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United States General Accounting Office

GAO

Report to the Ranking Minority Member,
Subcommittee on Energy and Water
Development, Committee on
Appropriations
United States Senate

April 1986

NUCLEAR SCIENCE

DOE Should Provide More Control in Its Accelerator Selection Process

129748

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Resources, Community, and
Economic Development Division

B-222223

April 4, 1986

The Honorable J. Bennett Johnston
Ranking Minority Member
Subcommittee on Energy and
  Water Development
Committee on Appropriations
United States Senate

Dear Senator Johnston:

This report responds to your request dated May 3, 1985. It includes information on the review and selection process used by the Department of Energy in approving the Southeastern Universities Research Association's proposal to plan, manage the construction of, and operate a continuous electron beam accelerator facility at Newport News, Virginia. The report also includes a recommendation to the Secretary of Energy directed toward improving future procurements of nuclear physics accelerator facilities.

Unless you publicly announce its contents earlier, we do not plan to distribute this report further until 14 days after its publication date. At that time, we will send copies to the Director, Office of Management and Budget; other interested committees; members of Congress; and the Department of Energy. Copies will be made available to others upon request.

Sincerely yours,

Neal P. Curtin for

J. Dexter Peach
Director

Executive Summary

On July 20, 1983, the Department of Energy (DOE) approved a proposal submitted by the Southeastern Universities Research Association (the Association) to plan, manage the construction of, and operate a facility known as the Continuous Electron Beam Accelerator Facility (CEBAF). The Association's proposal was selected from among five submitted by universities and laboratories for the new electron accelerator as part of DOE's nuclear physics program.

At the request of J. Bennett Johnston, Ranking Minority Member, Subcommittee on Energy and Water Development, Senate Committee on Appropriations, GAO reviewed the basis for DOE's selection and approval of CEBAF, including

- the events and procedures leading to the submission of proposals for a new electron accelerator and
- DOE's review of and selection process for proposals.

In addition, GAO also reviewed technical problems—identified during the selection process—associated with CEBAF's approved design and efforts to resolve them. (See p. 8.)

Background

DOE's Division of Nuclear Physics conducts research at universities and national laboratories that use large machines called "accelerators." These machines accelerate very small subatomic particles to almost the speed of light, and then crash them into targets made of various materials. The objective is to study the results of the collision to determine characteristics of the nuclei of the atoms comprising the target material. For almost a decade, a high priority of the nuclear physics community has been a new accelerator capable of producing a continuous—as opposed to pulsed—beam of electrons with a high-energy range.

In January 1983, a DOE advisory committee of physicists from universities and DOE laboratories, called the Nuclear Science Advisory Committee, reviewed five unsolicited proposals to design, build, and operate such an accelerator. On the basis of a recommendation from the Nuclear Science Advisory Committee, DOE approved the unsolicited proposal submitted by the Association. Since DOE's approval, the Association has received $4.5 million from DOE for research and development through fiscal year 1985. However, the project has not received any construction funds to date. Total construction costs for the project are expected to amount to $194.3 million (in 1985 dollars) and the estimated completion date for the project is 1992. (See pp. 8 to 12.)

Results in Brief

GAO found that the use of unsolicited proposals in selecting the CEBAF design resulted in

- DOE's approving a contractor for the CEBAF that had neither an organization nor the technical expertise to plan, manage the construction of, and operate a CEBAF. After receiving the contract, the Association established a CEBAF project office and hired experienced personnel.
- DOE's selecting a design for the CEBAF that had several technical uncertainties.
- DOE's not identifying and evaluating technologies that were better suited for the CEBAF and available at the time of the original design selection. A 1985 technology review by the CEBAF project office resulted in the selection of a different design.

While the problems associated with using unsolicited proposals have subsequently been corrected, DOE may wish to use other procurement methods for future accelerators. For example, DOE could have developed its own system design concept and then used the request for proposal procurement approach. Using this approach, DOE would have been in a better position to identify the best technology and select the most qualified organization to plan, manage the construction of, and operate the facility.

Principal Findings

An unsolicited proposal is a written offer by a prospective contractor to perform a task or effort for the government without prior government solicitation. DOE believes this method inspires innovative designs, heightens competition, and allows for maximum participation from the nuclear physics community. Officials in DOE's Division of Nuclear Physics stated that the unsolicited proposal method had historically been used to procure nuclear physics accelerators. (See pp. 21 and 22.)

Another characteristic of an unsolicited proposal is that the organization submitting the proposal owns the technical design or concept presented in the proposal if it is considered unique or innovative by DOE. Thus, in this case, to use what it considered to be the best technical design, DOE had little choice but to award a contract to the Association to locate, plan, manage the construction of, and operate CEBAF. DOE felt that the technical uncertainties with the design and the Association's lack of expertise to plan, manage the construction of, and operate the CEBAF could be resolved after the contract was awarded. In fact, most of these problems have been corrected since the selection of the Association's proposal in 1983. The Association has established a CEBAF project office with key personnel with experience in constructing, managing, and operating accelerators. (See pp. 21 and 22.)

The use of unsolicited proposals also did not draw out all available technical designs because only the technical designs contained in the five unsolicited proposals were reviewed and evaluated by the Nuclear Science Advisory Committee. In May 1985, about 2 years after the Association's design was selected, a technological review was initiated by CEBAF's project office to identify and evaluate technical designs that may be better suited for CEBAF. The review disclosed two technical designs—referred to by physicists as "standing wave" and "superconductivity"—that did not have the technical uncertainties associated with the original design. While the standing wave technology was fully developed and available at the time DOE selected the Association's proposal, the superconductivity technology was not available. However, research and development work was underway, and by November 1984, this technology would also have been available for use in a CEBAF. On the basis of results of the technology review, the CEBAF project office has decided to replace the original design with one which is based on the superconducting technology. (See pp. 32 to 37.)

Recommendation

GAO recommends that the Secretary of Energy direct DOE's Division of Nuclear Physics to explore other procurement approaches in future accelerator acquisitions, with a view toward assuring that DOE (1) considers all available and relevant technologies and (2) retains sufficient flexibility and control over all aspects of such acquisitions, before and after approval.

Agency Comments

GAO did not request DOE to review and comment officially on a draft of this report. However, the views of directly responsible officials were sought during the course of GAO's work and are incorporated in the report where appropriate.

Contents

Abbreviations

CEBAF	Continuous Electron Beam Accelerator Facility
DOE	Department of Energy
GAO	General Accounting Office
GeV	billion electron volts
MeV	million electron volts
NSAC	Nuclear Science Advisory Committee
OMB	Office of Management and Budget
RCED	Resources, Community, and Economic Development Division (GAO)
SURA	Southeastern Universities Research Association

Introduction

The Department of Energy (DOE) sponsors basic research in nuclear physics to explore the structure and characteristics of the atom's nucleus. DOE provides funding to universities and national laboratories for experimental research and for the construction and operation of large machines—called accelerators—used to conduct the research. Accelerators increase the speed and energy of subatomic particles, such as protons and electrons, and collide those particles with targets made of various liquids, solids, or gases. Debris from the collision is then analyzed to determine the composition of the particles and the forces that interact among them.

For several years, the nuclear physics community and DOE have been interested in constructing a new accelerator project called the Continuous Electron Beam Accelerator Facility (CEBAF). In 1982, the nuclear physics community identified the general specifications for the CEBAF; and by January 1983, DOE had received five proposals for a CEBAF. From among the five proposals, DOE selected a proposal submitted by the Southeastern Universities Research Association (SURA) to design, manage the construction of, and operate a new nuclear physics accelerator in Newport News, Virginia. During and after completion of the selection process, questions arose concerning the events leading to and after the selection. As a result, Senator J. Bennett Johnston, Ranking Minority Member, Subcommittee on Energy and Water Development, Senate Committee on Appropriations, requested us to review DOE's selection process. In response to his request, this report discusses the process used by DOE in selecting CEBAF, identifies problems associated with the process, and discusses efforts to resolve technical problems identified during the review that related to the new accelerator's design.

To provide the background for these topics, this chapter includes a perspective or description of DOE's physics research program; a brief historical description of the selection and funding of CEBAF; a description of the organization that was selected to build and operate the new facility; a description of how the accelerator is designed to work; and our objectives, scope, and methodology.

Description of DOE's Physics Research Program

Physics research conducted by DOE is divided into two programs: high-energy physics and nuclear physics. Both are basic sciences that explore the structure and fundamental characteristics of matter and energy. The major difference between the two sciences is that high-energy physics is directed toward the discovery and understanding of the most fundamental components of matter, while nuclear physics is primarily concerned with the interaction and structure of the atom's nucleus. Although the objectives and focus of high-energy and nuclear physics are somewhat different, both use accelerators to perform research. The CEBAF, which is the subject of this report, is a nuclear physics accelerator.

Accelerators are complex machines that enable physicists to "see" inside the atom and its nucleus and study the structure of subatomic particles. Such machines produce and accelerate beams of particles and collide those beams with targets composed of other subatomic particles. Configured in a variety of forms, accelerators can be linear or circular and can accelerate protons, antiprotons, electrons, positrons, or ions.[1] The differences between accelerators exist because such machines are generally designed to meet a specific research need or delve into a particular area of research. The largest accelerator facility in the United States—a high-energy physics accelerator—is located at the Fermi National Accelerator Laboratory in Batavia, Illinois. It consists of a number of connected accelerators, the largest of which is about 4 miles in circumference. A detailed description of various accelerator designs and their purposes can be found in our report entitled DOE's Physics Accelerators: Their Costs and Benefits, (GAO/RCED-85-96, Apr. 1, 1985).

In fiscal year 1985, DOE's Division of Nuclear Physics provided $172.6 million to support nuclear physics research at 11 accelerator facilities. Seven of these are designated national facilities, which are made available to all scientists on the basis of the scientific merit and technical feasibility of their proposed research. A list of the seven facilities follows:

- Argonne Tandem/Linac Accelerator System at the Argonne National Laboratory in Argonne, Illinois;
- Bates Linear Accelerator Center at the Massachusetts Institute of Technology in Middleton, Massachusetts;

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[1] These are all very small particles that are part of an atom or are derived through physical changes to the atom. For example, ions are charged particles that result from the atom losing or gaining one or more electrons.

- Clinton P. Anderson National Meson Physics Facility at the Los Alamos National Laboratory in Los Alamos, New Mexico;
- Holifield Heavy Ion Research Facility at the Oak Ridge National Laboratory in Oak Ridge, Tennessee;
- Superhilac/Bevalac at the Lawrence Berkeley Laboratory in Berkeley, California;
- Tandem/AGS Heavy Ion Facility at the Brookhaven National Laboratory in Upton, New York; and
- 88-Inch Cyclotron at the Lawrence Berkeley Laboratory in Berkeley, California.

The other four facilities are located at universities and are primarily used by the host university. The following is a list of these facilities: A.W. Wright Nuclear Structure Laboratory (Yale University, New Haven, Conn.); Cyclotron Institute (Texas A&M University, College Station, Tex.); Nuclear Physics Laboratory (University of Washington, Seattle, Wash.); and Triangle Universities Nuclear Laboratory (Duke University, Durham, N.C.). DOE sponsors research and experiments at these facilities and has provided funding for the construction and operation of the accelerators at the facilities.

The long-range goal of nuclear physics is to develop an understanding of the interactions, properties, and structures of the atom's nucleus at the most elementary level. The basic resources to accomplish the goal are dedicated scientists, engineers, and a variety of facilities. To identify facilities and scientists' needs, DOE and the National Science Foundation,[2] in 1977, established a Nuclear Science Advisory Committee (NSAC), made up of members from national laboratories and universities. The NSAC sets forth long-range plans, goals, and priorities and provides these agencies with information and recommendations on nuclear physics needs. To do this, NSAC conducts studies, often at the request of DOE, into future needs as expressed by the nuclear physics community. Although DOE makes the final decisions on all program activities, it relies heavily on NSAC for advice and planning for its program activities.

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[2] The National Science Foundation and DOE are the two federal agencies responsible for funding high-energy physics and nuclear physics research. DOE provides about 90 percent and 80 percent, respectively, of the federal dollars for high-energy and nuclear physics. The Foundation provides the rest.

Description of the Selection and Funding of CEBAF

For over a decade, the nuclear physics community, through NSAC, has expressed the need for a new accelerator that would provide a continuous beam of electrons in the 1-2 billion electron volt[3] (GeV) energy range. Present accelerators are not capable of producing a continuous beam of electrons at a high enough energy to conduct the experiments felt necessary by the nuclear physics community.

In April 1982, NSAC issued a report setting forth the specific energy requirement felt necessary to conduct the needed experiments. By January 1983, DOE had received five unsolicited proposals for such a facility. (An unsolicited proposal is a written offer by a prospective contractor to perform a task or effort for the government without prior solicitation by the government. Historically, DOE has used unsolicited proposals to procure nuclear physics accelerators). DOE requested NSAC to perform a review and recommend the best proposal. NSAC conducted its review of the five proposals from mid-January 1983 through April 1983.

On April 29, 1983, after reviewing and evaluating all five proposals, NSAC recommended to DOE that SURA's proposal be accepted. SURA proposed to construct CEBAF—which was to house a 4-GeV accelerator—as a new facility at Newport News, Virginia. SURA estimated the cost for constructing CEBAF to be $146.8 million (in fiscal year 1983 dollars). It is presently estimated by project officials to cost $194.3 million (in fiscal year 1985 dollars).

DOE officially selected the SURA proposal on July 20, 1983, and through fiscal year 1985, SURA has received $4.5 million for research and development work relating to CEBAF. In addition, in fiscal year 1986, SURA will receive about an additional $4.8 million for research and development. However, to date, SURA has not received any construction funding for the CEBAF. DOE requested construction funding in its fiscal year 1986 budget proposal. The Office of Management and Budget (OMB), however, placed a 1-year freeze on new federal construction starts, and consequently the construction funding was not approved. DOE is requesting $25 million for construction and about $6.2 million for research and development in fiscal year 1987.

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[3] An electron volt is a unit of measure that describes the amount of energy acquired by a particle (such as an electron) as it moves across an electric potential of one volt.

The estimated completion date for CEBAF is 1992. When completed, DOE believes this new facility will assume world leadership in electron accelerators in nuclear physics. According to DOE, no existing or planned accelerators are capable of providing a continuous stream of electrons at the high energy level planned for CEBAF.

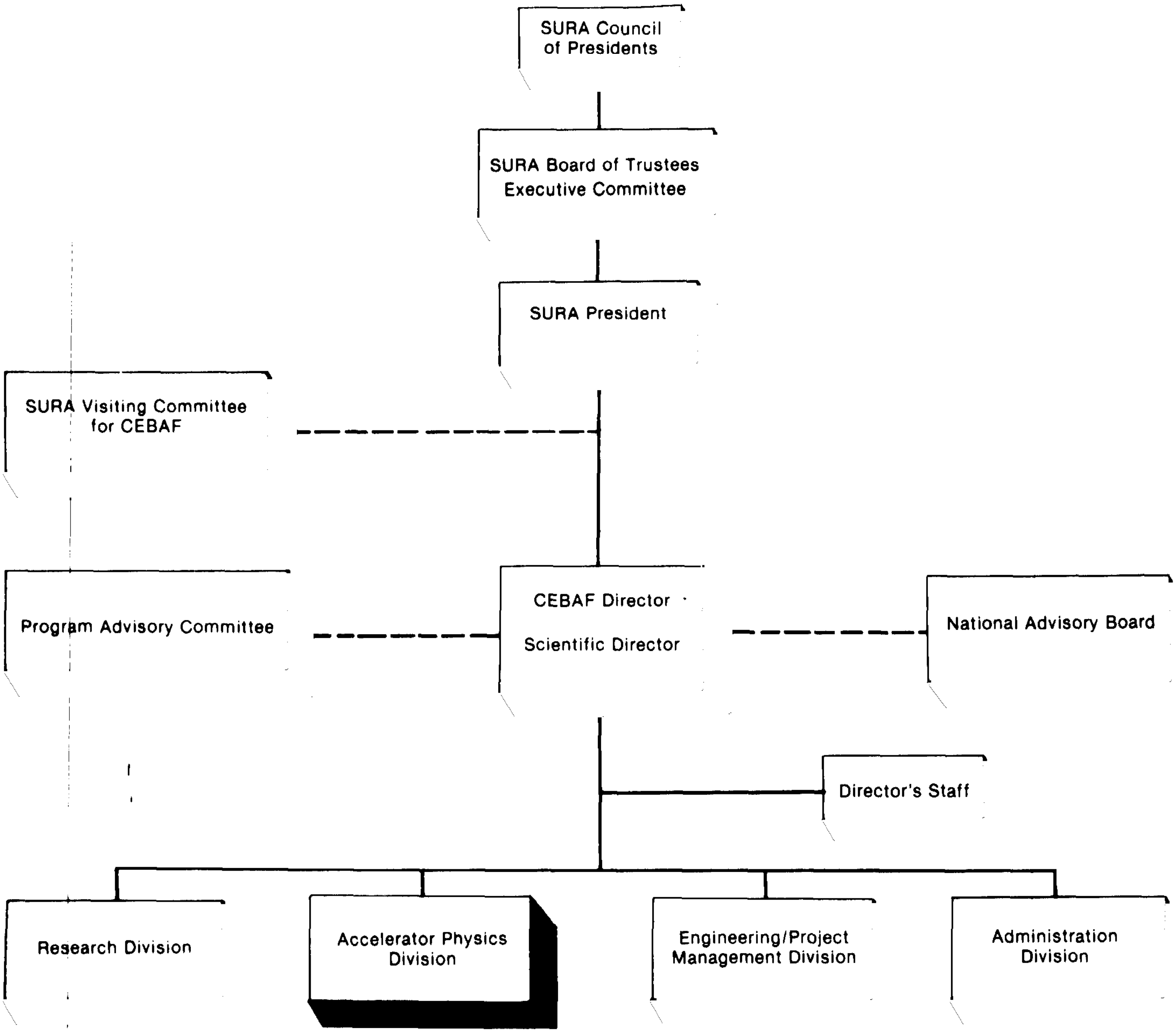
A more detailed description of the process used for selecting CEBAF, as well as problems identified with that process, is contained in chapter 2 of this report.

How SURA and the CEBAF Project Office Are Organized

SURA was incorporated in Virginia in August 1980. Its membership includes 35 universities and colleges that provided $1.2 million through September 1986 to support its operations. Decision-making responsibility for SURA rests with a Council of Presidents composed of one representative from each member institution. SURA also has a president, who oversees day-to-day business, and a board of trustees. The board of trustees is composed of one member from each institution and six at-large members.

The SURA organization appointed an acting director for the CEBAF project in late 1982 and began to organize a project office. SURA also formed a search committee in July 1983 to nominate a permanent director for the CEBAF project and fill some of the key staff positions in the project office. A project director was nominated but subsequently refused the position. A second committee was formed and nominated Dr. Hermann Grunder, who was approved by SURA in March 1985 as the permanent Director of the CEBAF Project Office. The present SURA/CEBAF office organization is shown in figure 1.1.

Figure 1.1: SURA/CEBAF Organizational Chart



Source: CEBAF Project Office.

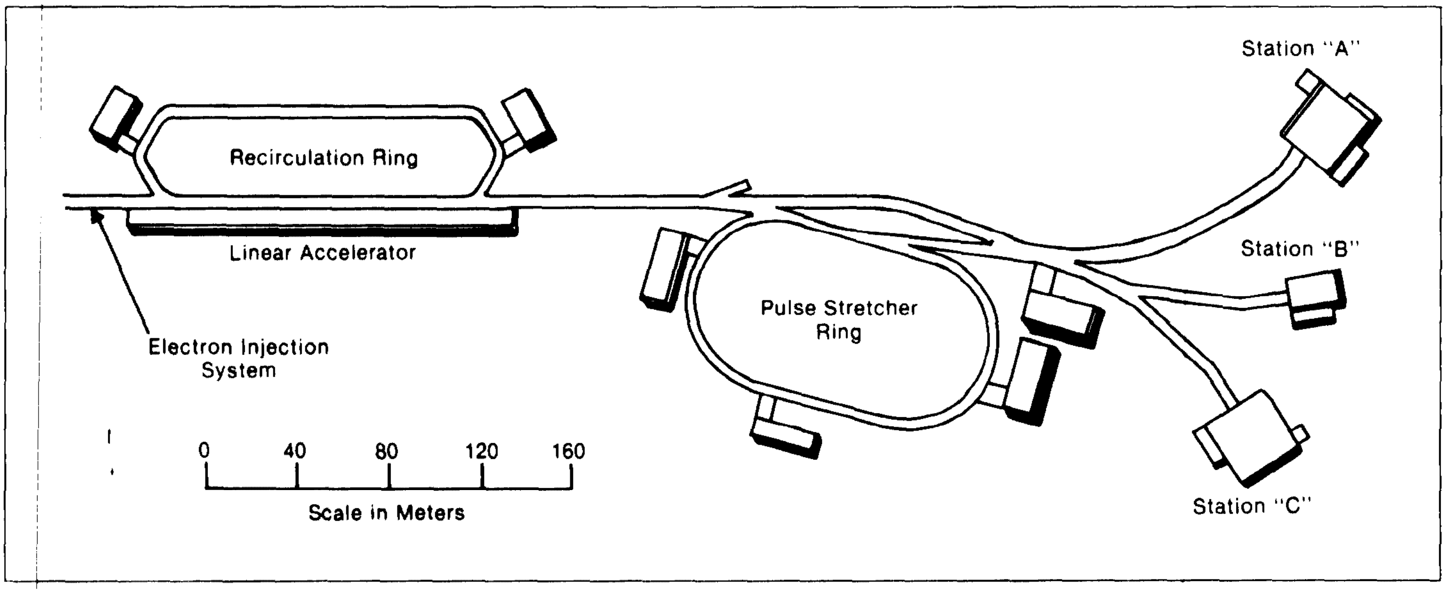
The project office, as of mid-January 1986, was staffed with 76 personnel. Seventeen of these are employed by the state of Virginia, and they will continue to be paid by the state for the duration of the project.

The state of Virginia is also making available to the CEBAF project land and facilities formerly used by the state. In addition, the city of Newport News, Virginia, is donating a total of 300 acres of land as a site for the CEBAF project.

How CEBAF Was Designed to Work

While the CEBAF design contained in SURA's original proposal has been revised, an explanation of the original design is presented here to provide a general description of what CEBAF was intended to be and how it would have operated. We believe that such an explanation, and the following figure of the components of the original CEBAF design, are important to understanding the selection process (discussed in ch. 2) and the resolution of technical problems (discussed in ch. 3).

Figure 1.2: CEBAF Accelerator Layout Proposed by SURA



Source: CEBAF Project Office.

Electrons are produced by an injection system and enter a linear accelerator that increases their energy. At this point, the electrons are bunched and receive pulses of energy as they go through the linear accelerator. The electrons are then routed into a recirculating ring to allow them to pass through the linear accelerator a second time to further increase their energy. The electrons are then routed into a pulse stretcher ring, which converts them into a continuous electron beam by stretching out the pulses. The particles are extracted from the pulse stretcher ring and sent to the experimental stations, which contain the targets. The entire sequence of events—from production of the electrons to their collision with the targets—covers a distance of about 225 miles and takes approximately 0.001 second.

The reason a continuous beam of electrons is considered necessary is that not all the electrons in the beam crash into an atom of the target material. Some electrons go between the target material atoms and some hit with glancing blows and deflect. Experimental information is obtained primarily when the electron hits a target atom head-on. This is referred to as an "event." As more events occur, more experimental data are obtained. In a pulsed accelerator, several events can occur at the same time, and the experimental information associated with each event cannot be separated by the experimenter. However, the continuous beam accelerator spreads out the events in time so that the experimenter can distinguish the particles from each event. Consequently, a continuous bombardment of electrons on a target is required to provide an increased frequency of separate measurable events for an experimenter to analyze.

Objectives, Scope, and Methodology

In a May 3, 1985, letter to us, Senator J. Bennett Johnston, Ranking Minority Member, Subcommittee on Energy and Water Development, Senate Committee on Appropriations, expressed concern over the manner in which large accelerator facilities are proposed to and approved by DOE. He specifically requested that we provide a report on the events and procedures leading to the CEBAF proposal and DOE's endorsement. He further requested that we include in the report a description of the review and selection process for CEBAF and considerations given by DOE and others to cost-effective alternatives. In order to provide a comprehensive report, we also developed information on technical problems associated with the approved design and the CEBAF project office's efforts to resolve them. These design problems had been identified by NSAC during the review of the proposals.

To identify the events and procedures leading to the CEBAF proposal and DOE's endorsement, we reviewed pertinent studies and reports prepared by NSAC or the nuclear physics community for DOE, the National Science Foundation, and the National Academy of Sciences—which helped establish the need and priority for a new electron accelerator for DOE's nuclear physics program. In addition, we interviewed officials at DOE, the CEBAF project office, Argonne National Laboratory, the National Bureau of Standards, and the Massachusetts Institute of Technology to obtain their views on the early events that prompted action leading to submission of proposals for the new accelerator.

To describe the review and selection process and determine cost-effective alternatives, we relied mainly on a report issued by an NSAC review panel in April 1983 entitled Report of the Panel on Electron Accelerator Facilities. This report was the basis for DOE's selection of the SURA proposal to plan, manage the construction of, and operate CEBAF. In this respect, we contacted members of the NSAC panel who performed the review of proposals and helped formulate the report. We also interviewed DOE officials who were cognizant of the NSAC panel's review. In addition, we interviewed officials from four of the five organizations submitting proposals. We did not contact officials at the University of Illinois because their proposal was for a low-power accelerator, which did not employ technologies relevant to our review.

To obtain information concerning the unresolved problems associated with the approved CEBAF design, we discussed with CEBAF project office officials the existing design problems and their plans and efforts to alleviate them. We also interviewed officials at the Stanford Linear Accelerator Center in Palo Alto, California, because these officials have considerable expertise in the areas presenting the major design problems pointed out by the NSAC review panel. In addition, we interviewed officials at Cornell University who developed an element of a linear accelerator that will serve as a basis for SURA's redesigned accelerator.

We made our review in accordance with generally accepted government auditing standards between June 1985 and December 1985. The views of directly responsible officials were sought during the course of our work and are incorporated in the report where appropriate. In accordance with the requester's wishes, in order to ensure issuance of this report in time for use during the current budget cycle, we did not request DOE to review and comment officially on a draft of this report.

CEBAF's Selection and Approval Process Limited DOE's Management Control and Flexibility

The nuclear physics community from time to time has expressed the need for newer and more sophisticated accelerators to progressively explore theories pertaining to the nuclear structure and its behavior. These accelerators, however, can cost hundreds of millions of dollars to build and tens of millions of dollars to operate. Therefore, they require a selection and approval process that results in the best possible combination of technical design, construction, managerial ability, and location.

The process DOE used to select CEBAF relied heavily on the nuclear physics community to (1) establish the physics need and priority, (2) submit unsolicited proposals to meet that need, (3) review these proposals, and (4) recommend the best proposal. The use of unsolicited proposals as the procurement method resulted in responsibility for management, construction, and operation of CEBAF being awarded to the proposer with the best technical design.

This chapter describes how the need and priority for a new nuclear physics electron accelerator was established and how the SURA proposal was selected and approved.

Physics Community Establishes the Need and Priority

DOE primarily relies on the nuclear physics community to establish nuclear physics research needs and priorities through studies, reports, workshops, and advisory committees. Many of these activities are requested and funded by DOE. The need for a new electron accelerator was first identified by the nuclear physics community and has since become its number one priority project.

In 1975, a panel to study the future of nuclear science was formed by the Governing Board of the National Research Council[1] to determine future opportunities and objectives of nuclear science. In a 1977 report,[2] the panel stated that a new nuclear physics electron accelerator capable of delivering energies of 1 to 2 GeV would be an extremely important future national facility. The panel recommended an early start on a feasibility and design study, and if the facility was found to be feasible, then early construction should be considered.

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[1] The Governing Board of the National Research Council consists of members from the Councils of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine.

[2] Future of Nuclear Science.

Another 1977 report,[3] prepared by a group of nuclear physicists at the request of DOE and the National Science Foundation, recommended that

> ". . . the nuclear physics community give serious consideration to a national electron accelerator facility with the following properties: 100% duty cycle, energy of 1 to 2 GeV, electron-beam current of approximately 100 microamps."[4]

The report also stated that with vigorous support from the nuclear physics community, construction could be started by 1981 or 1982.

Also in May 1979, DOE requested that the nuclear physics community, through NSAC, provide a long-range plan for nuclear physics advancement and make recommendations for necessary facilities and time frames. The plan was issued in December 1979 and accepted by DOE's nuclear physics program office. The plan stated that the key goal of nuclear physics was a new accelerator capable of providing a continuous beam of electrons at 1 to 2 GeV. In addition, the plan called for construction of the accelerator to begin in fiscal year 1985 with completion in fiscal year 1987. According to DOE nuclear physics program officials, the report and DOE's subsequent acceptance provided a signal to the nuclear physics community that proposals for such an accelerator would be given serious consideration.

In an April 1982 report, a NSAC subcommittee reiterated NSAC's support for construction of the new electron accelerator. However, in that report, the recommended energy level for the accelerator was 4 GeV or twice the energy level than in 1977. The subcommittee believed the higher energy level was necessary to further analyze significant features of the nuclear structure. The report also stated that a single 4 GeV accelerator would not cover the needed range of physics and recommended an additional facility at an energy level of less than 1 GeV. The NSAC subcommittee stated that the two facilities would provide a range of electron energies sufficient to support the "richest" possible nuclear physics research program.

Thus, by early 1982, the nuclear physics community clearly recognized a need for one or more continuous beam accelerators and recognized that this need was the number one priority of that community. The size, in terms of energy level, was not as clearly defined, and several opinions existed concerning the number of accelerators needed.

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[3] The Role of Electron Accelerators in U.S. Medium Energy Nuclear Science.

[4] A microamp is one-millionth of an amp.

DOE Receives Unsolicited Proposals for New Accelerators

After the physics community established the need for one or more continuous electron beam accelerators, if DOE chose to go forward with the project, it had two basic procurement options for selecting a contractor to build and operate the accelerator(s). DOE could send out a request for proposals or select from unsolicited proposals received from the physics community. DOE chose the unsolicited proposal approach, which it has historically used, and selected from the five unsolicited proposals it had received.

Request for Proposals

Competitive request for proposals are frequently used to solicit offers on large, expensive projects. To use this approach to select a contractor to plan, manage the construction of, and operate a new electron accelerator, DOE would have had to formulate a system design concept[5] for the accelerator and make such information available to prospective bidders. In preparing the system design concept, DOE could enlist the aid of NSAC, the nuclear physics community and outside contractors. Bids would then be prepared on the basis of these predetermined parameters, and DOE could select the contractor organization to plan, manage the construction of, and operate the accelerator.

In this respect, the OMB has established general policies that encourage federal agencies to solicit system design concepts from a broad base of qualified firms, including private industry, government laboratories, federal research and development centers, educational institutions, and other not-for-profit organizations. It is also OMB's general policy that federal agencies place emphasis on the initial activities of the acquisition process to allow competitive exploration of alternative system design concepts in response to the agencies' mission needs.[6]

Several advantages exist in the use of the request for proposals approach. It provides for a high level of competition in that all bidders are responding to the same system design concept and set of technical parameters. Since the technical aspects of the procurement, including the system design concept and technical parameters of the accelerator, are basically the same for all competitors, DOE can place selection emphasis for responsive bidders on factors such as cost, management ability, location, and established organizational expertise in accelerator

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[5] OMB defines this as an idea expressed in terms of general performance, capabilities, and characteristics of hardware and software oriented either to operate or be operated as an integrated whole in meeting a mission need.

[6] Office of Management and Budget Circular No. A-109.

technology. In addition, the system design concept and technical parameters do not become the exclusive property of any bidder.

According to DOE, the major disadvantage to this approach is that OMB policy dissuades government-owned facilities from competing directly with industry. Therefore, DOE believes its national laboratories[7] would be prohibited from participating in a competitive solicitation to plan, manage the construction of, and operate an accelerator facility. In this respect, DOE officials stated that national laboratories and other DOE-supported facilities with extensive nuclear physics accelerator experience would not be allowed to submit proposals. However, it is clear that DOE's laboratories are encouraged to participate in the development of the system design concept. In addition, we do not believe that OMB general policy prohibits DOE's laboratories and supported facilities from being considered in the competition to plan, manage the construction of, and operate an accelerator facility for research purposes. Moreover, since DOE laboratories are under a general contract to perform work for DOE and many are operated by private contractors, DOE could assign an accelerator for research purposes to a laboratory once the system design concept was known, rather than fund the construction of, in essence, a new single-purpose national laboratory to be operated by another private contractor.

Unsolicited Proposals

Unsolicited proposals are often used for procurements when the basic concept—such as a continuous electron beam accelerator—is defined, but the design and specifications have not been determined. The mechanism involved is usually quite simple: an unsolicited proposal is formulated by the proposer and is submitted to DOE, which, in turn, may choose either to fund the proposal or reject it.

DOE nuclear physics program officials told us that they believe that funding nuclear physics accelerator projects using the unsolicited proposal approach inspires innovative designs and heightens competition within the nuclear physics community. In addition, according to DOE, this approach does not prohibit DOE's laboratories from submitting proposals.

Several disadvantages to the use of unsolicited proposals, however, also exist. Because of the somewhat unstructured nature of the approach

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[7] National laboratories are government-owned facilities, which are available to the science community at large.

and the lack of a uniform system design concept, comparison of a number of unsolicited proposals could prove difficult because of vast differences in the basic designs, specifications, and performance capabilities of the facilities being proposed.

In addition, under the federal procurement regulations concerning unsolicited proposals, if the design or concept proposed is unique and innovative and not available from other sources, it is the property of the proposer. In the case of CEBAF, DOE formally certified that the design was unique and innovative. Since the design is the property of the proposer, the design cannot be assigned to another organization to plan, manage the construction of, and operate without agreement from the proposer or DOE legally taking the designs. Thus, unsolicited proposals, in effect, can lock the agency into a total package, including the design, management structure, and location. On the other hand, in the request for proposal approach, the government develops, or has a contractor develop, the system design concept for the government's use in solicitation. The request is put out for proposals and selection is made on the basis of cost, management ability, and other factors.

NSAC's Review of the Proposals and Selection of the SURA Proposal

By January 1, 1983, DOE had received five unsolicited proposals. These proposals consisted of

- a 0.5- to 4-GeV accelerator called a hexatron microtron, submitted by Argonne National Laboratory,
- a 0.5- to 4-GeV linear accelerator with pulse stretcher ring, submitted by SURA,
- a 0.02- to 0.75-GeV accelerator called a racetrack microtron, submitted by the University of Illinois,
- a 0.5- to 4-GeV (in three phases of 1, 2, and 4 GeV respectively)[8] linear accelerator with pulse stretcher ring, submitted by the Massachusetts Institute of Technology, and
- a 0.015- to 1-GeV racetrack microtron, submitted by the National Bureau of Standards.

NSAC was requested to review and evaluate the five proposals and select the most feasible one. An NSAC panel started review and evaluation in

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[8] This proposal included detailed information on obtaining only the second phase of 2 GeV. The proposal contained an explanation for obtaining 4 GeV but was not considered by the NSAC review panel to be sufficiently developed to warrant review.

mid-January 1983 and completed it on April 29, 1983. In the final analysis, only the SURA and Argonne proposals were competitively evaluated. The other three were eliminated from consideration during the review because they were not in the energy range felt necessary by NSAC or not fully developed.

NSAC's Review of the Proposals

On January 12, 1983, an NSAC panel was formed and assigned the task of examining each of the five unsolicited proposals. The panel, consisting of 13 members drawn from various universities and national laboratories, was told to review the information contained in the proposals and, on the basis of that information, to recommend the facility or combination of facilities that would best meet the need for basic nuclear physics research using electron beams. Within the 13-member panel, a 7-member subpanel was formed to conduct (1) a detailed examination of the technical and accelerator physics aspects of each proposal and (2) an evaluation of each proposal's feasibility, including the planned research and development work.

The NSAC panel began its review of the five proposals by requesting that each of the proposers review and comment on the four proposals that they did not submit. On January 31, 1983, the comments pertaining to a specific proposal were provided to the group that originated that proposal. The originating group was asked to respond to the comments it received. The panel also sent questionnaires to all proposers that contained questions on their estimated construction and operation costs, contingencies, and overhead.

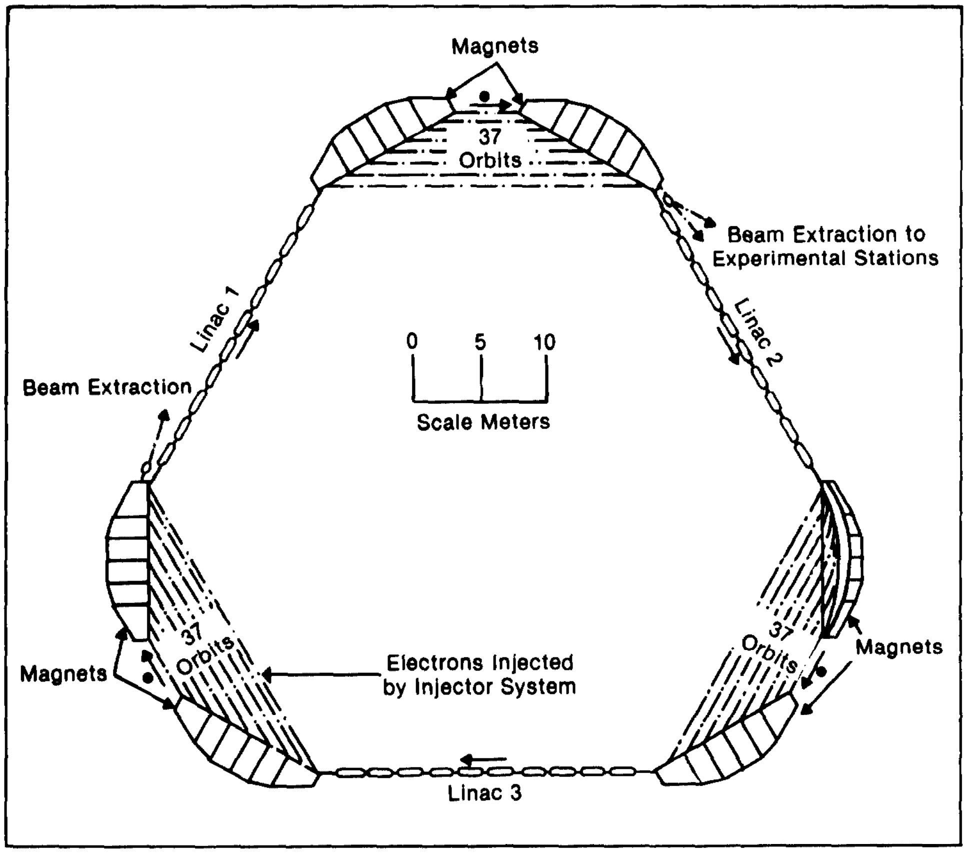
During mid-February 1983, members of the technical subpanel visited all five organizations (except the Massachusetts Institute of Technology, which was visited by one member) that had submitted proposals. These visits were conducted to gain additional knowledge on available supporting facilities, such as buildings, computer equipment, administrative support, and future utilization of these resources. Later in February, the panel conducted a meeting to allow the proposers to respond to the comments generated by the other proposers and to questions raised by the technical subpanel and by full-panel members. This meeting was followed by letters from the panel to each of the proposers in an effort to clear up unanswered management, scientific, and institutional support questions.

The panel met again on March 7, 1983, to focus on the current nuclear physics needs in terms of energy level and requirements for computers and other equipment that would be used to analyze the results of the experiments to be conducted on the new accelerator. The panel decided to recommend construction of an accelerator capable of providing 4 GeV. This recommendation effectively narrowed the field of proposals under consideration to the Argonne National Laboratory and SURA proposals, the only proposals fully developed that met the power range felt necessary by the panel. A brief description of these two proposals follows.

Argonne National Laboratory's Proposal

Argonne National Laboratory started developing a design for a continuous electron beam accelerator in the late 1970's. Work on the design was prompted by the studies discussed earlier in this chapter and, as a result, was initially directed toward a 2-GeV accelerator. After NSAC issued its 1982 report stating its preference for a 4-GeV accelerator, Argonne National Laboratory started redesigning to meet that energy requirement. The Argonne National Laboratory's proposed accelerator is shown in figure 2.1.

Figure 2.1: Argonne National Laboratory's Proposed 4-GeV Hexatron Accelerator



Source: A National CW GeV Electron Microtron Laboratory ANL-82-83, p. 84.

The basic design consists of three linear accelerator sections, referred to in the drawing as "linacs," and six 673-ton magnets. An injector system consisting of a small accelerator generates and injects an electron beam into the main accelerator. As the electron beam passes through each linear accelerator section, its energy is increased. The magnets precisely bend the beam of electrons into the next linear accelerator section. To reach 4 GeV, the electron beam would make 37 orbits of the accelerator, each orbit a little wider than the previous one.

The design of the hexatron accelerator allows for extraction of the beam at different energies. Since the beam would make 37 orbits with its energy increasing each time, the beam could be extracted from different orbits at different energies. The design called for three beam-extraction areas that would direct the beam to different experimental areas. The experimental areas would be located in existing buildings.

Advantages to Argonne's proposal: According to NSAC's final report, the major advantage of the Argonne National Laboratory's proposal was the established laboratory itself. Specifically cited were the Argonne National Laboratory organization, the existing facilities available to house the accelerator, and the in-place support facilities. Argonne has been involved in nuclear physics research for over 20 years and, according to the NSAC panel report, has developed a very capable staff of physicists, scientists, and engineers. At the time the hexatron proposal was submitted, a project director and several other key personnel had been designated. In addition, plans had been developed to obtain personnel in the areas where Argonne had no expertise. Also available were personnel and project support units, including a budget and accounting office, a personnel office, and a contracting office.

Argonne proposed to construct the hexatron in unoccupied buildings at the laboratory. These buildings had housed a proton accelerator for 16 years before it was shut down in 1979. According to the Associate Director of Nuclear Physics at Argonne, these buildings could house offices, laboratories, machine shops, and data equipment. In addition, he stated that Argonne has sufficient electrical and cooling capacity to operate the hexatron and other necessary support facilities including fire and rescue facilities, visitor housing, and site security system. While they envisioned some required alterations, Argonne officials felt that the existing facilities would save $30 million to $40 million in construction costs.

Disadvantage to Argonne's proposal: The NSAC panel's report cited two major technical disadvantages to Argonne National Laboratory's proposal. The first disadvantage cited was that the hexatron was not capable of being upgraded beyond 4 GeV, an attribute that panel members felt may be necessary for future physics experiments. The difficulty related to the characteristic of the hexatron whereby the electron beam grows larger or spreads out at higher energies. At 6 GeV, it was felt that the beam would have expanded beyond the guideholes in the magnets, which would result in the accelerator's failure.

The second disadvantage cited related to the hexatron's ability to withstand temperature changes and foundation settling. Once the hexatron's magnets were set in place and aligned, they could not move by more than 0.1 millimeter or about 0.004 inch. It was felt that foundation settling and temperature changes might move the magnets by more than 0.1 millimeter. In addition, concern was expressed over the fact that a computer would be required to make over 100 corrections in less than a second to keep the electron beam on course.

SURA's Linear Accelerator With Pulse Stretcher Ring

SURA, unlike the Argonne National Laboratory, originally designed its continuous electron beam accelerator to achieve a maximum energy level of 4 GeV. SURA's proposed design for the 4 GeV accelerator is shown in figure 1.2.

The proposed design was called a "linear accelerator/pulse stretcher ring" because a linear accelerator and a pulse stretcher ring are two of the major components—along with the recirculating ring—of the design. The electron beam is injected into a linear accelerator where it is accelerated by rapidly alternating the electrical fields within the accelerator. A recirculating ring is used to collect the beam after one pass through the linear accelerator and to direct the beam back to the beginning of the linear accelerator for a second pass. The recirculating ring was added to increase the system's energy from 2 GeV to 4 GeV. The recirculator was considered to be more economical than doubling the length of the accelerator and also offered potential to increase the energy of the beam to at least 6 GeV by recirculating the beam an additional number of times.

The pulse stretcher ring takes the accelerated beam—which is bunched up—and stretches it out into a smooth, continuous ring. As the electrons orbit the pulse stretcher ring, they are continually extracted to provide a continuous beam to the experimental area.

The basic concept of the linear accelerator/pulse stretcher ring for use as a continuous electron beam accelerator was discussed in a 1977 report.[9] The report stated that the concept was attractive and may be the only reasonable method of achieving a "high duty factor" (continuous beam) accelerator. The report also referenced a University of Saskatchewan study that set forth an accelerator concept closely resembling that proposed by SURA.

Advantages of SURA's proposal: The NSAC panel cited the use of technically proven components as the major advantage of SURA's proposal. One of the major components of the CEBAF proposed by SURA—the linear accelerator—was based on the linear accelerator design in use at the

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[9] The Role of Electron Accelerators in U.S. Medium Energy Nuclear Science, Department of Energy/National Science Foundation Study Group.

Stanford Linear Accelerator Center in Palo Alto, California. In addition, at the time of SURA's proposal, a recirculator was in use at the Bates Linear Accelerator Center and pulse stretcher rings were under development in Italy, West Germany, Sweden, and Japan. SURA stated that development of these rings by other countries could supply useful information and eliminate any large U.S. investment in prototypes.

Disadvantages of SURA's proposal: The NSAC panel's report cited two major disadvantages to SURA's proposal. First, while the major components had been proved technically, they had not been tested or proved at the energy level required for CEBAF. In other words, while the technology was available, it would require extensive research and development to ensure that the accelerator's specifications could be met. The major technical uncertainties and efforts to resolve those uncertainties are discussed in chapter 3.

The second major disadvantage cited was that SURA had no organization established to manage, construct, or operate an accelerator. At the time the proposal was reviewed, SURA personnel had only limited experience in accelerator design and construction and lacked in-house engineering and technical expertise. Also lacking were other organizational elements such as accounting and contracting staffs. In addition, a "new" single purpose national laboratory would essentially have to be constructed including all related support facilities.

NSAC's Recommendation to DOE

At the time the NSAC panel began evaluating the Argonne National Laboratory and SURA proposals, no formal criteria to evaluate the proposals existed and consequently none were formulated or used. However, as part of its review, between March 7 and March 30, 1983, each panel member independently studied and evaluated the advantages and disadvantages of these proposals. All members conducted their work independently in arriving at a recommendation.

At a March 30, 1983, meeting, listings prepared by each panel member on the advantages and disadvantages of each proposal were circulated to all of the panel members. Although the panel members used different criteria and weighting factors for each criteria used to judge the advantages and disadvantages, there was no disagreement on the facts—technical, financial, institutional, and otherwise—concerning the proposals. During April 1983, the NSAC review panel prepared a report and on April 29, 1983, submitted the report to DOE with a recommendation to approve SURA's proposal for construction. In the report, the panel noted that while its review identified technical limitations in both Argonne National Laboratory's and SURA's proposals, both proposals were feasible and could form the basis for a "powerful national nuclear physics accelerator facility."

According to the panel's report, the positive factors that influenced the decision and recommendation to select the SURA proposal were

- SURA's commitment to provide 35 nuclear physics faculty positions at its member universities (Argonne National Laboratory committed only 2 positions),
- SURA's design could be extended to an energy level of at least 6 GeV while Argonne National Laboratory's could not achieve more than 4 GeV, and
- SURA's design was judged to be more conservative and to present less risk of complete failure than Argonne National Laboratory's design.

While the NSAC review panel decided in favor of SURA, additional recommendations to DOE concerning SURA indicated that the panel believed that the proposal contained several shortcomings. The NSAC panel was concerned with SURA's lack of key personnel and stated that the ultimate success of CEBAF depended on the selection of a strong, dynamic director at the earliest possible date. The panel was also concerned that SURA had only limited experience in accelerator construction and stated that they be strongly reinforced by professionals from other national laboratories. In addition, the NSAC panel further stated that SURA had no construction management team and that the success of the proposal would critically depend on attracting a core group of experienced accelerator scientists and engineers. In this respect, the panel recommended that SURA management appoint an advisory board to become involved in all major decisions affecting the structure and future of CEBAF.

Since the SURA proposal was selected—primarily during 1985—SURA has staffed all the key positions, including the four major organizational divisions (Research, Accelerator Physics, Engineering/Project Management, and Administration) with qualified personnel. SURA has also attracted many experienced scientists and engineers from other accelerator facilities and national laboratories. In addition, SURA has appointed a permanent project director, who was recommended by a national search committee made up of nuclear physicists.

In addition to the panel's concerns above, they also recommended that SURA management consider the possible advantages of building the accelerator at a location with access to major universities and major airports. The panel felt that the Newport News, Virginia, site would not provide adequate access to the facilities.

Observations

DOE used the unsolicited proposal approach to award the CEBAF contract. Of the five unsolicited proposals received, DOE, on the basis of the NSAC panel's recommendation, selected what it believed to be the best of the five proposals. Under the unsolicited proposal approach, the proposer owns the design; therefore, DOE had no alternative (short of legally taking the design or obtaining the permission of the owner to make the design available to others) but to award the contract to the proposer of the design selected by DOE, if DOE wanted to go forward with the project. Consequently, DOE selected and approved a contractor for the CEBAF that had neither an organization nor the technical expertise to plan, manage the construction of, and operate the facility. However, if DOE would have used the request for proposal approach, it would have identified and evaluated the best design and then could have chosen the contracting organization on the basis of managerial and technical ability.

Technical Problems Eliminated by New Design

The CEBAF project office planned to contract for a major portion of the research and development work needed to resolve several technical uncertainties identified by the NSAC review. These uncertainties dealt mainly with two components of the accelerator system—the klystron tubes and modulators—which, if not resolved, would prevent the accelerator from achieving its performance objectives. However, before such contracts were awarded, a permanent director for CEBAF had been approved and a review begun to assess the available technologies that might be applicable to a CEBAF. As a result of that review, a design employing a new technology was submitted by the CEBAF project office to DOE in November 1985 for its approval. The new design, which was approved by DOE in December 1985, eliminated the need to solve the technical uncertainties because they no longer existed.

To provide a perspective of the technical uncertainties of the original design and how they were eliminated by the new design, this chapter discusses the major technical uncertainties of the original design and how the technology review led to the present design.

Selected Design Has Technical Uncertainties

In early June 1985, we asked CEBAF officials to rate the critical components—which the NSAC review panel was concerned with—relative to (1) the impact on the accelerator performance and operation and (2) the difficulty of achieving a component's design performance objective. CEBAF officials informed us that the klystron tube was the most critical in terms of accelerator performance and together with components called modulators, which deliver power to the klystrons, are the most difficult to develop. The next two sections provide a description of the klystron tube and modulator problems associated with them and the CEBAF project office's efforts to resolve the problems.

Klystron Tube Uncertainties

Klystron tubes perform two major functions in nearly all large accelerators. The klystrons supply increased power to the particles as they move down the linear accelerator and provide a "wave" that accelerates the particles. The original CEBAF design required 40 klystron tubes.

The klystrons needed for CEBAF to reach its performance goals require a very high power output. According to CEBAF officials, klystron development basically involved two problem areas. The high power of the klystron would increase the heat in the tube, thus requiring additional cooling. In addition, more power would pass from the klystron tube into the linear accelerator through what is called a "window." The window is made of ceramic and seals the klystron while permitting the power to go through. However, with the additional power, the ceramic window gets hotter and often fails.

Klystron tubes that can withstand the high power required for CEBAF currently do not exist. Consequently, a new high-powered klystron had to be developed to ensure CEBAF's performance goals could be met. To do this, the CEBAF project office planned to use two contractors working simultaneously, but separately, toward developing the new klystron tube. The CEBAF project office estimated it would take 2 years and about $2 million to develop a workable klystron tube.

During our review, we visited with officials of the Stanford Linear Accelerator Center because of their expertise in the manufacturing and utilization of klystron tubes. Center officials confirmed that increased heat would be the major problem. However, these officials felt that the new tube was feasible if designed with ample cooling to dissipate the heat. In addition, the Center is developing a new design that uses two windows instead of one and employs a new window element made out of beryllium oxide, which Center officials believe would withstand the increased heat produced by the additional power.

While officials at the CEBAF project office were confident the new tube could be developed in a timely manner, they did have a fall-back plan in case the research and development was unsuccessful or delayed. The plan consisted of using two lower-powered klystron tubes in place of each of the 40 klystrons needed. In other words, instead of the 40 klystrons, there would be 80 klystrons that would produce nearly the same peak power but less average power than the planned 40 klystrons. The fall-back klystrons were identical to those produced and used by the Stanford Linear Accelerator Center. Center officials said they could provide the tubes if CEBAF needed them for the fall-back plan.

According to the Director of the CEBAF project office, the disadvantages of using the fall-back plan were that the intensity of the beam would not be as great as originally planned and, consequently, experiments would take longer to complete. In this respect, CEBAF project office officials stated that the additional time to run the experiments was not significant or critical to the program's success. In addition, about 4 of 23 presently proposed experiments could not take place because of the lower intensity level. However, CEBAF officials believed that the CEBAF could operate and perform 19 of the planned experiments while higher-powered klystrons were being developed.

Modulator

The modulator is part of the klystron tube system and basically is the electrical pulse power source or the on/off switch for the klystron. The klystron tube requires rapid on/off switching (1,000 pulses per second) because if the high power was continuously fed into the klystron, it would become too hot and melt. Consequently, the power is "pulsed" by the modulator.

The major uncertainty associated with the modulator has to do with its ability to hold up under the rapid pulse rate. Present modulators operate at about 360 pulses per second, about one third of that required for CEBAF. As with klystron tube development, CEBAF project office officials planned to contract with two contractors to concurrently develop a prototype modulator.

If CEBAF's modulator development effort fails, CEBAF project office officials plan to connect three modulators to each klystron (instead of one) and pulse them alternately. This would require about 333 pulses per second from each modulator and, according to CEBAF officials, should provide a relatively long life and reliable operation for the modulators.

Technology Review Discloses New and Better Designs

The approved CEBAF design was proposed by SURA in October 1982 but was actually conceived in 1980. Consequently, the original design was at least 4 years old by May 1985 when the new director was approved for the CEBAF project. During that period, the CEBAF project office had concentrated almost entirely on improving or ensuring the success of the proposed design. In June 1985, shortly after he was appointed, the director initiated a study of recent accelerator design developments and other technologies for their applicability to CEBAF. The review identified two technologies that were better than the one originally proposed. As a result, the CEBAF project office has received approval from DOE to go forward with a completely new and better design.

The Technology Review

An internal review was conducted by a technology review team to update the CEBAF design technology base and select the best design technology for meeting such criteria as increased performance, cost effectiveness, simplicity, minimum risk, and readiness for construction beginning in fiscal year 1987.

The technology review team was made up of 32 participants, including 14 from the CEBAF project office; 7 from Stanford Linear Accelerator

Center; 3 from private industry; and the remainder from other universities, national laboratories, and nuclear physics facilities. Through July and part of August 1985, the review team concentrated on identifying the available technologies and narrowing the choices. The review team also focused on key components, such as the klystron tubes and modulators, and the anticipated klystron window problem.

In mid-August, a technical review workshop was held and members of the review team discussed and clarified key issues. From the workshop, it was the determination that the original design was not the optimal design and that two other designs should be further defined, complete with cost estimates and schedules. While the technology review team considered the original design to be a good physics tool and buildable, it concluded that it was not the latest technology. In addition, the review team pointed out that the risks in the klystrons and modulators in the original accelerator design were unnecessary and that the original design would consume large amounts of electric power (20 megawatts)[1] while operating. The two designs, which were to be further defined, were known as the "standing wave" design and the "superconducting" design.

The "Standing Wave" Design

The standing wave design employs the same components (linear accelerator, recirculator, and pulse stretcher ring) in SURA's initial design pictured in figure 1.2. The energy is supplied in pulses from klystron tubes. However, the linear accelerator is designed differently internally and uses a different technology to energize the electrons in the accelerator.

The basic difference in the initial design and the standing wave design is the way the electromagnetic waves are used in the linear accelerator. In the original design, or "traveling wave design," the electromagnetic wave in the accelerator moved at about the same speed as the electrons. As the wave proceeded down the length of the accelerator, it received pulses of energy from the klystrons. Some of the wave's energy would be absorbed by the electrons and the beam would be accelerated. However, the majority of the energy would be absorbed into the walls of the accelerator and would be lost.

In the standing wave design, the electromagnetic wave does not move through the accelerator. Instead, the wave is contained in short sections of the accelerator and is reflected in the opposite direction once it

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[1] A megawatt is equivalent to 1,000 kilowatts.

reaches the end. As a result, the energy of the reflecting wave reinforces the energy of the initial wave and less energy is required of the klystrons. Consequently, lower-powered klystrons can be used in the standing wave design without a reduction in total energy to the electrons. This technology has been used for 14 years and is presently being used in accelerator technology development work at the National Bureau of Standards.

According to the Director of Nuclear Physics at the Bureau and CEBAF project office officials, the accelerator sections meet the requirements of the CEBAF performance goal. In addition, essentially "off the shelf" klystrons could be used in the new CEBAF design, and the requirements or performance specifications for the modulators would be less stringent because of the lower-powered klystrons. Thus, the standing wave design could eliminate the klystron uncertainties and alleviate most of the modulator uncertainties associated with the initial design.

The "Superconducting" Design

The superconducting design employs a linear accelerator made out of special material that is super-cooled to about -455 degrees Fahrenheit by a large refrigeration system. The term "conducting" applies to the ease by which the electrical energy is introduced into and moves through an accelerator. Good conductors of electricity are materials that present less resistance for the movement of electricity than others. When these materials are cooled to extremely cold temperatures, their resistance is even lower. Thus, the combination of a good conductor and a very cold temperature results in superconductivity.

The energy efficiency of a superconducting CEBAF design allows the use of low-powered klystrons that provide a continuous wave in the accelerator instead of a pulsed wave. As a result, the superconducting design does not require the pulse stretcher ring because the electrons are not bunched.

This technology had not been proved at the time DOE selected the original SURA proposal for CEBAF. However, Cornell University has conducted research and development on this design for 7 years. Using the technology in an accelerator did not become feasible until November 1984, when researchers at Cornell solved material deficiency and design problems. Cornell accelerator officials informed us that since November 1984, they have built and tested several sections of the accelerator and the documented results show that use of the technology would exceed the performance goals of CEBAF.

The Director of the CEBAF Project Office told us that the major advantages of the superconducting linear accelerator design were

- about a 50-percent reduction in the electric power necessary to operate the accelerator,
- an overall lower risk of failure than the other designs,
- the possibility of upgrading CEBAF's energy to about 16 GeV,
- the ability to produce multiple energy beams and direct them simultaneously to three different targets, and
- better beam quality and energy resolution.[2]

The Director also told us that four different companies had been contacted concerning the production and cost of the accelerator sections. Three of the companies contacted are willing to guarantee the minimum performance level of 4 GeV necessary for the CEBAF to attain its performance goals.

Observations

DOE, on the basis of the NSAC panel's recommendation, selected a CEBAF design that had technical uncertainties when at least one better design (standing wave) was available and another technology (superconducting), superior to both, was nearing completion and availability. We believe that it is DOE's responsibility to ensure that all applicable technologies have been identified and evaluated, and that the best technology is selected. However, in the case of the CEBAF selection, the use of unsolicited proposals did not draw out from the nuclear physics community all applicable technologies; therefore, 2 years passed before the better technologies were identified and evaluated.

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[2] Allows the experimenter to better distinguish between two adjacent events at nearly the same energy level.

DOE nuclear physics program officials told us that unsolicited proposals have historically been used as a procurement method because the approach inspires competition and innovativeness in the nuclear physics community. In this case, however, only two of five unsolicited proposals received for CEBAF were judged to be competitive in NSAC's final analysis, and while the detailed design in SURA's proposal may have been innovative, the underlying concept (linear accelerator/pulse stretcher ring) had been known for at least 6 years prior to the CEBAF selection.

DOE's use of unsolicited proposals in its CEBAF selection process resulted in DOE's awarding the project to SURA, which had neither an organization nor the technical expertise to build such a facility. In addition, the accelerator design or technology that was the basis for DOE's selection was not the best technology available at the time of the selection. In this respect, the design DOE selected had several technical uncertainties that, if not resolved, would prevent the accelerator from obtaining the performance level envisioned.

In the case of the CEBAF selection, the unsolicited proposal approach did not draw out from the nuclear physics community all the available technologies applicable to a CEBAF. At least one technology was available at the time of the CEBAF selection that would have eliminated the major technical uncertainties associated with the selected design. However, this technology was not included in any of the five unsolicited proposals and, consequently, was not evaluated.

Conclusions

Since SURA's proposal was selected in 1983, a CEBAF project office has been established at Newport News, Virginia, to plan, manage the construction of, and operate the accelerator. We believe the CEBAF project office has developed an organization with key personnel capable of managing and operating the project. More importantly, the CEBAF project office in May 1985 initiated a review of all available technologies applicable to a CEBAF and consequently is going forward with a completely new and innovative design.

However, we believe DOE could have achieved the same results 2 years earlier during the selection process. For example, DOE could have used NSAC to perform a review and evaluation of all available technologies and decided which one was most suited for a CEBAF. Then, DOE could have issued a request for proposals to all interested organizations or assigned the project to one of its national laboratories.

In our opinion, it is important in awarding contracts for large nuclear physics accelerator projects, such as CEBAF, that an evaluation of all potential technologies be performed and the best technology selected. Such an evaluation would prevent millions of dollars from being spent needlessly. It is equally important that assurances exist as to the ability of the selected organization to plan, manage the construction of, and operate such a project.

Recommendation

GAO recommends that the Secretary of Energy direct DOE's Division of Nuclear Physics to explore other procurement approaches in its future accelerator acquisitions, with a view towards assuring that DOE (1) considers all available relevant technologies and (2) retains sufficient flexibility and control over all aspects of such acquisitions, before and after approval.

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