

January 2000

NUCLEAR WEAPONS

Challenges Remain for Successful Implementation of DOE's Tritium Supply Decision



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Accountability * Integrity * Reliability

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Abbreviations

DOE	Department of Energy
NRC	Nuclear Regulatory Commission
TVA	Tennessee Valley Authority



United States General Accounting Office
Washington, D.C. 20548

Resources, Community, and
Economic Development Division

B-284005

January 2000

The Honorable John W. Warner
Chairman, Committee on Armed Services
United States Senate

Dear Mr. Chairman:

The Department of Energy (DOE) has not produced tritium, a radioactive gas that must be periodically replaced for nuclear weapons to function as designed, since the last of its production reactors was shut down in 1988 because of safety and operational problems. To replace that production capacity, DOE has been considering two technologies for producing tritium—a commercial reactor and an accelerator.¹ In 1997, DOE requested proposals from commercial reactor owners for DOE to either purchase a reactor or purchase irradiation services. The Tennessee Valley Authority (TVA), another federal government agency, was the only responsive bidder; TVA offered proposals both for finishing the construction of a partially complete commercial reactor and for providing irradiation services.² In December 1998, the Secretary of Energy chose the commercial reactor technology, specifically, the purchase of irradiation services from TVA's commercial power reactors, as the means for producing tritium. In addition, the Secretary decided to continue with the development and design—but not with the construction—of an accelerator that could function as a backup for the production of tritium, if needed.

¹The production of tritium in an accelerator is accomplished by the impact of a high-intensity proton beam onto a tungsten target, which produces neutrons through a process called spallation. The neutrons interact with helium-3 gas in a lead blanket that surrounds the target, thereby producing tritium and hydrogen.

²Special components, called burnable absorber rods, designed by DOE will be inserted in TVA's commercial reactors in place of a standard rod that TVA currently uses. The rods will then be irradiated during normal power production operations.

You asked us to determine (1) if the cost estimates used by the Secretary during the process of selecting between the tritium production technology options were comparable and adequately supported; (2) what management, technological, and legal activities could affect the completion of the commercial reactor option on schedule and within budget; and (3) whether DOE's current plan for the development and design of the accelerator option is an effective backup that DOE could construct and operate within cost and schedule estimates.³ To answer your questions, we reviewed the cost estimates used to support the Secretary's technology selection decision; reviewed independent assessments of each option's cost, schedule, technical systems, and management systems; and met with senior DOE officials to discuss the status and the current implementation plans for each option. In addition, we also met with officials at TVA and the Nuclear Regulatory Commission (NRC) to gather information on the contractual and legal issues pertinent to implementing the commercial reactor option. (See app. II for details of our scope and methodology.)

Results in Brief

The Secretary of Energy's December 1998 technology selection decision was based, in part, on the estimated costs of the two technologies under consideration—a commercial reactor and an accelerator—to produce tritium over the program's 40-year life cycle. The commercial reactor option was estimated to cost from \$1.2 billion to \$3.6 billion over the program's 40-year life cycle, depending on whether DOE decided to invest in TVA's partially complete reactor or to purchase irradiation services.⁴ The accelerator option, which was estimated to cost about \$9.2 billion, would produce a comparable amount of tritium over the same time span. We examined the DOE cost estimates used by the Secretary in his decision and found them to be reasonable, well supported, and prepared under consistent assumptions.

In order to ensure that the selected option—the production of tritium in a commercial reactor—is successful, several key activities must be

³DOE's fiscal year 1999 Stockpile Stewardship Plan defines the approach for an accelerator backup option as a design package for a plant that could be built and could begin operations within 5 years, assuming that funds are available.

⁴Since TVA—the only responsive bidder—is also a federal government agency, DOE would not have purchased a reactor but would instead have provided funds for TVA to finish constructing a largely complete reactor at its Bellefonte Nuclear Plant in Hollywood, Alabama.

accomplished on schedule and within budget. First, DOE must closely monitor the reactor program's cost and schedule baseline. In particular, because of a congressional moratorium on tritium-related construction in fiscal year 1999, the schedule for completing the facility needed to process new supplies of tritium has very little time left to accommodate any further schedule slippage. Consequently, the design and construction of this facility must be carefully managed. Second, if DOE selects a non-U.S.-owned company to manufacture the specially designed rods that will be placed in TVA's reactors to produce tritium, additional time may be needed to qualify the company for access to the necessary classified technical data. Third, DOE must implement the detailed interagency agreement under which TVA will provide DOE with irradiation services. Finally, the NRC must approve amendments to TVA's operating licenses in order for its reactors to install the specially designed rods that will produce tritium to meet DOE's defense-related needs. Current law prohibits NRC from licensing DOE's defense activities, although the term defense activities is not defined in the statute. While DOE and NRC believe that NRC's licensing actions are authorized, this report recommends that the Congress clarify NRC's authority to review such amendments in order to preclude any potential legal challenge that could delay the implementation of the commercial reactor option.

DOE's current approach for developing the accelerator introduces cost and schedule risks that threaten the accelerator's availability as a tritium production backup option as originally intended. In its fiscal year 1999 Stockpile Stewardship Plan, DOE stated that if the accelerator were chosen as a backup, the Department would need to complete an extensive technological development effort and develop preliminary and final design packages. The objective of this effort was to create an "off the shelf" design package for a plant that, if it were adequately funded, could be constructed and operated within 5 years. Subsequently, however, DOE reduced the funding allocated to the accelerator and redefined its approach to the accelerator backup option. Because of this, DOE will not complete all of the identified technology development activities, such as confirming and characterizing the system's performance, and has eliminated most of the work on the final design of the accelerator plant. While there is general agreement that an accelerator could ultimately produce tritium, it is highly unlikely, under DOE's current plans, that the development and design activities that were cut could be completed and that the plant could be built and begin producing tritium within DOE's original 5-year time frame. However, other alternatives for implementing the backup accelerator

approach exist. This report recommends that the Secretary of Energy reassess the Department's current approach for the backup accelerator.

Background

Tritium, an isotope of hydrogen, is a gas used to boost the reaction in nuclear weapons. Because tritium decays at a rate of 5.5 percent a year, it must be periodically replaced for weapons to function as designed. However, DOE has not produced tritium since 1988, when the last of its production reactors was shut down because of safety and operational problems. National security requirements for the current and projected nuclear weapons stockpile are based on the Strategic Arms Reduction Treaty between the United States and the former Soviet Republics. The treaty, commonly referred to as START I, entered into force in December 1994. To support the current stockpile, DOE must have new supplies of tritium ready by about fiscal year 2005 or else DOE must begin to use the tritium reserve, which is intended to last 5 years. Under current requirements, if DOE does not have a new tritium supply source by about 2010, the 5-year reserve supply of tritium would be depleted. If additional arms reduction treaties are implemented, new tritium supplies may not be needed until 2011 or later.

DOE has been exploring alternatives for a new source of tritium, which include building a new reactor, purchasing a commercial power reactor, purchasing irradiation services from a commercial power reactor, and building an accelerator. In 1995, DOE determined that using a reactor and an accelerator were the only practical methods of producing a sufficient quantity of tritium to meet its stockpile requirements. At that time, the Department eliminated the option of building a new production reactor and decided to pursue a "dual track" strategy that considers using either a commercial reactor or an accelerator to produce tritium. After 3 years of study, the Department would select one of the tracks as its primary source of tritium and develop the other track, if feasible, as a backup tritium source. During the 3-year study interval, DOE issued a request for proposals for either the purchase of a commercial reactor or the purchase of irradiation services from the owner of a commercial reactor. TVA, a federal agency, was the only utility that offered responsive proposals, including both a proposal for DOE to invest in finishing the construction of a largely complete reactor at TVA's Bellefonte Nuclear Plant at Hollywood, Alabama, and an irradiation services proposal. If the Bellefonte proposal were selected, DOE would receive a share of any revenue generated by the sale of electricity from the plant, although ownership would remain with TVA.

In December 1998, the Secretary selected the commercial reactor option as the primary source for tritium and designated the accelerator option as the backup.⁵ One of the criteria for the Secretary's decision was the cost of the two options, based on life-cycle cost estimates prepared by each of the programs, including the costs to design and construct necessary facilities, the costs to operate the facilities over 40 years, and the costs for decommissioning the facilities at the end of the tritium production mission. Specifically, both the reactor and accelerator programs estimated costs in constant fiscal year 1999 dollars for producing approximately 100 kilograms of tritium over 40 years.⁶ DOE excluded sunk costs—costs incurred before fiscal year 1999—from its analysis. In addition, the reactor program estimated the costs for two methods of procuring reactor services from TVA—the investment in a new, partially complete commercial reactor and the purchase of irradiation services from existing commercial reactors. The reactor program's cost estimates also included high- and low-case scenarios for key cost drivers where substantial uncertainty existed, such as the cost of completing a reactor and the cost of irradiation services. The accelerator's cost estimate included the cost to develop the accelerator technology for tritium production, as well as the costs previously listed. Both programs have received favorable reviews from independent cost estimators under contract to DOE. In addition, each program has also had an independent assessment of its technical scope, cost, and schedule, as required by the Congress for large DOE construction projects begun in fiscal year 1998.⁷

DOE produced tritium in its own reactors for more than 40 years, using specially designed components to produce and capture the tritium. After being irradiated in the reactor, the components were transferred to a processing facility where the tritium was extracted and used or stored as a gas. In a commercial power reactor, components called burnable absorber rods are used to dampen or control the nuclear reaction during power production. DOE has designed a new rod, called a tritium-producing burnable absorber rod, that can be substituted for those usually used in commercial reactors. As the commercial reactor produces power, the rods

⁵The Secretary's decision was formally documented in the Consolidated Record of Decision for Tritium Supply and Recycling of May 6, 1999 (64 *Fed. Reg.* 26,369 [May 14, 1999]).

⁶The exact amount of tritium needed for the stockpile is classified. The planning number of 2.5 kilograms per year is an unclassified approximation of the tritium requirement.

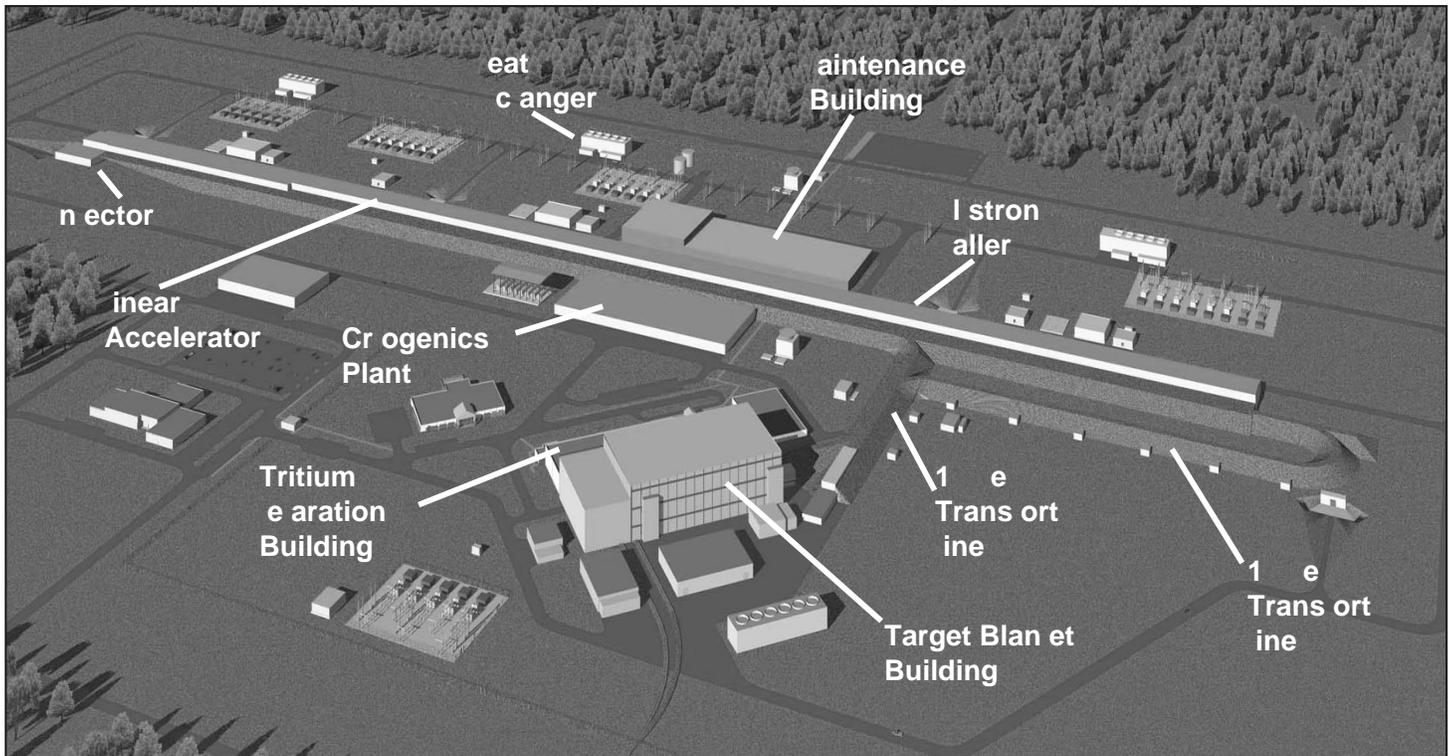
⁷See H. R. Rep. No. Report 105-271 (1997).

are irradiated, performing the reaction control function and producing and storing tritium within the rods. After irradiation, the tritium will be extracted, using processes similar to those that DOE has used for many years to process tritium from its own reactors.

DOE has also explored using an accelerator to produce tritium. The integration of four major systems is required to do this. (See fig. 1.)

- A linear accelerator that produces and directs an intense high-energy continuous-wave proton beam to a tritium-producing target/blanket.
- A target/blanket building in which protons strike heavy metal targets, producing neutrons that subsequently produce tritium in a helium-3 gas feedstock.
- A tritium separation building that recovers, purifies, and processes tritium produced in the helium-3 gas feedstock.
- Balance of plant facilities that house the systems and support their integrated operation.

Figure 1: Current Plan for an Accelerator-Based Tritium Production Plant



Source: National Accelerator Production of Tritium Project Office, Los Alamos National Laboratory.

While the operation of all essential accelerator systems has already been demonstrated separately, albeit on a smaller scale and often in more benign environments, producing tritium would require an accelerator of much greater power than any built so far. It would also require the maturation and integration of these systems in an operational environment to determine the optimal performance and reliability of an entire accelerator plant. Cost Estimates Used to Support the Secretary's Decision Were Well Supported and Developed Using Consistent Assumptions

The Secretary of Energy considered a variety of factors—one of which was cost—in selecting an option for tritium production.⁸ Other factors that were considered included the maturity of the technology, the ability to produce the amount of tritium needed to support the current stockpile, the degree of schedule risk, regulatory and licensing issues, nonproliferation policy issues, flexibility to meet changing stockpile requirements, and

environmental impacts. The commercial reactor option was estimated to cost from \$1.2 billion to \$3.6 billion for the program's 40-year life cycle, depending on whether DOE selected an investment in a new, partially complete TVA reactor or the purchase of irradiation services. The accelerator option was estimated to cost about \$9.2 billion to produce a comparable amount of tritium over the same time span.

Our analysis of the reactor and accelerator programs' cost estimates showed that, overall, the estimates were reasonable, well supported, and prepared with consistent assumptions. We judged the programs' cost estimates to be reasonable. For example, the reactor program presented a range of probable costs to the Secretary that captured the impact of uncertainties, such as whether DOE would invest in a partially complete TVA reactor or purchase irradiation services. We also found that both the reactor and accelerator programs' estimates could be traced to supporting documentation for the basis of costs and the methodology used to prepare the estimates. Finally, we determined that both programs used consistent assumptions in preparing the estimates, such as calculating costs over a 40-year production period. As you requested, we applied some alternative assumptions and estimating methodologies to DOE's cost estimates to provide a more complete analysis. Even after making these adjustments, the cost estimate for the reactor option remained less than half of the estimated cost of the comparable accelerator option. (See app. I for discussion of the adjustments we made and the results of our analysis.)

Challenges Remain for the Commercial Reactor Program

The commercial reactor program must meet several challenges in order to successfully supply tritium to the stockpile as planned. DOE has already established a sound management structure as well as a cost and schedule baseline against which to measure performance. However, DOE must still successfully complete four major activities to implement the selected tritium production option—(1) complete the Tritium Extraction Facility at Savannah River (S.C.), (2) contract for the manufacture of the specially designed tritium-producing rods, (3) implement an interagency agreement with TVA that will govern tritium production, and (4) get NRC's approval for amendments to the operating licenses of TVA's reactors. If any of these

⁸A complete discussion of each of the factors considered by the Secretary is given in the Consolidated Record of Decision for Tritium Supply and Recycling of May 6, 1999 (64 *Fed. Reg.* 26,369 [May 14, 1999]).

activities are not completed in a timely manner, the success of the overall program in meeting its cost and schedule goals could be threatened.

The Reactor Program Has a Sound Management Plan in Place to Manage the Cost and Schedule Baseline

DOE's Office of Commercial Light Water Reactor Production, which is responsible for managing the reactor program, has demonstrated sound management practices by articulating its mission, recruiting experienced managers, and putting the tools in place to manage and coordinate the activities needed to implement the commercial reactor option. The program has a clearly defined mission statement, that is, to establish "the production capability and operations systems necessary to produce tritium in a commercial reactor." To accomplish this mission and implement the management plan, DOE has recruited an experienced management team to oversee the work being done at several DOE sites—Savannah River (S.C.), Pacific Northwest National Laboratories (Wash.), Sandia National Laboratory (N. Mex.), and Argonne National Laboratory-West (Idaho). Among the tools being used are annual operating plans for each participant, regular quarterly meetings, monthly reports, and the day-to-day coordination of activities by headquarters Task Managers, who serve as focal points to ensure that problems are promptly resolved.

In addition, the reactor program has established an integrated cost and schedule baseline that provides a means to measure the program's progress across sites and activities. Any change to the baseline that increases work scope or cost must be approved by DOE headquarters. For example, when the Pacific Northwest National Laboratories projected cost growth of nearly \$64 million in 1998, DOE headquarters' management worked with the lab to identify unneeded activities and bring the lab's cost and schedule back into alignment with the approved baseline. In another example, when a testing program at the same lab fell behind schedule and several months passed without substantial progress, DOE headquarters' management insisted that changes be made. The lab replaced the manager responsible for that testing program. On the other hand, DOE has also approved changes that have increased costs when they were justified. For example, Savannah River received approval to increase the cost and delay the schedule for the construction of the Tritium Extraction Facility when substantial increases in the cost of the gloveboxes⁹ to be used for

⁹Gloveboxes are enclosures used for radioactive processing in which the pressure, temperature, and atmosphere are carefully regulated to minimize the risk of radioactive releases or accidents.

radioactive processing were identified and to accommodate a congressionally mandated delay for tritium-production-related construction during fiscal year 1999.

While DOE has a good plan in place, the Department has had a poor track record of implementing good management practices in other projects. Our work has repeatedly highlighted continuing problems with DOE's management of projects and contracts. From a historical perspective, we and others have reported that the lack of sufficient DOE personnel with the appropriate skills to oversee contractors' operations was one of the key factors underlying the cost overruns and schedule slippages that DOE has experienced in major systems acquisitions from 1980 through 1996.¹⁰ More recently, we noted that ineffective management by both the contractor and DOE resulted in cost overruns and schedule slippage on the In-Tank Precipitation project at Savannah River.¹¹ In addition, a 1999 National Research Council committee report recommended numerous changes to DOE's project management process, ranging from project planning and baselining to contract incentives.¹² Furthermore, DOE identified a number of systematic problems, including "inadequacies in technical scope, schedule planning and control, cost estimating, and lack of clarity on roles and responsibilities." In June 1999, DOE announced a number of actions to improve its management of major projects, which include establishing a project management tracking and control system that includes planned and actual cost and schedule performance data and establishing mechanisms for greater accountability for a project's success by both DOE and its contractors. While it is too early to determine whether these actions will improve project management across DOE, it is important that the current sound management approach, in terms of both project planning and implementation, used to manage the reactor tritium production effort to date be continued.

¹⁰See *Department of Energy: Opportunity to Improve Management of Major System Acquisitions* (GAO/RCED-97-17, Nov. 26, 1996).

¹¹See *Nuclear Waste: Process to Remove Radioactive Waste From Savannah River Tanks Fails to Work* (GAO/RCED-99-69, Apr. 30 1999).

¹²*Improving Project Management in the Department of Energy*, National Research Council, Committee to Assess the Policies and Practices of the Department of Energy to Design, Manage, and Procure Environmental Restoration, Waste Management, and Other Construction Projects (Washington, D.C., 1999).

Schedule Challenges for the Tritium Extraction Facility Have to Be Successfully Resolved

In order for new supplies of tritium to be used for the weapons stockpile, DOE is designing and building a new Tritium Extraction Facility, where the tritium will be extracted from the specially designed rods after the rods have been irradiated in TVA's commercial reactors. The preliminary design of the new facility was completed on schedule and under budget, and the final design is now under way. However, the Congress enacted a moratorium that prohibited tritium-production-related construction during fiscal year 1999 in order to allow time for congressional review of the Secretary's technology selection decision, which had not yet been made at the beginning of fiscal year 1999. That moratorium delayed the planned start of the Tritium Extraction Facility's construction by 12 months. The new facility is now scheduled to begin operations in February 2006—a few months after the fiscal year 2005 need date for new tritium supplies. As a result, DOE will have to use some of the 5-year reserve supply of tritium, and tritium production will have to be adjusted to replenish the reserve. Because there is very little time in the new schedule to accommodate further slippage, it is critical that DOE manage the construction and start-up of the Tritium Extraction Facility very carefully to minimize further delays and to minimize the impact on the tritium reserve supply.

In an attempt to recover as much of the schedule slippage as possible, DOE has taken actions that add some risk to the project. First, DOE is splitting the final design of the facility into two segments—the civil and structural design (the building walls and foundations of the Remote Handling Area) and the remainder of the plant (the Tritium Processing Area and all handling and processing lines). This strategy will allow DOE to begin construction of the Remote Handling Area building while the final design of the processing lines is being completed and has helped DOE to regain 3 months of the construction schedule's slippage. Second, DOE has changed the strategy for procuring design and construction services for the facility. The original strategy would have used a design and general construction services contractor that, in turn, would have subcontracted portions of the work. External reviewers cited the concept as problematic because of its complexity and the additional layers of overhead and construction management that it would entail. Instead, design and construction services will be managed directly by Westinghouse Savannah River, the site's management and operating contractor. Third, while the final design of the remainder of the plant proceeds, DOE is proceeding with a component development and testing program to ensure that full-scale versions of the extraction processes will operate as expected. As part of this program, DOE will install and test full-scale mock-ups of key pieces of handling and processing equipment, such as the extraction furnace, in a demonstration

and test facility.¹³ While the testing to be done in the component development and testing program is expected to confirm the results of testing already done in the laboratory, only about 8 months lie between the scheduled end of the confirmatory testing and the end of the final design. Thus, if the testing should uncover unexpected problems or if the completion of the demonstration and test program is delayed, the final design and construction of the Tritium Extraction Facility may also be delayed. If the final design is delayed, the risk of not completing the extraction facility on schedule and on budget would be increased.

DOE has also planned when it will procure key pieces of equipment—the heavy-duty cranes and the gloveboxes where much of the processing will occur. However, these procurements will require long lead times and large commitments of funding. For example, the gloveboxes, which have a total estimated cost of about \$40 million, must be ordered well in advance of the time when they are to be installed to allow time for the vendors to fabricate them to the design specifications. These procurements could be delayed for several reasons if, for example, the final design specifications are not ready in time, the procurements are not well managed, or sufficient funding is not available when needed. If the procurements are delayed, the risk of not completing the Tritium Extraction Facility on schedule is increased.

Special Procurement Challenges Concerning the Tritium-Producing Rods Need to Be Overcome

DOE plans to contract for the manufacture and assembly of the specially designed tritium-producing rods that will be used in TVA's commercial reactors. Finalizing the contract with a commercial vendor for the tritium-producing rods is critical to the reactor program's success in two ways. First, the cost of the specially designed tritium-producing rods is the last major component of the cost of producing tritium in a commercial reactor that is not known, although an estimate for this component was included in the reactor program's cost estimates used for the Secretary's technology decision. Second, there are only a few potential commercial vendors for this reactor component and only one that is a domestically owned company.

The cost estimate for DOE's reactor program used a cost of \$2,000 each for the specially designed rods that will be used to produce tritium in TVA's

¹³The facility for the demonstration and test program will continue to be used after testing is completed to train operating personnel for the Tritium Extraction Facility, refine operating procedures, and resolve problems that may arise after the facility is in full operation.

reactors. This represented the lower end of a range from \$2,000 to \$5,000 per rod and a major reduction in cost from the \$20,000 per rod that DOE spent for the small number of hand-crafted rods that were used in a limited-scale production test in TVA's Watts Bar reactor in Tennessee.¹⁴ The reactor program would need about 128,000 of the specially designed tritium-producing rods at the currently required level of about 2.5 kilograms of tritium per year.¹⁵ We found that using the high end of DOE's original range of cost estimates for this component (\$5,000 per rod) could raise the total life-cycle cost of the program by about \$375 million (13 percent). According to DOE officials, the design lab, Pacific Northwest National Laboratories, has made significant progress in refining the design to make tritium-producing rods amenable to full-scale manufacturing since the production test rods were manufactured. For example, the lab has developed a powder for one component of the rods that can be poured into molds rather than spooned in by hand. Because of these advances, DOE officials believe that their cost estimate of \$2,000 per tritium-producing rod is achievable. However, the accuracy of this estimate will be known only when bids are received from commercial vendors who have the expertise and facilities to mass-produce the specially designed tritium-producing rods.

Since some of the technical specifications of the specially designed tritium-producing rods are classified, DOE may need to take some additional steps to qualify the selected vendor if a foreign company is chosen. Non-U.S. companies can perform classified work for DOE after they receive a favorable "foreign ownership control or influence" determination from DOE. The purpose of this determination is to ensure that access to any classified national security information or materials will not "pose an undue risk to the common defense and security through the possible compromise of that information or material." Thus, a foreign company can qualify if it mitigates the risk of endangering classified material. For example, a foreign company might create a U.S. subsidiary that meets certain criteria concerning its corporate structure and officers. According to DOE officials, these determinations can take anywhere from a few months to 2 or 3 years to secure, depending on the vendor's willingness to make appropriate changes to the company's structure and how focused

¹⁴This test, called the Lead Test Assembly, irradiated 32 of DOE's specially designed tritium-producing rods for a full fuel cycle. The rods functioned as expected and were removed from the reactor in February 1999.

¹⁵The exact amount of tritium needed for the stockpile is classified. The planning number of 2.5 kilograms per year is an unclassified approximation of the tritium requirement.

DOE is on completing the process. Given the magnitude of this procurement and DOE's obligation to deliver tritium to the stockpile, both the vendor and DOE should have an ample incentive to resolve these issues quickly.

In order to allow time for the foreign ownership, control, or influence determination, if needed, DOE is using a phased procurement for purchasing production rods. In the first phase, the Pacific Northwest National Laboratories will manufacture the components and deliver them to a vendor who will assemble them into the specially designed tritium-producing rods. The first phase will provide DOE with enough rods for several years of tritium production. During the first phase, DOE officials believe that there will be sufficient time to resolve any issues related to foreign ownership, control, or influence. For the second phase of the procurement, when DOE plans to transfer control of the manufacture of the components for the specially designed rods to the vendor, the vendor must have facility and personnel security clearances in place. If the resolution of issues of foreign ownership, control, or influence is not completed in time for the second phase, DOE is preparing a backup plan under which DOE would continue to control the manufacture and assembly of the components of the rods.

Interagency Agreement Between DOE and TVA for Long-Term Irradiation Services Needs to Be Implemented

In order to deliver tritium to the weapons stockpile as planned, DOE must successfully implement an interagency agreement with TVA, the only utility that offered to provide irradiation services in response to DOE's 1997 request for proposals to supply reactor services. The working relationship between the two federal agencies will be governed by an interagency agreement, which has been negotiated and approved by both DOE and TVA. The agreement provides a basis for DOE to coordinate tritium production activities with TVA and for TVA to proceed with preparing amendments to the NRC licenses for the reactors that will participate in tritium production. The interagency agreement will run through 2035 and has a value of approximately \$680 million.¹⁶

¹⁶The total value of the interagency agreement is not fixed for two reasons. First, it is a cost-based agreement under which TVA will generally recover all costs attributable to its role in the tritium program. Second, the agreement provides for payments for "unanticipated costs," which, by their very nature, cannot be estimated.

When an agency of the federal government obtains goods or services from another federal agency, it does not use a commercial contract. Instead the agencies negotiate an interagency agreement under the Economy Act,¹⁷ which permits goods and services to be provided at actual cost. Interagency agreements are usually brief statements of the agencies' agreement to cooperate to achieve some goal or provide some service. Unlike a commercial contract, there is no provision for the supplying agency (TVA, in this instance) to make a profit on the transaction under an interagency agreement, but the full cost of performing the service is reimbursable. However, because of the value of the work and the length of time covered by the tritium agreement, it is not a typical interagency agreement.

The interagency agreement that DOE and TVA negotiated provides a solid framework for their long-term cooperation to produce tritium, based on our review of the draft document. In this case, the interagency agreement, like a commercial contract, defines what is to be done, what each party's roles and responsibilities are, how progress will be measured and performance monitored, and how disputes will be resolved. In fact, the draft agreement incorporates good controls and has protections for both DOE's and TVA's interests. For example, each agency has only one point of contact who has the authority to make changes to the agreement that affect the cost or scope of work to be performed. DOE's interests are protected through provisions that require TVA to provide notice of any extended reactor shutdowns that could affect tritium production. In addition, TVA will provide an annual operating plan detailing the activities to be performed and their associated costs for each fiscal year for DOE's approval. TVA's interests are also protected, for example, by a provision that requires DOE to perform biennial audits of the costs that TVA has submitted for payment. Under the typical interagency agreement, audits are not performed until the agreement ends, which, in this case, would expose TVA to financial liability for many years if, for example, DOE should determine that a submitted cost was not payable under the agreement. By providing for biennial audits, TVA will have prompt assurance that any disputes with DOE about the allowability of costs have been closed out. The agreement allows DOE and TVA to proceed with time-critical activities, such as TVA's preparation of the license amendments for the reactors that will produce tritium for DOE.

¹⁷See 31 U.S.C. § 1535 (1994).

Questions About NRC's Authority to License TVA's Use of DOE's Specially Designed Tritium-Producing Rods Should Be Resolved

NRC currently licenses TVA to produce electricity in its Watts Bar and Sequoyah reactors in Tennessee, the ones that will also be used to produce tritium for DOE. NRC licenses TVA's operations, as it does other commercial nuclear reactors, to ensure that TVA will operate its reactors properly. Changes in a reactor's design or operating practices may present potential "unreviewed safety questions" that require advance approval from NRC in the form of a license amendment.¹⁸ This ensures that the safety implications of every change are fully considered and documented. NRC has determined that a license amendment is required before a commercial power plant would be permitted to substitute DOE's specially designed tritium-producing rods for standard absorber rods in a reactor's fuel assembly. However, under current law—42 U.S.C. §7272—NRC lacks authority to expend funds for the purpose of licensing "any defense activity or facility of the Department of Energy. . . ." The term defense activity is not defined in the statute.

Officials in NRC's Office of General Counsel believe that, under current law, NRC can review and act on TVA's license amendments to place DOE's tritium-producing rods in the three Watts Bar and Sequoyah reactors. As NRC sees it, the license amendment review process is limited to studying the questions associated with TVA's request to substitute the DOE's tritium-producing rods for standard absorber rods in its reactors. TVA's reasons for using the specially designed tritium-producing rods instead of standard absorber rods are not NRC's concern in the license review process, nor is DOE's subsequent use of the irradiated rods for tritium production. With respect to 42 U.S.C. §7272, NRC officials believe that the legislative history of this section indicates that it was primarily directed at prohibiting NRC from directly regulating DOE's defense activities. NRC officials are of the view that there is nothing in the statute or its legislative history to suggest that the provision would be applicable to a "mixed activity," where a defense activity—in this case, irradiating DOE's specially designed tritium-producing rods—is being undertaken as an ancillary function to a commercial licensee's production of electricity.

DOE also maintains that NRC has the authority to review and act on TVA's license amendments. As evidence of this, DOE is actively participating in preparing for the license amendment process. Specifically, the Department has executed a 1996 Memorandum of Understanding with NRC to establish

¹⁸See 10 C.F.R. § 50.59.

the framework for resolving issues related to the regulation of nuclear facilities and activities involved in the production of tritium. DOE prepared a technical report, called a topical report, to support a pilot test of a limited number of its tritium-producing rods in TVA's Watts Bar reactor. NRC reviewed the topical report and TVA's reactor-specific license amendment application prior to the pilot test. The pilot test was successfully completed, and the rods were removed from the reactor in February 1999. In addition, DOE has prepared a topical report to support the use of a larger number of tritium-producing rods for full production. NRC has also reviewed that report and issued its findings that all generic safety questions related to use of the tritium-producing rods have been resolved in a May 1999 Safety Evaluation Report, leaving only reactor-specific issues to be resolved in TVA's license amendment applications.

While both DOE and NRC maintain that current law permits the license amendment review, NRC's General Counsel has recognized that different interpretations of 42 U.S.C. §7272 are possible. Specifically, in a November 1997 memo to NRC's Inspector General, NRC's General Counsel acknowledged that DOE's defense activities are the cause for NRC's review of TVA's license amendment and therefore, NRC's licensing process could arguably serve, at least indirectly, to block or place conditions on DOE's production of tritium. If the law is interpreted this way, the process could be viewed as the licensing of a defense activity, which would be prohibited by 42 U.S.C. §7272, thus, requiring legislative change before NRC could act. If NRC's authority to grant license amendments were challenged, serious project delays could result.

Therefore, while both agencies believe that adequate authority exists, both agencies have also suggested that specific legislative authority would be useful, given the possibility of different interpretations of the current law and the potential consequences for the tritium production program. To this end, in May 1997, the Secretary of Energy submitted proposed legislative language to the Congress that would have allowed the Secretary of Energy to obtain irradiation services for tritium production and would have waived the prohibition on NRC's use of appropriated funds for licensing any defense facility or activity with respect to tritium production. However, the Congress did not enact clarifying legislation at that time. Likewise, NRC's General Counsel has, on several occasions, stated that legislation to clarify NRC's authority would be desirable. Recently, the National Defense Authorization Act for Fiscal Year 2000 directed DOE to implement the reactor option for tritium production, but this legislation does not expressly mention 42 U.S.C. §7272.¹⁹

DOE's Current Approach to Developing a Tritium Production Backup Option Increases Cost and Schedule Risk

DOE's current approach for developing the accelerator increases the cost and schedule risk that the tritium production backup will not provide an "off the shelf" option in 5 years as DOE originally intended. In its fiscal year 1999 Stockpile Stewardship Plan, which was in place at the time of the Secretary's decision, DOE stated that if the accelerator were chosen as a backup, the Department would complete an extensive technological development effort and develop a preliminary and final design package. Completing this development and design work would create an "off the shelf" design package for a plant that, if it were adequately funded, could be constructed and operated within 5 years. However, because of the limited funds the Department allocated to the accelerator, DOE reduced the scope of the accelerator's development and design activities. Not completing all of the necessary development activities introduces the risk that the costs and schedule to build, operate, and maintain the accelerator over its 40-year production life could increase. Outside experts, who support the accelerator's development, have also expressed concern that by not completing all the necessary development activities, DOE has introduced risk that the accelerator backup option could experience cost and schedule overruns if it is eventually needed for tritium production. However, other alternatives exist for developing an accelerator backup.

DOE Has Changed Its Approach to the Backup Tritium Option

Originally, DOE stated in its Stockpile Stewardship Plan that if the accelerator were chosen as a backup, the Department would complete the activities in an Engineering Development and Demonstration plan and develop a preliminary and final design package for the accelerator. The Engineering Development and Demonstration plan was developed to resolve the many technical issues needed for efficient plant design through testing and prototyping. Using the completed Engineering Development and Demonstration work, DOE planned to prepare final design documents and drawings for the accelerator. These would provide an "off the shelf" design package for a plant that could be built and operated within 5 years—assuming that adequate funds are made available.

In December 1998, following the selection of the accelerator as the backup, DOE officials significantly reduced the funding and scope of activities for completing the accelerator backup option because of the limited

¹⁹See the National Defense Authorization Act for Fiscal Year 2000, Pub. L. No. 106-65, § 3134(a), 113 Stat. 512 (1999).

availability of funds within DOE's Office of Defense Programs' budget. Specifically, DOE reduced the funds to complete the accelerator backup by about 50 percent—from an original estimate of about \$600 million to about \$300 million. The accelerator's backup costs include the preliminary and final design activities; the Engineering Development and Demonstration activities; the environmental, safety, and health reports and documentation; and the associated project and DOE program management costs. As shown in table 1, over 70 percent (\$219 million of \$304 million) of the reduction came in the design activities' costs.

Following its decision to reduce funding for the accelerator option, DOE, in its fiscal year 2000 Stockpile Stewardship Plan released in March 1999, redefined its approach for an accelerator backup option as one that completes the development and demonstration activities of key components of the linear accelerator and target/blanket technologies and the preliminary design of the accelerator plant. DOE now plans that, by the end of fiscal year 2002, the accelerator backup option would be in a state of maturity that would make it possible to start construction and build an accelerator plant rapidly. However, DOE officials could not define what is meant by "rapidly." We have chosen to use the 5-year time frame for evaluating the accelerator backup option because (1) any time line that extends beyond 2005 will cause DOE to begin to use its tritium reserve, (2) DOE could not define what is meant by "rapidly," and (3) the 5-year time frame was in place at the time of the Secretary's decision.

Table 1: Results of DOE's Decision to Reduce Funds for Accelerator Backup Activities

Constant fiscal year 1999 dollars in millions

Accelerator backup activities	Original estimate for backup	Current estimate for reduced scope backup	Change in backup cost estimates
Design	\$340.2	\$120.9	(\$219.3)
Engineering Development & Demonstration	139.3	151.3	12.0
Environmental, Safety & Health	61.6	11.0	(50.6)
Project management, DOE program, etc.	71.4	24.8	(46.6)
Total	\$612.5	\$308.0	(\$304.5)

Note: Cost estimates to complete the original full backup activities are extracted from the cost estimate to complete the accelerator option contained in the Secretary's December 1998 decision memo. The current cost estimates to complete the reduced backup activities are taken from the support for the accelerator's baseline change proposal that was approved in June 1999. The costs to complete the backup are for the period fiscal year 1999 through fiscal year 2002.

Source: GAO's calculations of data from the Los Alamos National Laboratory's accelerator project.

Although the Engineering Development and Demonstration activities' costs increased by about 10 percent, the director of the Engineering Development and Demonstration program acknowledged that the increase occurred because program officials had underestimated the costs of performing the development activities in the superconducting portion of the accelerator. Funding these necessary activities and the addition of some new development activities in the accelerator system—the most costly of the plant's major systems—resulted in cutbacks in other areas of the Engineering Development and Demonstration program. DOE estimates that it would cost an additional \$50 million to complete all the originally planned development activities. Another \$65 million to complete newly identified development activities that would provide additional confidence of achieving high operational availability has also been identified. The total of these activities is in addition to the \$308 million that DOE currently anticipates spending on the accelerator backup option. A further breakout of the accelerator's current backup cost estimate by fiscal year is shown in table 2.

Table 2: Current Accelerator Backup Cost Estimates by Fiscal Year

Constant fiscal year 1999 dollars in millions

Accelerator backup activities	Fiscal year 1999	Fiscal year 2000	Fiscal year 2001	Fiscal year 2002	Total
Design	\$38.1	\$29.0	\$36.0	\$17.7	\$120.9
Engineering Development & Demonstration	69.2	40.7	32.3	9.1	151.3
Environmental, Safety & Health	4.4	2.4	3.4	0.8	11.0
Project management, DOE program, etc.	10.8	6.9	4.3	2.8	24.8
Total	\$122.5	\$79.0	\$76.0	\$30.4	\$308.0

Source: GAO's calculations of data from the Los Alamos National Laboratory's accelerator project.

Not Completing Development and Design Activities Increases the Risk of Construction and Operating Cost and Schedule Overruns

Resolving potential problems prior to final design and construction through technology development activities helps to control potential cost and schedule increases in the event that the accelerator is needed and also helps to minimize the costs to operate and maintain the accelerator over its 40-year production life. While there is general agreement in the scientific community that an accelerator can produce tritium, technical risks involving the accelerator's performance and reliability remain. Reducing the need for overly conservative designs and contingency requirements and establishing component performance levels well enough to ensure that the accelerator can be built and operated with 90-percent confidence within an ultimate cost and schedule estimate was the goal of DOE's Engineering Development and Demonstration plan. Consequently, most of the development activities in the original plan focused on confirming and characterizing the systems' performance and structure, as well as building and testing prototypes in an integrated, operational environment. However, DOE's current plan results in canceling some of these development activities, reducing the scope of others, and generally eliminating work on the final design of the accelerator plant. As a result, there is increased risk that, if needed, the accelerator could not be built and become operational on time and within budget.

Originally, the Engineering Development and Demonstration plan addressed about 68 design data needs. As development activities that resolve these design data needs are completed, the information is conveyed

to the design team, where decisions are made on the optimal design features for the major systems of the accelerator plant. As a result of some initial development activities, several design changes that have reduced the estimated construction costs and contingency requirements have already been made to the conceptual design of the plant. For example, by building and operating prototypes of two major mechanical-electrical systems that are responsible for injecting and accelerating the proton beam into the accelerator, DOE has reduced the costs for design and construction of the balance of the plant support system by about \$14 million.

In response to funding cutbacks and the selection of the accelerator as the backup option, DOE developed a revised Engineering Development and Demonstration plan. While the revised plan contains about the same overall number of design data needs (64), it cancels about 21 of the associated original development activities; reduces the scope of about 26 activities; and adds, replaces with new activities, or increases the scope of about 30 activities. Table 3 shows the breakout of these design data needs by major components of the Engineering Development and Demonstration program.

Table 3: The Accelerator’s Engineering Development and Demonstration Design Data Needs

Category name	Original needs	Canceled needs	Reduced scope	New or replaced needs or increased scope	Current needs
Low Energy Demonstration Accelerator	10	0	4	6	14
Target/Blanket & Materials	24	6	10	17	24
Tritium Separation Facility	24	12	8	1	13
High Energy Linac	10	3	4	6	13
Total plan	68	21	26	30	64

Note: Because the categories contain overlap, the figures in the rows may not total to the current needs shown.

Source: GAO’s analysis of the accelerator’s 1997 Core Technology Plan and its current June 1999 Preliminary Design Plan.

Many of the canceled development activities affect the tritium separation system. The primary functions of the tritium separation system are to separate and purify the tritium from the helium-3/hydrogen isotope mixture and to process contaminated waste gas streams generated in the target/blanket and separation facilities to recover the tritium and helium-3. The development activities that have been canceled primarily affect the potential cost of the isotope separation process and its long-term operation and maintenance, as well as the gathering of data on the amount of radioactive waste that would be generated. In addition, DOE has identified new development activities in each of the accelerator's systems that are not included in its current plan but would provide important reliability and operational data. If a decision is made that the accelerator is needed to produce tritium, a new design team will need to determine if it has the time and money to perform all of these development activities. If the team decides to begin final design and construction without performance data, the risk of successfully producing tritium on schedule and within budget using an accelerator increases.

DOE has reduced the scope of about one-third of the original development activities in its current backup plan. Much of this scope reduction comes from simply testing selected components as opposed to actually operating them in an integrated environment for long periods of time to get performance data. If DOE decides to restart the project, a new design team will have to quickly develop final design drawings and specifications without good integrated performance data. Without full performance data prior to final design and construction, the risk of cost and schedule overruns to build an accelerator plant of this size increases. The lack of good performance data also increases the risk of higher operation and maintenance costs for the plant over its 40-year life.

DOE added and replaced some activities with new development activities and increased the scope of others in its current plan. This is a normal and expected evolution in any technology development program. However, in DOE's current plan, while the largest increase in development activities occurs in the target/blanket system, it primarily results from dividing what were originally single activity descriptions into several descriptions. For example, in DOE's original plan, one data need described the materials durability activities for the entire target/blanket system. In the current backup plan, this one development activity description has been replaced with five (one for each affected component of the system). Another target/blanket water corrosion activity was replaced by water corrosion

activities for each of the three components of the target/blanket system that are affected.

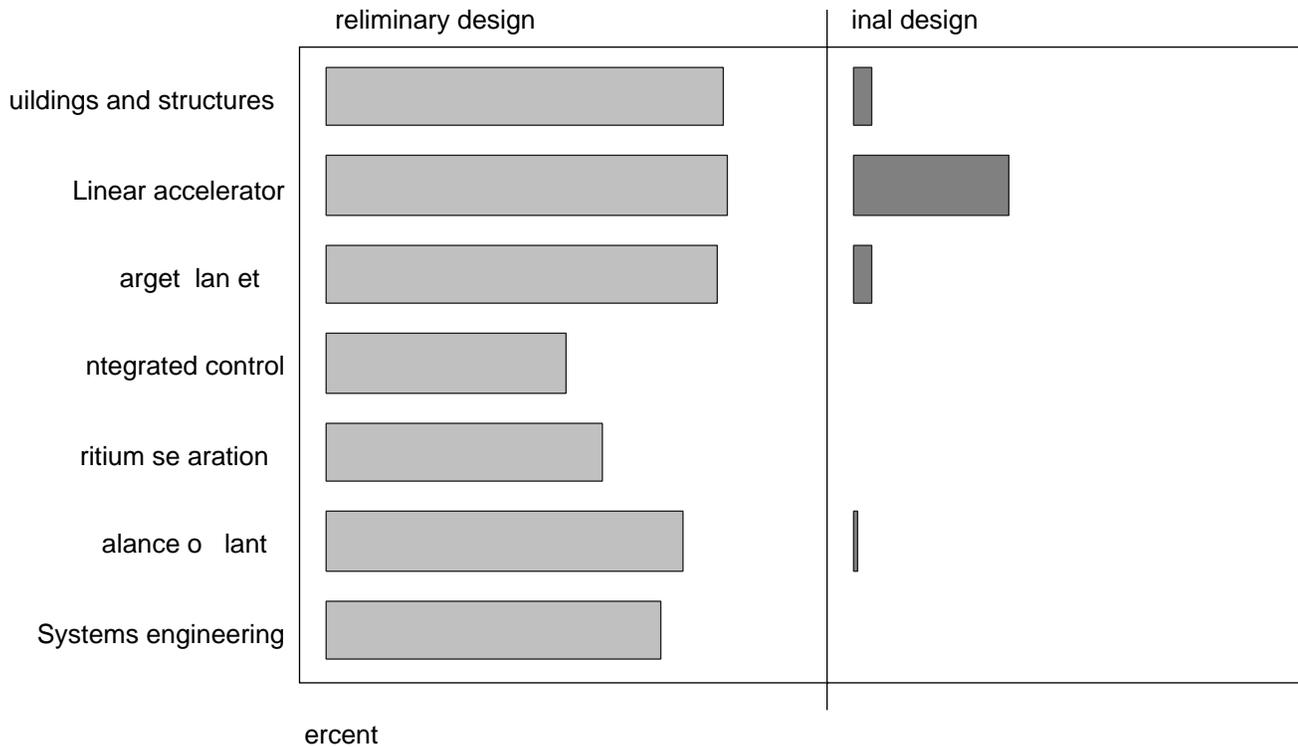
The maturity of technology at the start of any new program is an important determinant of the program's ultimate success. For example, in a recent report, we found that the Defense Department's weapon system programs that began by accepting developing technologies without the level of maturity that the original Engineering Development and Demonstration effort would have provided experienced significant cost and schedule increases.²⁰ These cost and schedule overruns were due, in part, to problems with the technologies during the program's implementation. DOE officials acknowledged this concern by initiating the Engineering Development and Demonstration effort for the accelerator in the first place. DOE's original plan for the Engineering Development and Demonstration program consistently notes that the failure to establish good design values by addressing the design needs of the accelerator systems' technologies risks large cost and schedule overruns while the systems' design is adjusted to compensate. Also, many of the original and newly identified design data needs address the maintenance of components and operational efficiency, which can have a significant impact on the eventual operating costs of the plant (the most significant portion of the life-cycle costs for the accelerator option). However, DOE has chosen to cancel or not include many of these operational performance and reliability activities in its current backup plan because of limited funds.

In its current backup plan, DOE stopped most of its design work for the accelerator prior to completing the preliminary phase. DOE does plan to complete final design on some portions of the accelerator plant, such as the proton injector, the tunnel for the accelerator, the construction management building, and the pad for the target/blanket building. These final design activities help form the basis for a "rapid restart" concept that DOE has proposed along with its current backup plan. Completing these design activities now would allow DOE to begin some long-lead procurement and construction activities on the accelerator plant while it finishes the remaining development and design activities. This restart plan would also balance out funding for the accelerator to accommodate expected budget constraints. However, this restart plan only helps DOE to build the accelerator quickly if a decision is made by 2002, before the

²⁰See *Best Practices: Better Management of Technology Development Can Improve Weapon System Outcomes* (GAO/NSIAD-99-162, July 30, 1999).

current design team is dispersed. After 2002 a new design team would be hired and it would take several years before final design activities are completed and procurement and construction activities could begin. Figure 2 shows how much of the total potential design activities the current design team plans to complete.

Figure 2: The Accelerator’s Current Plans for Completing Preliminary and Final Design Activities



Source: Los Alamos National Laboratory’s accelerator design team.

Outside Groups Support the Accelerator’s Development but Have Expressed Concerns

Several outside expert groups, including the Mitre Corporation’s JASON panel and Booz, Allen and Hamilton management consultants, have reviewed the accelerator program and provided feedback on its technology decisions and management plans. Also, since its inception, the accelerator program has had semiannual input on its technical program from an external review committee comprising experts in accelerator and nuclear

technology and project management. At its most recent meeting, in June 1999, the external review committee provided comments on the accelerator's current backup plan. The committee's recommendations included identifying the design uncertainties that exist under the current plan and those that were part of the original plan and determining the minimum resources required to complete these development activities during the remaining years of the project. The external review committee was concerned that, while these development activities could be initiated after a decision to restart is made, it could take at least 4 to 5 years to perform, analyze, and absorb the results into final design drawings before construction could begin. The committee also recommended that the project develop a new restart plan with attention to realistic rates of staff buildup and other factors likely to affect the program if such a decision is made after the current team is dispersed. The committee recommended these actions because it believed that after 2002, a restart of the accelerator project would require bringing on a large number of new people, unfamiliar with old—perhaps even obsolete—designs. This situation could necessitate the redesign of crucial subsystems to accommodate the loss of manufacturing techniques or a design advantage understood only after the current program's termination.

In 1998, a congressionally mandated independent review team was tasked with providing an objective analysis of the technical, economic, and management aspects of the accelerator program. Specifically, the team was asked to determine the validity and credibility of the technical scope of the project, including its proposed technology, cost, schedule, and project management system. The team concluded that the validity and credibility of the technical scope of the project was well established, that the project's cost and schedule determinations were reasonable and sound, that the project was very well managed, and that the project used a well-integrated team approach. The independent review team also concluded, though, that if the project were not selected as the primary source of tritium, DOE should supply backup funds that are "sufficient for the most expeditious truncation and archiving of the project design and lessons learned."

A Range of Alternative Accelerator Backup Approaches Exist

In October 1999, the Congress directed DOE to complete the development and preliminary design activities needed to ensure that the accelerator is a backup source of tritium to its commercial reactor approach.²¹ The Congress also directed DOE to make funds available to complete the necessary development activities, the preliminary design, and the detailed design of key elements of the system. The conference committee expressed

concern that DOE's fiscal year 2000 budget request for its tritium production program was driven more by the limited funds available for its stockpile management program than from an objective assessment of the activities required to provide an efficient and effective primary and backup production source for tritium. DOE was encouraged in the Congressional Conference Report to use funds from its stockpile management program, if necessary, to complete the critical elements of the accelerator backup system.

DOE's accelerator officials acknowledge that the reduced scope in the Department's current development plan does introduce some additional technological risk into the program. This risk does not affect whether the accelerator will produce tritium. Rather, it affects how much the tritium will cost and how much time it will take to complete the development and design activities, and build and operate the accelerator, if needed. For example, will DOE be able to perform hands-on maintenance on the accelerator without the need for radiation protection equipment, or will DOE have to replace equipment more rapidly in the target/blanket system because the equipment does not last as long as DOE thought it would? While DOE's accelerator officials consider these increased risks relatively low, they agreed that they would prefer to address them now rather than later. They also agree that the risks increase substantially after the current team is dispersed.

Several alternative approaches exist for the accelerator backup. These approaches weigh the activities to be performed with their associated costs and risks in different ways. First, DOE could complete all necessary development activities as well as the preliminary and final design of the accelerator plant as originally intended. This would require about \$335 million more than DOE has budgeted for the accelerator backup. However, if DOE were to make this investment, it could produce a design that was outdated. Second, DOE could complete all development activities, including those related to increasing the operational availability of the plant, archive the results, and terminate the design efforts. This approach would ensure that all technical issues are explored as fully as DOE originally intended and that the information would be available for the Department to complete design activities if the accelerator is needed. This approach would require about \$62 million more than DOE has budgeted for

²¹See the National Defense Authorization Act for Fiscal Year 2000, Pub. L. No. 106-65, § 3134(c), 113 Stat. 512 (1999).

the accelerator backup. However, DOE may not be able to complete the design and begin producing tritium within the 5-year time frame. Finally, while the Congress has expressed its support for a backup, DOE could assume that because the reactor approach is based on 50 years of experience, it will work as planned and the accelerator can be eliminated as a backup and quickly wound down. Assuming that DOE needs its fiscal year 2000 funds to wind down the accelerator project, this approach could save about \$106 million in fiscal year 2001 and 2002. However, this alternative assumes that DOE will effectively implement the reactor management systems that it has put in place.

Conclusions

The management plans and systems that DOE has put in place to implement the commercial reactor option have placed the Department in a good position to successfully address most of the challenges we have identified over the next few years as the program matures. However, given the Department's past history of weak project management, it is vital that the kind of effort we observed in the reactor program so far be sustained so that the tritium needs of the nation's nuclear weapons stockpile will be met on schedule and within budget. One activity—the licensing of TVA's reactors—is largely outside of DOE's control. While we believe that NRC's and DOE's interpretation of the current law—that the reactor safety aspects of using the specially designed tritium-producing rods can be the subject of a license amendment without licensing a defense activity—is reasonable, it would be possible for a third party to challenge NRC's legal authority and argue that NRC is licensing a defense activity in violation of 42 U.S.C. §7272. Such a challenge could significantly delay the production of tritium needed for the nation's nuclear weapons.

DOE's current approach for developing the accelerator increases the cost and schedule risk that the tritium production backup option will not, as originally intended, provide an "off the shelf" option that can be ready to produce tritium with a high degree of confidence. By reducing both development and design efforts, the approach that DOE is pursuing introduces risk that the accelerator could not be built and operated within a 5-year time frame. Any time line for completing the accelerator, if the backup option is needed, that extends beyond 2005 will cause DOE to begin to use its tritium reserve. Just as importantly, DOE's current approach increases the risk that operating costs—the biggest portion of the accelerator's life-cycle cost—could rise. DOE's approach to a backup source for tritium production should reflect a complete assessment of the development and design activities necessary to provide a backup facility

that can be quickly built and operated at the least known cost with minimal risk, if the accelerator is needed in the future.

Recommendation to the Congress

To avoid any potential delay in licensing the use of DOE's tritium-producing rods in TVA's commercial power reactors, we recommend that the Congress enact legislation that specifically authorizes NRC to review and act on requests for license amendments to use DOE's tritium-producing rods for tritium production.

Recommendation to the Secretary of Energy

To ensure that DOE balances its desire for an effective tritium backup with the need to make effective use of its limited resources, we recommend that the Department reassess its current approach for developing and designing the accelerator backup and select an approach that weighs not only the near-term cost but also the total life-cycle cost and schedule risk. In doing this, DOE should consult with the Congress and seek legislative authority, if needed, to implement its chosen approach.

Agency Comments

We provided DOE, TVA, and NRC with a draft of this report for their review and comment. With regard to the need for legislation, all three agencies reiterated their belief that 42 U.S.C. §7272 does not preclude NRC from acting on license amendments that will allow TVA to use DOE's specially designed tritium-producing rods in its commercial reactors. DOE stated that, in the interests of clarity, it would support legislation. In addition, a Senior Attorney in TVA's Office of the General Counsel told us that TVA agrees that it would be desirable for the Congress to enact legislation specifically authorizing NRC to review and act on requests for license amendments to irradiate tritium-producing rods. Finally, NRC stated that the report is generally accurate. However, NRC believes that the passage of the National Defense Authorization Act for Fiscal Year 2000 removes "any substantial doubt" about NRC's authority to regulate commercial reactors participating in DOE's tritium production program. We do not agree with NRC's position because the legislation does not directly address 42 U.S.C. §7272. (See app. III for DOE's comments and app. IV for NRC's comments.)

Regarding our recommendation that DOE reassess its current approach for the accelerator backup, DOE concurred. However, as a point of clarification, DOE noted that all of the costs cited in our draft report for completing the accelerator development activities are not necessary. Some

are not required if the accelerator were to assume a backup role and some are not applicable unless the accelerator is actually built. This DOE position is not consistent with its previously expressed views on the subject. According to program documents, these activities are needed to either complete the original scope of the Engineering Development and Design program or to address new technology questions that could affect the cost or risk associated with the accelerator. Since the exclusion of the activities could introduce cost and schedule risk, we continue to believe that these activities and their costs need to be considered as part of any evaluation of DOE's current approach to the accelerator backup option. Nevertheless, while DOE stated the need to balance having an effective tritium backup with the need to make effective use of its limited resources, the Department concurred with our recommendation that it should reassess its current approach for the accelerator backup.

We conducted our review from May through January 2000, in accordance with generally accepted government auditing standards. Appendix II provides details of the scope of our work and the methodology we used.

As arranged with your office, unless you publicly announce its contents earlier, we plan no further distribution of this report until 30 days after the date of this report. At that time, we will send copies of the report to the Honorable Bill Richardson, Secretary of Energy; the Honorable Craven Crowell, Chairman, Tennessee Valley Authority; the Honorable Richard Meserve, Chairman, Nuclear Regulatory Commission; and the Honorable Jacob S. Lew, Director, Office of Management and Budget. We will make copies available to others upon request.

If you or your staff have any questions about this report, please contact me on (202) 512-6877. Major contributors to this report were James Noël, Delores Parrett, Carolyn McGowan, and Margaret Armen.

Sincerely yours,



Jim Wells,
Director, Energy, Resources,
and Science Issues

Total Life-Cycle Cost Estimates for the Reactor and Accelerator Program Scenarios for Producing Tritium

The tables that follow show the original Office of Commercial Light Water Reactor Production's cost estimates used in the Secretary of Energy's December 1998 technology selection decision, our adjustments to the Department of Energy's (DOE) cost estimates, and the total cost, including our adjustments. We also discuss what impact updated cost information has had on the reactor program's cost estimates used to support the Secretary's decision. Finally, we present the cost estimates prepared by the Office of Accelerator Production of Tritium and discuss the adjustments we made to the accelerator program's cost estimates.

Analysis of the Cost Estimates for DOE's Reactor Program

DOE presented four commercial reactor START I scenarios to the Secretary in the December 1998 technology selection decision memo.¹ These were defined as follows:

- Reactor purchase—low: Investing \$1.87 billion in the Tennessee Valley Authority's (TVA) partially complete Bellefonte reactor over 3 years and sharing in revenues produced by that reactor.
- Reactor purchase—high: Investing \$1.25 billion in TVA's partially complete Bellefonte reactor but foregoing revenue sharing in return for lower payments over 6 years.
- Irradiation services—low: Purchasing services from existing reactors using an adjusted Congressional Budget Office estimate for irradiation costs.
- Irradiation services—high: Purchasing services from existing reactors using DOE program officials' best estimate of the highest reasonable cost for irradiation services.

DOE also estimated costs for producing tritium under a START II scenario. Under this scenario, tritium production would begin approximately 5 years later, and the amount of tritium would be lower (approximately 1.5 kilograms per year versus 2.5 kilograms under the START I scenario).² For the START II cases, DOE used the same investment timing as it did for the START I cases, that is, all design, construction, and procurement work

¹The amount of tritium needed for the current stockpile is based on the START I treaty, which entered into effect in December 1994.

²The precise amount of tritium that would actually be produced is classified. The planning numbers given here are unclassified approximations. Therefore, the calculations of cost per kilogram of tritium produced are also approximations.

Appendix I
Total Life-Cycle Cost Estimates for the
Reactor and Accelerator Program Scenarios
for Producing Tritium

necessary to start production would be completed as planned in the program's approved baseline. The delay in production start-up would necessitate "stand-by" payments to vendors and lower DOE costs to support a core production team so that tritium production could begin when required. These cases still assume that tritium will be produced for 40 years, once production begins.

The largest adjustment we made removed the revenue-sharing assumed in the reactor program's analysis of the lowest-cost START I and START II scenarios—that of investing in TVA's partially completed Bellefonte Nuclear Plant at Hollywood, Alabama. We made this adjustment for several reasons. First, including potential off-setting revenues in this reactor cost case reduced comparability, since no potential revenues were included in the cost estimate for the accelerator. While the Department had a firm revenue-sharing proposal from TVA, there were no formal proposals or estimates for revenue from the potential sale of medical isotopes produced in the accelerator. Second, several factors could have reduced or eliminated the revenue sharing that TVA projected, including the deregulation of the electricity industry, changes in the plant's operating costs or reliability, and the assumption that the revenues received could be used to offset other DOE program costs.³

We also made other, smaller adjustments to the reactor program's START I and START II cost estimates. First, we applied a cash payment alternative for fuel enrichment to the cost estimates for irradiation services. No fuel cost adjustment was applied to any of the Bellefonte scenarios because there was no sound technical basis on which to estimate what, if any, cost would be incurred for that reactor. Second, we estimated the impact of higher than expected fabrication costs for the specially designed tritium-producing rods. Third, we made the timing of operating functions consistent across all scenarios and corrected minor data entry errors in DOE's cost models. Table 4 summarizes DOE's cost estimates and our adjustments to the estimates for the various START I scenarios. Table 5 provides the same information on the START II scenarios.

³In general, receipts collected by federal agencies are returned to the Treasury's General Fund, unless the agency has specific statutory authority to retain the proceeds. 31 U.S.C. §3302 (1994).

**Appendix I
Total Life-Cycle Cost Estimates for the
Reactor and Accelerator Program Scenarios
for Producing Tritium**

Table 4: Reactor Program December 1998 Tritium Production Cost Estimates, Assuming START I Requirements, and GAO's Adjustments

Constant fiscal year 1999 dollars in millions

Scenario	DOE's total cost estimate	Cost per kilogram ^a	GAO's adjustments				GAO's adjusted total cost estimate	Adjusted cost per kilogram ^a
			Revenue	Fuel cost	Rod cost	Timing		
Reactor purchase—low	\$1,174	\$11.7	\$2,217	N/A	\$375	\$8	\$3,774	\$37.7
Reactor purchase—high	2,802	28.0	N/A	N/A	375	(13)	3,164	31.6
Irradiation services—low	2,195	22.0	N/A	\$144	375	28	2,742	27.4
Irradiation services—high	3,555	35.6	N/A	144	375	28	4,102	41.0

Note: N/A means that this adjustment is not applicable to the scenario.

^aThe precise amount of tritium that would actually be produced is classified. The planning numbers given here are unclassified approximations. Therefore, the calculations of cost per kilogram of tritium produced are also approximations.

Source: GAO's analysis of DOE's data.

Table 5: Reactor Program December 1998 Tritium Production Cost Estimates, Assuming START II Requirements, and GAO's Adjustments

Constant fiscal year 1999 dollars in millions

Scenario	DOE's total cost estimate	Cost per kilogram ^a	GAO's adjustments				GAO's adjusted total cost estimate	Adjusted cost per kilogram ^a
			Revenue	Fuel cost	Rod cost	Timing		
Reactor purchase—low	\$1,119	\$18.7	\$2,217	N/A	\$214	\$(7)	\$3,543	\$59.1
Reactor purchase—high	2,802	44.5	N/A	N/A	219	(89)	2,932	48.9
Irradiation services—low	2,056	34.3	N/A	\$98	219	(13)	2,360	39.3
Irradiation services—high	3,417	56.9	N/A	98	219	20	3,754	62.6

Note: N/A means that this adjustment is not applicable to the scenario.

^aThe precise amount of tritium that would actually be produced is classified. The planning numbers given here are unclassified approximations. Therefore, the calculations of cost per kilogram of tritium produced are also approximations.

Appendix I
Total Life-Cycle Cost Estimates for the
Reactor and Accelerator Program Scenarios
for Producing Tritium

Source: GAO's analysis of DOE's data.

As more updated cost information has become available since the Secretary's decision, the cost estimates for irradiation services have continued to be below the cost range presented to the Secretary in December 1998. In April 1999, DOE used updated costs for TVA's irradiation services and program costs for the construction, operation, and decontamination and decommissioning of the Tritium Extraction Facility in Savannah River to revise the reactor program's total life-cycle cost estimates. DOE's revised estimates range from \$1.4 billion to \$2.9 billion under the START I scenarios and from \$1 billion to \$2.4 billion under the START II scenarios.

We reviewed these revised cost estimates. After applying the same type of adjustments that we had made to the December 1998 cost estimates, we derived adjusted cost estimates for irradiation services, ranging from \$1.8 billion to \$3.3 billion under the START I scenarios and from \$1.3 billion to \$2.7 billion under the START II scenarios. Thus, newer cost data continue to support the conclusion that the reactor program's cost estimates presented to the Secretary were fairly stated and did not understate the program's projected costs.

Analysis of Cost Estimates for DOE's Accelerator Program

We also made some minor adjustments to the accelerator program's life-cycle cost estimates for plants capable of meeting the tritium requirements under both START I and START II. The most significant adjustment we made to the accelerator estimates accounted for the lower contingency costs that resulted from the savings achieved by the design changes made at the Los Alamos project office. The net effect of our adjustment was to reduce the accelerator's construction cost estimate by about \$26 million out of a total life-cycle cost estimate of \$9.2 billion for the START I plant and about \$1 million out of a total of \$7.5 billion for a START II plant. We also adjusted the average cost per kilogram of tritium produced because we believed that DOE's estimating methodology was not consistent with a similar calculation for the reactor program. In the estimates provided to the Secretary, an average-cost-per-kilogram estimate was made for both technology options. For the reactor program, this calculation was based on the approximate annual amount of tritium produced—about 2.5 kilograms per year for START I requirements and about 1.5 kilograms per year for START II requirements—over the expected 40-year life of the project.⁴ However, the accelerator program included additional kilograms of tritium because it expected to produce additional tritium during the accelerator's

Appendix I
Total Life-Cycle Cost Estimates for the
Reactor and Accelerator Program Scenarios
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3-year start-up phase. This gave the accelerator program a higher total amount of tritium produced over its lifetime than the amount under the reactor program. By using the same production amount over the life of the two programs, we made these estimates more uniform. Table 6 summarizes the accelerator life-cycle cost estimates and our adjustments to them under both START I and START II scenarios.

Table 6: Accelerator Program December 1998 Tritium Production Cost Estimates, Assuming START I and START II Requirements, and GAO's Adjustments

Constant fiscal year 1999 dollars in millions

Scenario	DOE's estimate		GAO's adjusted estimate	
	Total cost	Cost per kilogram ^a	Total cost	Cost per kilogram ^a
Accelerator— START I plant	\$9,166	\$89.0	\$9,140	\$91.4
Accelerator— START II plant	7,539	123.0	7,538	125.6

^aThe precise amount of tritium that would actually be produced is classified. The planning numbers given here are unclassified approximations. Therefore, the calculations of cost per kilogram of tritium produced are also approximations.

Source: GAO's analysis of DOE's data.

⁴The precise amount of tritium that would actually be produced is classified. The planning numbers given here are unclassified approximations. Therefore, the calculations of cost per kilogram of tritium produced are also approximations.

Scope and Methodology

To review the cost estimates used in the Secretary of Energy's technology selection decision, we obtained copies of the cost estimates and supporting documents prepared by the reactor and accelerator programs. We interviewed the Department of Energy (DOE) and contractor officials responsible for preparing the cost estimates to determine how the estimates were prepared, what costs were included, and the assumptions used by each program. We met with officials at the Los Alamos National Laboratory to review the technology development and construction cost estimates for the accelerator. For the reactor program's cost estimate, we focused our review on the basis for the Tennessee Valley Authority's proposal for finishing construction of the Bellefonte Nuclear Plant to produce tritium and sharing the potential electricity revenues of the plant with DOE. We also reviewed the estimates for key cost drivers in the cost estimates for the reactor program, such as the estimated cost of procuring the tritium—producing rods. In addition, we prepared adjustments, as appropriate, to DOE's cost estimates for both programs.

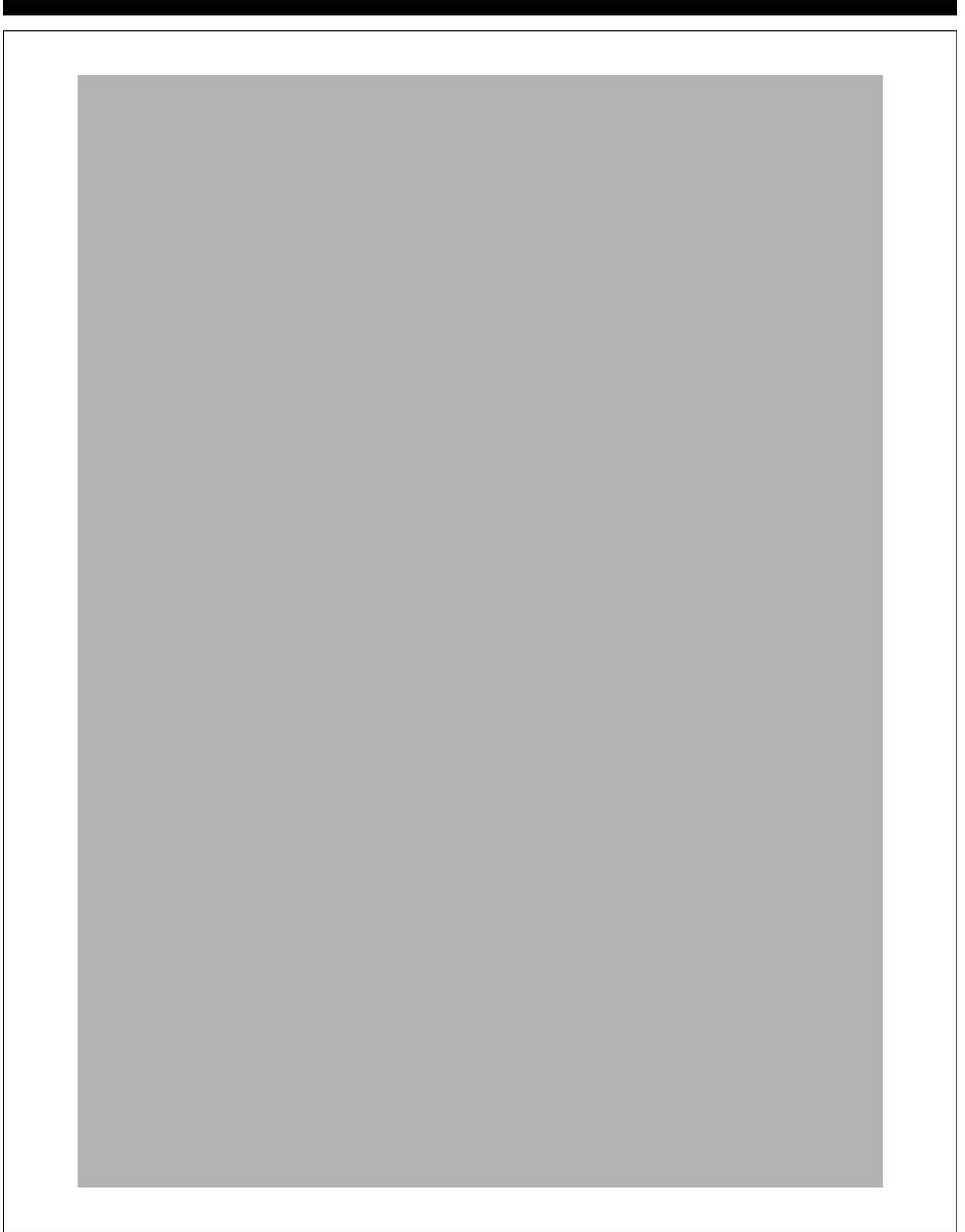
To review the management, technological, and legal risks that could affect the reactor program, we met with the Associate Deputy Assistant Secretary for Tritium Production, the Director of the Office of Commercial Light Water Reactor Production, and the Deputy Director. We reviewed the program's annual operating plans and monthly reports for each of the four DOE sites performing work for the program and discussed management and technical risks with each of the headquarters Task Managers responsible for monitoring and coordinating the work at the sites. We also visited DOE's Savannah River site in South Carolina to review progress on the cost, schedule, design, and construction of the Tritium Extraction Facility. We reviewed independent cost estimates and a congressionally mandated review of the Tritium Extraction Facility, as well as management plans and assessments of the reactor program as a whole. Finally, to assess potential legal risks for the reactor program, we interviewed DOE's and the Nuclear Regulatory Commission's attorneys; researched relevant public laws and their legislative histories; and reviewed pertinent documents.

To review the cost and schedule risks of DOE's current plan for the accelerator as a backup option for tritium production, we interviewed various DOE and contractor officials, including the Director and Deputy Director of the Accelerator for Production of Tritium program office in DOE's headquarters Office of Defense Programs. We reviewed the accelerator program's original and current work plans and monthly progress reports. We also reviewed reports on the accelerator program from its external review committee, as well as other outside review groups,

Appendix II
Scope and Methodology

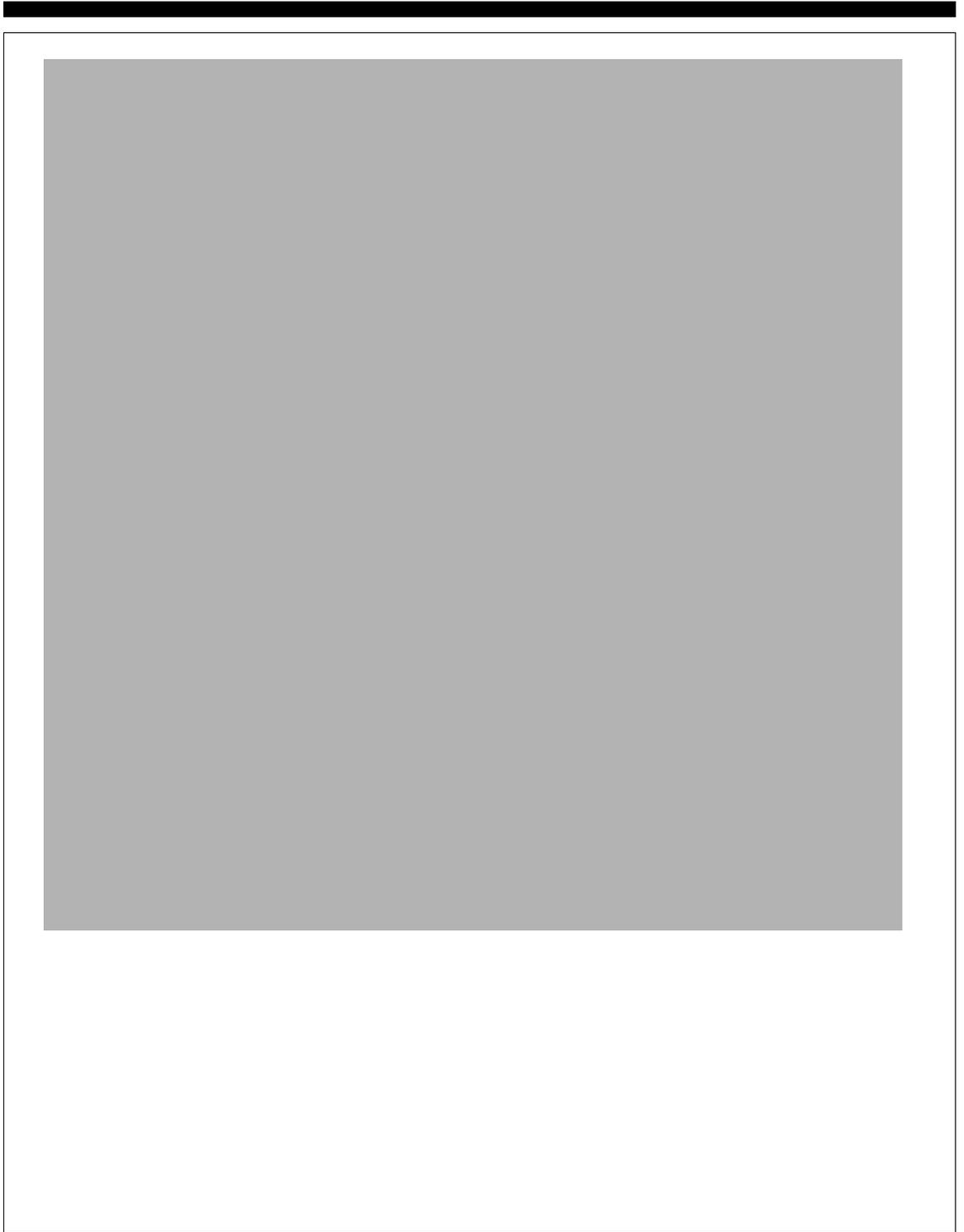
such as the Mitre Corporation's JASON Panel; Booz, Allen, and Hamilton; and the congressionally mandated external independent review. We also visited Los Alamos National Laboratory to review the status of the accelerator's Engineering Development and Demonstration and preliminary and final design plans.

Comments From the Department of Energy





Comments From the Nuclear Regulatory Commission



**Appendix IV
Comments From the Nuclear Regulatory
Commission**



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