1971 budget request, even if your final report cannot be prepared by that time.

Sincerely yours,

Chet Holifield
Chairman

Excerpt from GAO report dated May 13, 1970, to the Chairman, Atomic Energy Commission, on selected aspects of the management of the high energy physics research program (B-159687)

CHAPTER 2

METHOD OF MANAGING AND CONDUCTING HIGH ENERGY PHYSICS RESEARCH

MANAGING HIGH ENERGY PHYSICS RESEARCH

The Division of Research at AEC Headquarters has the responsibility for the technical administration of the high energy physics research program in AEC contractor-operated laboratories and outside organizations. Although AEC's operations offices, which are located throughout the United States, provide contract administration, they generally do not get involved in the programmatic direction and management of high energy physics research activities.

The Office of the Assistant Director for the High Energy Physics Program within the Division of Research comprises three branches: the Advanced Accelerator Branch, the University Research Branch, and the Accelerator Centers Branch.

The Advanced Accelerator Branch is concerned with that part of the high energy physics research program relating to the development of future accelerator capability. The University Research Branch is responsible for that part of the program carried out by university research groups. These include theory groups, accelerator user groups, and other experimental groups.

The Accelerator Centers Branch is responsible for that part of the program directly related to AEC's six accelerator laboratories. In addition to supporting the four laboratories included in our review, AEC supports accelerator laboratories at Harvard and Princeton Universities. According to AEC, the responsibility for carrying out the day-to-day activities at the accelerator laboratories is placed upon the laboratory directors and associate directors who are directly involved in the laboratories' programs and who are considered to be experts in their respective fields.

CONDUCTING HIGH ENERGY PHYSICS EXPERIMENTS

Each of the four accelerator laboratories included in our review has several research groups which plan and execute experiments on the accelerator as well as groups which perform such support functions as maintenance of certain equipment. There is a great diversity in the types of experiments undertaken in high energy physics and in the methods employed in carrying them out. Some experiments are conducted entirely by members of the research groups associated with the laboratories. Other experiments, however, are conducted by the many university research groups or by joint laboratory-university groups. University research groups usually perform the initial planning, prepare specialized equipment, and conduct the final analysis of the experimental data at their home institutions.

Before developing an experiment proposal, a research group studies the physics process to be investigated and reviews experimental requirements and methods of making measurements, detection devices to be used, and the characteristics of the particle beam needed. The experiment proposal resulting from the above process is submitted to an accelerator laboratory for review and possible acceptance.

If the proposal is accepted, the research group proceeds to design and fabricate any special equipment required for the experiment. The experiment is scheduled, and available equipment and space are allocated by the laboratory for the duration of the proposed experiment. The staff at the accelerator laboratory, often assisted by university groups, designs and sets up the beam and other major pieces of experimental apparatus required for the experiment and cooperates with the research group in working out the final details of accelerator operations.

During a given running period at an accelerator, several experiments usually run simultaneously. While these experiments are gathering useful data, others are usually being removed, installed, tested, or held in standby.

When energetic particles collide with, and dislodge electrons from, the atoms located near their path, they leave a trail of ions as a brief trace of their existence.

Under suitable conditions, this trail of ions can be made to appear as a track of small bubbles in a superheated liquid, such as hydrogen in a bubble chamber; as a flash of light in a counter; or as a series of sparks between electrically charged plates in a spark chamber. The detection device to be used generally depends upon the objectives of the experiment.

A typical spark chamber research group might spend several months setting up its equipment at the accelerator site, follow this with a comparable period of running time at the accelerator, and then return to the university for a period of extensive measurement and analysis of the data resulting from the experiment and for preparation of the results for publication.

A bubble chamber research group obtains film for analysis by sending some of its members to the accelerator site for an extended period to assist with the bubble chamber experiment. AEC advised us that such a group also operates the particle-beam-control magnets and supervises the operation of the bubble chamber. The bubble chamber facility, however, generally is provided and operated by the accelerator laboratory.

Data analysis requires extensive facilities for scanning, measuring, and encoding the data as well as many hours of high-speed computer processing time. The need for such facilities accounts for a significant portion of the costs of high energy physics research.

Once the data are analyzed and the theoretical implications are reviewed, the experimental results are usually published in the open literature and otherwise distributed so that other groups of theorists and experimentalists may assess the observed results in the light of their own research work and future plans.

CHAPTER 3

PROCEDURES FOR REVIEW AND APPROVAL OF EXPERIMENTS

To perform an experiment using one of the major accelerators, a research group must submit to the laboratory operating the accelerator a proposal outlining the objectives, methods, and requirements of the proposed investigation. The proposal is reviewed for acceptance by a laboratory program advisory committee (program committee) which evaluates the proposal on the basis of its scientific merit and feasibility and in the light of the existing accelerator experimental schedule and other proposed experiments.

The program committee meets periodically to evaluate proposals and makes appropriate recommendations concerning their disposition. On the basis of the recommendation of the program committee, the laboratory director (associate laboratory director at Argonne) may either approve, reject, or defer the experiment; or approve the experiment partially for a smaller number of running hours than requested; or require modification of the experiment.

Therefore, the committees, acting as bodies of specialists in the field of high energy physics research, substantially influence the selection of, and emphasis placed on, the type of research experiments conducted.

COMPOSITION OF PROGRAM COMMITTEES

As shown below, the program committees at the four laboratories included in our review were composed of individuals from various institutions.

Membership of program committees as of January 1970

	Total members	Institution with which associated		
		Laboratory at which accelerator is located	Universities	Other AEC laboratories
Argonne	7	1	5	1
Brookhaven	11	5	6	-
Berkeley	9	3	5	1
SLAC	9	4	4	1

The program committees are composed of physicists who are generally appointed for 2-year terms by the laboratory directors, except at Argonne where the associate laboratory director for high energy physics makes such appointments on a yearly basis. All the program committees except the SLAC committee have, in addition to the members shown in the above table, ex officio members who serve as consultants.

We noted that as of January 1970 there was one individual who was serving on three of the four program committees functioning at the four laboratories included in our review. This individual was serving on committees at Berkeley, Brookhaven, and SLAC.

The Brookhaven program committee has found it beneficial to have a physicist from the European Organization for Nuclear Research high energy physics facility sit as an observer at its meetings and to have a physicist from Brookhaven sit as an observer at the European Organization's meetings. By mutual agreement these physicists serve 1-year terms as participants in the research programs of the respective laboratories, and during these terms they attend program committee meetings as observers. Brookhaven officials advised us that this arrangement enabled the two facilities, which are very similar, to preclude unnecessary experiment duplication and to capitalize from the experiences gained by each.

In addition, three of the laboratories have a physicist from one of the other laboratories serving on their program committees. We were told by Argonne that this arrangement provided a very good means of determining what items of scientific interest were occurring at the other laboratory.

METHODS OF MONITORING PROGRAM COMMITTEES

The AEC contract with Stanford University requires that the procedures of the SLAC program committee, including written procedures for programming and scheduling experiments, be approved by AEC. Contracts with the other three laboratories do not have a similar requirement. The SLAC program committee's scheduling procedures are also reviewed by the SLAC Scientific Policy Committee, which reports to the president of Stanford University, and whose members are appointed with the concurrence of AEC.

AEC provided us with the following additional information concerning the monitoring of program committees.

Each laboratory's program committee receives appreciable direct monitoring from various organizations composed of accelerator users and from laboratory management. There is also much indirect monitoring of the actions and procedures of the committees by AEC. For example, very close contact is maintained between the AEC high energy physics staff and (1) program committee members, (2) accelerator laboratory personnel, including the director and top staff, (3) accelerator user groups, principal investigators, and senior physicists, and (4) various program evaluation committees, such as the High Energy Physics Advisory Panel, SLAC's Scientific Policy Committee, and user committees, AEC also maintains close contact through receipt of frequent periodic reports and through publications.

POLICIES AND PROCEDURES
OF PROGRAM COMMITTEES

We were advised that data relating to proposed experiments were informally exchanged between the program committees at the various laboratories. We were told that committee members also received information relating to proposed or completed experiments informally through personal contacts with physicists from other laboratories.

Laboratory officials stated that, in evaluating a proposed experiment, the program committees generally considered the following factors, although not necessarily in this order of priority.

1. The scientific value of the proposed experiment and whether it could be considered "good physics."

2. The ability of the experimental group to accomplish the objectives of the proposed experiment.

3. The characteristics of the proposed experiment and its compatability with the capabilities of the accelerator and with other scheduled or proposed experiments.

4. The magnitude of the proposed experiment, as measured in terms of cost and running time required.

We have noted the following differences in the procedures of the program committees at the four laboratories.

1. In evaluating experiment proposals, only the program committee at Berkeley receives, as a standard procedure, an oral presentation from a spokesman representing the research group. The presentation describes the nature, goals, justification, technique, and apparatus to be used in the proposed experiment. At SLAC, research groups may request to present their proposals orally and, in some cases, the program committee may request that they do so. At Argonne, a spokesman for the research group is requested to attend the program committee meeting to answer questions concerning the proposal. At Brookhaven, however, research groups are not given the opportunity to present their proposals to the program committee unless the committee specifically requests that they do so.

2. The Brookhaven program committee has found it very useful to make a compilation of data concerning proposed and completed experiments at other laboratories that are similar to each experiment proposed for consideration by the committee. These "memory refreshers" are provided to each committee member in advance of the meetings and are used, among other things, to avoid duplication of effort. The other three laboratories do not use similar-type memory refreshers.

3. After an experiment proposal is received at Argonne, the program committee appoints one of its members to act as a "contact man" with the research group. It is the contact man's responsibility to make judgments on program areas and to provide pertinent and relevant information concerning the proposal to the program committee. In addition, for counter and spark chamber experiment proposals, a coordinator is appointed to act as a consultant to work with the research group and to assist it in evaluating beam requirements and length of running time. This coordinator is appointed at the request of the program committee by the operations committee--a committee which aids the program committee in evaluating the feasibility and compatibility of proposed experiments. Brookhaven stated that all proposals were studied by the Experimental Planning Division and that its findings were reported to the committee via its division leader and the chairman of the Accelerator Department who were ex officio members of the program committee. SLAC advised us that, after a proposal was received by the program committee, two of the committee members were assigned responsibility for making a detailed analysis of the proposal for presentation before the committee at one of its bimonthly meetings. Prior to September 1969, Berkeley did not have a similar procedure. We have been advised, however, that Berkeley currently employs a procedure whereby its committee assigns one or more members to make a detailed evaluation of each proposal before the meeting at which it is to be considered.

EFFECTIVENESS OF PROCEDURES FOR
REVIEWING AND APPROVING EXPERIMENTS

As previously noted, the program committees at the accelerator laboratories, acting as bodies of specialists in the field of high energy physics research, substantially influence the selection of, and emphasis placed on, the type of experiments conducted. As shown on page 12, more than half of the committee members at each accelerator laboratory we reviewed were associated with institutions other than that AEC laboratory and thus provided outside users of the accelerator with a voice in the selection of experiments.

On the basis of our review, it appears that the existing program committee system should provide an effective method of selecting the most appropriate experiments to be performed at each accelerator from those proposed and that the broad spectrum of accelerator users represented on the committees should provide reasonable assurance against unnecessary duplication of research activities. We did note, however, that AEC was not represented on these committees and that AEC officials generally did not attend committee meetings, even as observers.

We recognize the advantages of AEC's indirect monitoring of the program committee's actions, as discussed on page 14. We believe, however, that attendance at some of the committee meetings by AEC representatives could provide an additional method of reviewing and evaluating the procedures in use to independently determine whether proposed research experiments are being adequately evaluated and whether the decisions to approve, reject, defer, or modify proposed experiments appear appropriate under the circumstances.

Therefore, in view of AEC's responsibilities for ensuring that the substantial funds being expended on the high energy physics research program are used as effectively as possible, we proposed that AEC Division of Research representatives attend as many of the program committee meetings at the various laboratories as necessary to directly observe the procedures in use and to independently evaluate their effectiveness. AEC officials could also become aware of differences in the procedures used by the various committees, such as those pointed out in this report, and, where appropriate, could suggest changes designed to improve the selection process. By attending some of the program committee meetings, AEC could, in our opinion, further assure itself that (1) proposed experiments are receiving adequate consideration, (2) steps are being taken to avoid unnecessary duplication of experimental effort, and (3) experiments are being approved consistent with the overall aims and purposes of the high energy physics research program.

AEC stated that a number of the monitoring procedures previously discussed had a clear advantage over personal attendance at the program committee meetings and personal evaluation, in that they not only utilized the individual technical capabilities of the AEC staff member but also made fuller use of the judgment, knowledge, and technical capability of the foremost experts in the field.

AEC recognized, however, that it might be useful for Division of Research representatives to attend such meetings from time to time and agreed to do so as an additional monitor and source of information on the relative values and activities of the various parts of the high energy physics program. AEC stated that attendance at the meetings would be an additional source of information for evaluation of the various user groups as well as the accelerator laboratories and that there might also be value in attending some of the meetings to intercompare the committee procedures and perhaps suggest improvements in the procedures of some of the committees.

GAO ESTIMATES OF FISCAL YEAR 1969

ACCELERATOR OPERATIONS COSTS

AND BEAM HOURS

AT SELECTED OPERATING LEVELS

ARGONNE NATIONAL LABORATORY

	Actual FY 1969	Optimum level (note a)	75% level	50% level
Salaries	$2,291,288	$ 2,851,998	$2,243,824	$1,885,463
Materials and services	1,906,847	2,459,959	1,941,873	1,449,476
Power	1,664,270	2,003,040	1,637,280	1,271,520
Overhead and other indirect costs	2,293,645	2,760,798	2,255,059	1,932,747
Total	$8,156,050	$10,075,795	$8,078,036	$6,539,206
Accelerator beam hours	6,045	7,503	5,627	3,751

LAWRENCE RADIATION LABORATORY

	Actual FY 1969	Optimum level	75% level	50% level
Salaries	$2,364,240	$2,678,376	$2,253,526	$1,963,421
Materials and services	686,151	775,649	648,487	560,854
Power	631,501	639,674	512,469	426,773
Overhead and other indirect costs	1,358,100	1,536,972	1,289,275	1,116,126
Total	$5,039,992	$5,630,671	$4,703,757	$4,067,174
Accelerator beam hours	6,159	6,277	4,708	3,139

[a]The cost data at the optimum level are based on an average of six to seven simultaneous experiments which Argonne officials stated could be accommodated by the accelerator at that operating level. Subsequent to our review, however, the laboratory's officials stated that their reanalysis of the experimental program indicated that only an average of four simultaneous experiments could have been run and that the estimated costs at the optimum level would be somewhat lower than the amounts shown above.

BROOKHAVEN NATIONAL LABORATORY

	Actual FY 1969	Optimum level	75% level	50% level
Salaries	$ 3,519,927	$ 4,035,200	$ 3,487,100	$3,125,600
Materials and services	1,216,457	1,436,900	1,228,200	1,093,000
Power	889,739	961,000	846,000	744,000
Overhead and other indirect costs	2,004,051	2,201,400	1,986,400	1,835,900
Total	$ 7,630,174	$ 8,634,500	$ 7,547,700	$6,798,500
Accelerator beam hours	4,890	5,770	4,346	2,960

PRINCETON-PENNSYLVANIA ACCELERATOR

	Actual FY 1969	Optimum level	75% level	50% level
Salaries	$ 1,875,319	$ 2,206,632	$ 1,790,190	$1,416,863
Materials and services	906,289	1,126,928	825,142	523,356
Power	368,743	448,700	358,766	284,974
Overhead and other indirect costs	1,529,719	1,700,316	1,373,962	1,079,081
Total	$ 4,680,070	$ 5,482,576	$ 4,348,060	$3,304,274
Accelerator beam hours	3,791	5,700	4,000	2,600

STANFORD LINEAR ACCELERATOR CENTER

	Actual FY 1969	Optimum level	75% level	50% level
Salaries	$ 1,995,552	$ 2,106,480	$ 1,995,552	$1,826,115
Materials and services	5,489,805	7,233,253	5,588,335	4,658,437
Power	767,791	1,012,000	806,700	568,533
Overhead and other indirect costs	2,809,752	3,079,584	2,809,752	2,597,814
Total	$11,062,900	$13,431,317	$11,200,339	$9,650,899
Accelerator beam hours	4,627	6,360	4,776	3,184

U.S. GAO, Wash., D.C.