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Report to Selected Congressional Committees

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URANIUM ENRICHMENT

DOE Needs to Pursue Alternative AVLIS Deployment Options

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GAO

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Congressional Committees

This report presents the results of our examination of the technical, program, and economic issues of the Department of Energy's (DOE) demonstration of the atomic vapor laser isotope separation (AVLIS) program and the building of an AVLIS plant. We initiated this examination because of the ongoing congressional debate over the future structure of DOE's uranium enrichment program and the potential impact that AVLIS could have on that program.

We are sending copies of this report to the Secretary of Energy; the Director, Office of Management and Budget; and the Chairman, Nuclear Regulatory Commission, and to others upon request.

This work was performed under the direction of Victor S. Rezendes, Director, Energy Issues, who can be reached at (202) 275-1441. Other major contributors are listed in appendix III.

J. Dexter Peach
Assistant Comptroller General

List of Addressees

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The Honorable Mark O. Hatfield, Ranking Minority Member
Committee on Appropriations
United States Senate

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The Honorable Malcolm Wallop, Ranking Minority Member
Committee on Energy and Natural Resources
United States Senate

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House of Representatives

Executive Summary

Purpose

In 1990, the Department of Energy (DOE) initiated a 2-year project to illustrate the technical and economic feasibility of a new uranium enrichment technology, the atomic vapor laser isotope separation (AVLIS) process. DOE expected the project to cap a 20-year, $1.4 billion research and development effort by providing the technical and cost data it needed to make an informed decision on building an AVLIS plant, which could cost $1 billion. However, the administration decided in early 1991 that DOE would not build an AVLIS plant; rather, the agency determined that a new government uranium enrichment corporation, which it hopes the Congress will establish soon, will decide when and if an AVLIS plant is built.

Because of the impact AVLIS could have on the ongoing congressional debate over the restructuring of DOE's uranium enrichment program as a government corporation, GAO undertook this review to identify the technical, program, and market issues that need to be addressed before an AVLIS plant is built.

Background

Since 1969, the government has enriched uranium for use as fuel in commercial nuclear power reactors at gaseous diffusion plants built in the 1940s and 1950s for defense purposes. Currently, DOE's uranium enrichment program faces financial problems partly caused by foreign competitors using more modern and less costly production technology.

In 1973, DOE's Lawrence Livermore National Laboratory, in Livermore, California, began conducting research on AVLIS—a technology that uses laser light to separate the specific uranium atoms needed to sustain nuclear reactions from natural uranium metal. In 1985, DOE selected AVLIS to eventually replace the energy-intensive gaseous diffusion process because it expects AVLIS to produce enriched uranium at a much lower cost. DOE officials believe, however, that its two remaining gaseous diffusion plants could continue to operate for 20 or more years.

In January 1990, DOE submitted an AVLIS demonstration and deployment plan to the Congress. The plan outlined DOE's efforts to (1) demonstrate the technology using commercial-scale equipment and decide by November 1992 whether to build a production plant, (2) complete site selection and licensing activities prior to the start of construction in 1993, and (3) begin plant operations by January 1997. However, the administration did not follow through on DOE's 1990 plan. In February 1991, the administration determined that an AVLIS plant should be built

with private funds by a private company or the new government corporation DOE hopes the Congress will create. Under its new strategy, DOE plans to complete the technology demonstration while curtailing site selection and other program activities.

Results in Brief

GAO believes that completing the AVLIS demonstration project will provide important information about the technical viability and cost of the plant and keep future options for building an AVLIS plant open. However, the Congress should be aware of the following:

- DOE still needs to adequately demonstrate AVLIS with full-scale equipment and develop convincing cost projections. At the end of 1992, the scheduled end of the demonstration, several unanswered technical questions will hinder completion of an independent cost analysis needed for a decision on building a plant. In addition, DOE will not have completely demonstrated how a new AVLIS plant that uses and produces uranium metal will relate to existing nuclear fuel companies, which process uranium in a gaseous form.
- Program activities, such as completing the plant-licensing process, that must be accomplished before a plant is built, could take many years. Under DOE's current plan, the proposed government corporation would have to complete these activities before beginning to build a plant.
- An updated and expanded uranium enrichment market analysis will be needed before any decision is made about building an AVLIS plant.

The future of AVLIS cannot be considered separately from existing legislative attempts to restructure DOE's uranium enrichment program as a government corporation. GAO has long supported such legislation and supports DOE's goal of transferring AVLIS to the corporation. This could reduce the government's financial risk and help ensure that the decision to build an AVLIS plant is based on commercial concerns. However, DOE has not identified any contingency plans for AVLIS should the government corporation not be formed. Further, by curtailing a planned public access program, which would have provided private firms the opportunity to learn about the technology during the demonstration project, DOE may limit its ability to transfer AVLIS to the private sector.

Principal Findings

Technical Problems Must Be Addressed to Reduce AVLIS Cost Uncertainties

Independent technical experts hired by DOE to critique the AVLIS program believe that DOE's demonstration program will prove that the technology works using full-scale equipment. However, those same experts agree that the demonstration will not provide the cost information needed to make a deployment decision by the end of 1992, because some remaining technical issues could have significant cost implications. For example, by 1992 DOE does not expect to develop or operate lasers that are as powerful and efficient as those projected for use in the AVLIS plant. Further, the scheduled demonstration program will not provide time to operate the full-scale separators long enough to define maintenance requirements. In addition, by the end of 1992, DOE will not have completely demonstrated the processes it believes will allow the plant to effectively interact with existing fuel cycle companies.

Necessary Program Activities Will Delay an AVLIS Plant

A number of program activities that must be addressed before a plant is built may take a long time to complete. In particular, the Nuclear Regulatory Commission (NRC) has not planned to direct significant resources to an AVLIS license review, which could take much longer than the 2 years DOE anticipates. Also, according to DOE officials, selecting a site and preparing the required environmental impact statement may prove controversial and time-consuming. Although DOE plans to continue the technical demonstration of the AVLIS technology, it plans to curtail most program activities required for a future AVLIS plant. Accordingly, a government corporation, if and when it is formed, would have to complete them before building a plant, further delaying an AVLIS plant.

Market Conditions Cloud the Future of AVLIS

The current enrichment market is very different from the one that existed when laser separation research began in 1973. Today, annual production capacity exceeds demand by about 60 percent if production by the Soviet Union is included. In addition, only a few countries are building new nuclear power plants, and some energy experts do not expect any new U.S. plants to be completed until after 2010. An updated and expanded analysis of the enrichment market will be needed to clearly lay out the advantages and disadvantages of building an AVLIS plant in a market in which capacity already exceeds demand. Initial market analyses of a future AVLIS plant have shown varied results. For example, the Lawrence Livermore National Laboratory reports that an

AVLIS plant would save the current program up to $800 million per year because of reduced production costs. However, DOE's initial analyses considering dynamic market factors such as a continuing aggressive Soviet sales strategy suggest that under some conditions, an AVLIS plant would not increase sales enough to recover construction costs.

DOE Needs to Develop Other Deployment Options

DOE has not identified other options for building an AVLIS plant should a government corporation not be created. In particular, it has not examined the possibility of making the technology available to the private sector under the National Competitiveness Technology Transfer Act of 1989. Further, DOE has stopped a planned program that was to obtain private companies' expertise in deploying a commercial plant. Such a program may be needed to identify potential private investors.

Recommendations to the Secretary of Energy

GAO recommends that the Secretary of Energy update the AVLIS demonstration plan to (1) realistically reflect revised program goals and remaining technical development, (2) include an independent cost analysis and updated market study, (3) identify other deployment options should a government corporation not be established, and (4) promote private industries' participation in the development program to enhance future deployment options.

Matters for Congressional Consideration

As the Congress considers restructuring DOE's uranium enrichment program as a government corporation, it could also consider transferring responsibility for AVLIS to the new corporation. Such action could reduce the government's financial risk and help ensure that the decision to build an AVLIS plant is based on commercial concerns.

Agency Comments

DOE and NRC provided official comments on a draft of this report. Several of their comments were directed at the need to modify the report to reflect recent changes to the AVLIS demonstration project brought about by DOE's 1992 budget request to the Congress. GAO has made changes throughout the final report to take into account DOE's revised strategy and reflect several other specific comments by NRC and DOE. In addition, GAO revised the report's recommendations because of DOE's decision that the proposed government corporation, not DOE, will build an AVLIS plant. DOE and NRC also made several general observations, which are discussed in chapters 2 and 3.

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Figures

Abbreviations

AVLIS	atomic vapor laser isotope separation
DOE	Department of Energy
GAO	General Accounting Office
GCEP	gas centrifuge enrichment plant
LLNL	Lawrence Livermore National Laboratory
NEPA	National Environmental Policy Act of 1969
NRC	Nuclear Regulatory Commission
SWU	separative work unit
TERG	Technical Evaluation Review Group

Introduction

Uranium enrichment is the process that prepares uranium ore for use as a nuclear reactor fuel or for defense applications. The federal government has enriched uranium for national defense purposes since the 1940s and commercial nuclear power plants since 1969. No private company has ever enriched uranium in the United States.

Over the past 20 years, the government's uranium enrichment program has made many valuable contributions to the nation. For example, the program has provided a safe, secure supply of enriched uranium for domestic nuclear utilities, which provide about 20 percent of the country's electricity, and has supplied the fuel for the nuclear-powered ships of the U.S. Navy. In addition, foreign sales of uranium enrichment services have recently contributed between $400 million and $500 million annually to the U.S. balance of trade. The program has also helped to promote the nation's nonproliferation goals through its involvement in international efforts to control the availability of weapons-grade materials.

Background

When the government began the commercial enrichment program, the United States was the free world's sole supplier of enrichment services. Throughout the mid-1970s, the expected growth of nuclear power led the Department of Energy (DOE) to expand its three gaseous diffusion enrichment plants,[1] built in the 1940s and 1950s, and begin construction of a large gas centrifuge enrichment plant (GCEP)[2] to provide additional capacity. In the late 1970s and into the 1980s, growth in the nuclear power industry slowed, and as a result, the anticipated demand for enrichment services did not materialize. In addition, foreign suppliers cut into DOE's domestic and foreign markets for enriched uranium. Facing an increasingly competitive market, DOE shut down one gaseous diffusion plant and initiated a number of other steps to try to make the enrichment program more cost-efficient. For example, DOE reduced the costs of operating the existing plants, which DOE officials believe can operate for 20 or more years. Other steps included proposing legislation that would restructure the program into a government corporation. We

[1]The gaseous diffusion technology enriches uranium by repetitively pumping uranium hexafluoride gas through fine porous membranes to separate one stream with a higher content of fissionable material.

[2]The centrifuge technology uses large centrifuge machines to separate the fissionable material in uranium hexafluoride gas.

have supported this proposal, because we believe a government corporation could better manage the enrichment activities in a competitive business environment.[3]

In 1985, the Secretary of Energy also terminated the GCEP program following the Process Evaluation Board's extensive analysis of the advanced gas centrifuge technology and the emerging atomic vapor laser isotope separation (AVLIS) technology. The Board, which DOE established because of rising costs and other problems with the GCEP program, determined that the AVLIS technology was more likely to provide for low-cost, reliable production of enriched uranium in the future. DOE canceled construction of the GCEP plant after having spent over $3 billion on the project and selected AVLIS as the technology that would eventually replace the existing gaseous diffusion plants. Other countries—Japan and France—are also pursuing AVLIS, although DOE believes they are approximately 5 years behind the U.S. program.

Currently, DOE's uranium enrichment program continues to face a number of financial problems including the need to pay back past unrecovered costs to the U.S. Treasury. In addition, stiff foreign competition, most recently from the Soviet Union, still exists. DOE also faces the prospect of paying perhaps billions of dollars to clean up and eventually decommission the existing plants. Further, DOE officials believe that many of its current customers will look to cheaper foreign suppliers in the mid-1990s as the customers' current contracts expire. DOE officials hope that an AVLIS plant can allow the program to compete better in the competitive world uranium enrichment market.

The AVLIS Process

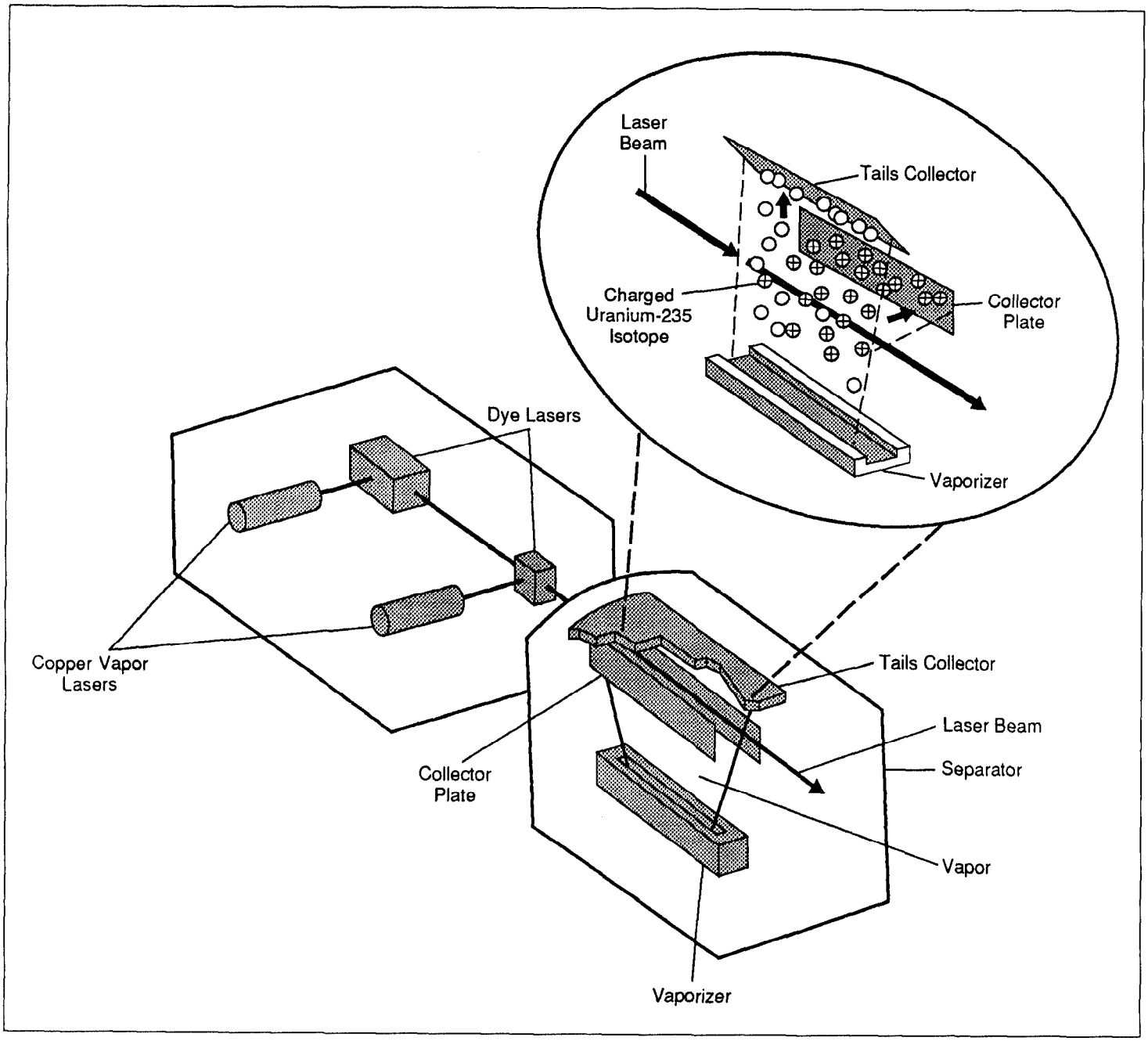
DOE's Lawrence Livermore National Laboratory (LLNL) began conducting research on AVLIS in 1973. Throughout the 1970s, DOE examined a number of competing enrichment technologies using lasers before concentrating on the current approach in the 1980s. LLNL's efforts throughout the 1980s were directed at demonstrating the AVLIS technology and designing a plant to produce enriched uranium for commercial utilities. The AVLIS technology will not be capable of producing highly enriched uranium for defense purposes without considerable additional research and development. Therefore, in order to meet defense needs, DOE may need to continue to operate part of its gaseous

[3]See Uranium Enrichment: Congressional Action Needed to Revitalize the Program (GAO/RCED-88-18, Oct. 19, 1987).

diffusion plant at Portsmouth, Ohio, if and when an AVLIS plant is built. Other alternatives are also being considered for meeting defense needs.

Basically, AVLIS takes advantage of the fact that the fissionable isotope contained in uranium (uranium-235), which is needed to sustain nuclear reactions, can be ionized—charged or magnetized—when exposed to a specific color of laser light. The charged isotope can then be collected on magnetic plates. The AVLIS technology consists of two major systems: lasers and separators. Two types of lasers are used: copper vapor lasers energize dye lasers, which cannot be powered directly by electricity. The dye lasers generate the colored light that ionizes the uranium-235 isotope. In the separator, an electronic beam melts and vaporizes uranium metal. Laser light passes through the vapor within the separator and the charged uranium-235 atoms are deflected by an electromagnetic field to a collector plate. The rest of the uranium passes through to other equipment called the tails collector. Figure 1.1 shows the AVLIS process.

Figure 1.1: The AVLIS Process

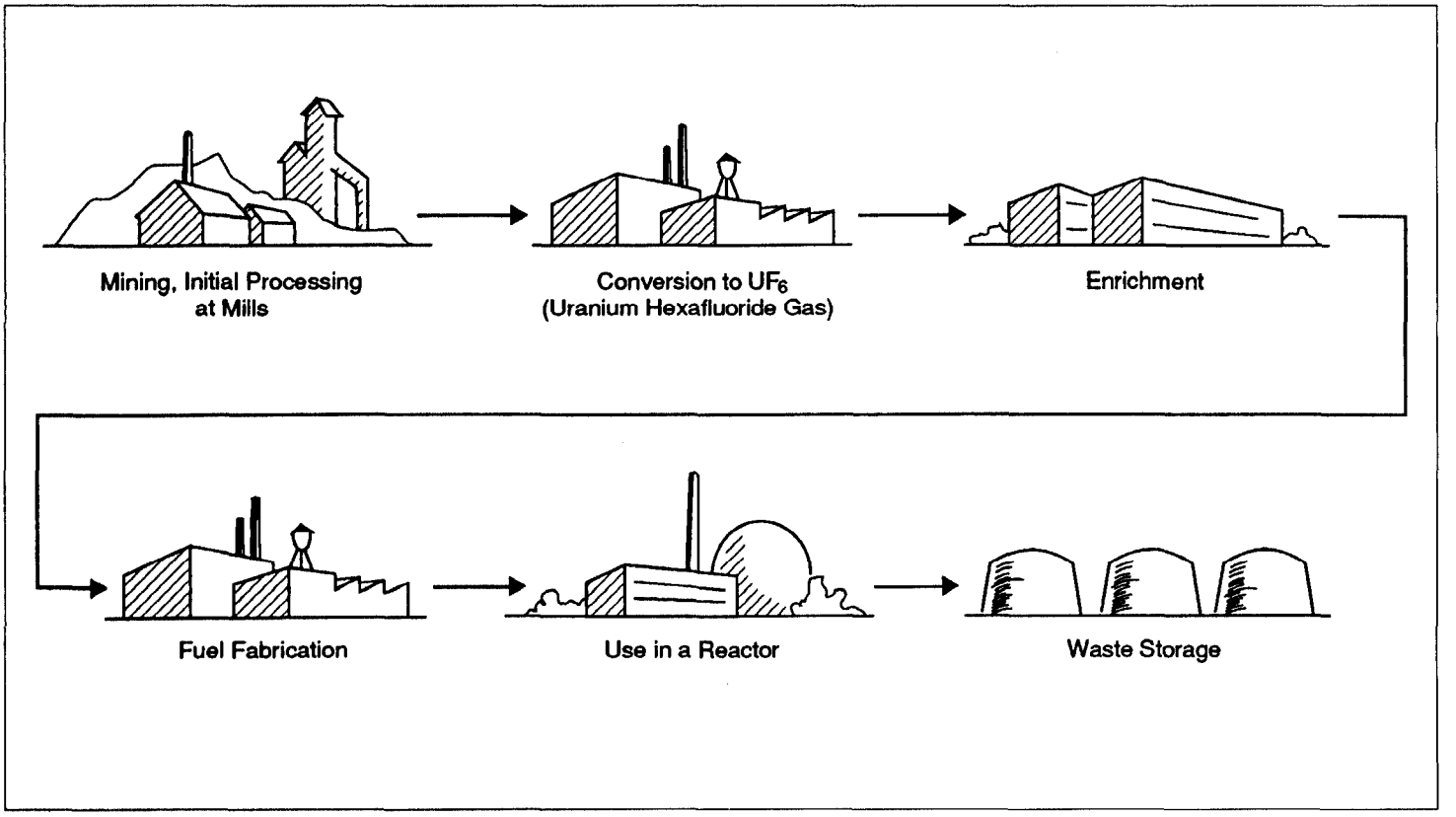


Source: DOE.

The Nuclear Fuel Cycle

The AVLIS technology is metal-based; that is, an AVLIS plant will use uranium metal as a feed for the enrichment process and produce enriched uranium metal. Currently, however, private companies called fuel converters convert uranium ore into uranium hexafluoride, which is processed as a gas in DOE's gaseous diffusion plants. Once the gas is enriched, DOE sends the enriched uranium hexafluoride to private companies that fabricate it into nuclear fuel for commercial reactors. Foreign enrichment facilities also use the gas-based fuel cycle. Figure 1.2 illustrates the current nuclear fuel cycle.

Figure 1.2: The Existing Nuclear Fuel Cycle



In order to accommodate an AVLIS plant's requirements for a metal-based fuel cycle, new processes will need to be introduced to the current fuel cycle at either the industry plants or at the AVLIS plant. Some processes under consideration would eliminate the need to produce uranium hexafluoride. However, these new processes, if not performed at the AVLIS plant, will require nuclear fuel converters and fabricators to change

their current activities. As an alternative, the AVLIS plant could convert uranium hexafluoride into metal before enrichment and then reconvert the enriched uranium metal product to uranium hexafluoride, which is now used by fuel fabricators.

Alternative Uses for AVLIS

The continued development of the AVLIS technology could be useful to more than just the uranium enrichment industry. The technology can be adapted to separate other isotopes within a given element. For example, in the late 1970s, LLNL began examining laser technology to separate plutonium isotopes for defense purposes. Since that time, LLNL's plutonium and uranium separation programs have shared the costs of developing lasers at the laboratory, saving the uranium enrichment program up to $300 million. However, in early 1990, the Secretary of Energy announced that DOE would indefinitely postpone construction of a planned plutonium production plant at DOE's Idaho National Engineering Laboratory. As a result, DOE expects to end LLNL's plutonium program by the end of fiscal year 1991, and the AVLIS uranium enrichment program will have to assume responsibility for all future costs of LLNL's laser facility.

In October 1989, the Secretary of Energy proposed exploring other potential applications for the AVLIS technology. DOE requested the National Academy of Sciences' National Research Council to conduct an independent study of potential applications of the AVLIS technology, including but not limited to reducing or minimizing nuclear waste, enhancing metals' resistance to corrosion, and improving the purity and quality of materials for the electronics industry. The Academy submitted a proposal in December 1989, and a contract was signed in February 1990 for a 16-month study to cost about $382,000, with a final report due by July 15, 1991.

DOE's 1990 AVLIS Demonstration and Deployment Plan

In a July 1989 report on the Energy and Water Development Appropriation Bill for 1990, the Senate Committee on Appropriations expressed concern that an AVLIS plant would not be built in time to respond to competitive market pressures, thereby dissipating the United States' lead in laser technology and investment in AVLIS. The report expressed alarm with the time being taken to complete a full-scale demonstration of AVLIS and with DOE's slowness in transferring the technology from LLNL to a private company that would build and operate a production plant for the government. The Committee said it wanted to avoid another situation like the GCEP program, in which billions of dollars were lost because,

in part, DOE failed to implement a new technology in a timely manner. Consequently, the Committee directed DOE to present a plan to the Congress.

As required, DOE issued a plan to the Congress in January 1990 for the demonstration and deployment of AVLIS. The plan outlined a program to (1) conclude the development and demonstration by September 1992, (2) increase the level of private industry's involvement in all phases of the transition from laboratory development to commercial production, and (3) begin plant construction in 1993 and operations by January 1997. The plan outlined milestones leading to a decision in November 1992 about building a production plant. Table 1.1 shows the major technical and related program milestones set out in the plan.

Table 1.1: Major AVLIS Milestones Established in DOE's 1990 Plan

Date	Milestone
Technical	
June 1990	Select uranium feed process
June 1991	Complete construction of prototype facility to produce uranium feed
December 1991	Complete construction of advanced copper vapor laser corridor
June 1992	Provide large quantities of AVLIS-produced enriched uranium to fuel fabricators
September 1992	Demonstrate plant prototype dye laser chain
September 1992	Demonstrate multipod[a] separator enrichment
Program	
August 1990	Establish program for private sector's involvement
December 1990	Select alternative plant sites
March 1991	Issue conceptual design report
March 1991	Submit licensing application to the Nuclear Regulatory Commission (NRC)
March 1991	Select a commercial deployment contractor
November 1992	Decide on building a plant
November 1992	Complete site selection
March 1993	Complete environmental impact statement
March 1993	Obtain plant license from NRC
March 1993	Start plant construction
March 1994	Transfer uranium feed processing technology to industry
January 1997	Operate first module of plant

[a]A pod is the smallest building block within a separator module that contains all of the components needed to enrich uranium. Several separator pods will be operated within a vacuum chamber to control the uranium vapor.

AVLIS Management and Funding

DOE's Deputy Assistant Secretary for Uranium Enrichment has overall managerial responsibility for the AVLIS program. At DOE headquarters, an AVLIS project office director, responsible for establishing overall research and development policy for AVLIS, reports to the Deputy Assistant Secretary. LLNL, which is responsible for the day-to-day management of research and development for DOE, is supported by Martin Marietta Energy Systems, Inc. Martin Marietta also manages the fuel cycle research and development program at DOE's Oak Ridge Gaseous Diffusion Plant in Tennessee. In addition, DOE's Argonne National Laboratory, in Illinois, is responsible for developing site selection criteria and related environmental assessment information for the AVLIS program.

By the end of fiscal year 1990, DOE had spent about $1 billion on AVLIS and planned to spend an additional $400 million through the end of fiscal year 1992, when the demonstration was scheduled to conclude. DOE officials estimated at that time that construction and additional development and technical support activities for a large plant (which would expend about 9 million separative work units [SWU][4] per year) would cost an additional $1.6 billion from fiscal year 1993 through the end of fiscal year 1998.[5] Table 1.2 shows prior and projected AVLIS costs as anticipated in DOE's 1990 plan.

[4]A SWU is a measure of the energy required in a uranium enrichment plant to separate uranium into two components, one containing the higher content of uranium-235.

[5]The present value of these planned expenditures is about $1.2 billion in 1991 real dollars.

Table 1.2: AVLIS Actual and Projected Funding Requirements

Dollars in Millions

Fiscal year	Development and demonstration funding	Technical support	Capital construction	Total costs
1973-83	$205	$0	$0	$205
1984	101	0	0	101
1985	105	0	0	105
1986	126	0	0	126
1987	79	0	0	79
1988	89	0	0	89
1989	125	0	0	125
1990	134	0	0	134
1991[a]	155	0	0	155
1992	188	0	54	242
1993	79	70	144	293
1994	52	70	243	365
1995	31	70	257	358
1996	19	67	218	304
1997	16	55	111	182
1998	0	55	6	61

[a]Cost figures for 1991 and beyond are projected budget figures. Past costs are actual sunk costs.
Source: DOE.

In February 1991, the administration and DOE drastically revised their AVLIS deployment strategy through the budget process. In submitting DOE's fiscal year 1992 budget request, the administration determined that the AVLIS plant should be built with private funds by the private sector or by a new government uranium enrichment corporation. Therefore, the 1992 budget request, while asking for funds for completing the technological demonstration, did not request funding for certain program activities, such as those needed to complete an NRC license review, or a plant site environmental impact statement. DOE officials stated that these activities should be the responsibility of the private sector or whoever builds the plant. Under its 1990 plan, DOE had planned to complete these activities by the end of the demonstration project—November 1992—and begin building a plant by 1993.

Objectives, Scope, and Methodology

Because of the ongoing congressional debate over the future structure of DOE's uranium enrichment program and the potential financial impact AVLIS could have on that program, we examined the technical, program,

and market issues associated with the demonstration and deployment of AVLIS.

To obtain general information for this report, we reviewed various DOE documents including DOE's January 1990 report to the Congress Plan for the Demonstration, Transition, and Deployment of Uranium—AVLIS Technology, and LLNL's November 1989 report with the same title. In addition, we reviewed testimony from several hearings held by the Senate Committee on Energy and Natural Resources and the House Committees on Energy and Commerce, Science and Technology, Interior and Insular Affairs, and Appropriations, at which DOE presented its AVLIS demonstration strategy.

To obtain technical data as well as other information on the AVLIS demonstration program, we interviewed the Director, AVLIS Project Management Office, and various members of his staff at DOE headquarters. We also met with officials at DOE's San Francisco Operations Office, California, to obtain information on their responsibilities for and views on AVLIS technical issues. We also interviewed various LLNL officials, including the directors of the AVLIS project office and laser operations, as well as several Martin Marietta officials located at LLNL. We contacted two members of the Technical Evaluation Review Group, an independent evaluation group, to obtain their views on the status of AVLIS technical issues.

To obtain technical information on AVLIS fuel cycle integration issues and problems, we contacted DOE's AVLIS fuel cycle manager with Martin Marietta, which is located at Oak Ridge, Tennessee; two U.S. fuel converters; and all five domestic fuel fabricators. We also attended a March 1990 conference, Fuel Cycle 90 Conference, sponsored by the U.S. Council for Energy Awareness. The conference provided information on many areas pertaining to the fuel cycle, including potential industrial involvement in the uranium enrichment process. In addition, we met with Edison Electric Institute officials to obtain the nuclear utility industry's views on AVLIS, including problems in integrating AVLIS into the fuel cycle. We also reviewed the Edison Electric Institute's March 1991 report The DOE AVLIS Program: An Industry Assessment. In addition, we met with the Vice President for Nuclear Fuels, Commonwealth Edison, one of the largest nuclear utilities in the United States.

To obtain further information on AVLIS program issues, we interviewed those DOE officials responsible for specific AVLIS activities. We also

obtained DOE's June 1990 site selection criteria and various environmental assessment planning documents, and visited the Argonne National Laboratory, in Chicago, Illinois, to interview Laboratory officials responsible for evaluating potential sites for an AVLIS plant and preparing related environmental assessment data. We also met with NRC's Director, Nuclear Material Safety and Safeguards, and his staff to obtain their views on the issues and problems related to licensing an AVLIS plant.

To obtain additional information on AVLIS economic issues, we interviewed a DOE marketing official, officials within DOE's Office of Business Operations, and LLNL officials. From both DOE headquarters and LLNL, we obtained numerous computer-generated economic analyses of the future viability of DOE's uranium enrichment program and the expected impact of AVLIS deployment on the program. We reviewed various economic analyses and future revenue projections contained in LLNL's November 1989 report Plan for the Demonstration, Transition, and Deployment of Uranium—AVLIS Technology. We did not, however, verify the data used in the various computer analyses. We also reviewed the marketing analyses and projections in a May 1990 assessment of DOE's uranium enrichment program by Smith Barney Harris Upham & Co., Inc., and reviewed a report prepared by a panel of experts convened by Smith Barney to assess AVLIS.

To determine the private sector's views on the economic risks of deploying AVLIS, we contacted the former chairman of the American Enrichment Company, Inc., who has experience with private enrichment efforts. We also spoke to the Vice President for Research and Development and the Vice President and Manager of the Nuclear Fuel Cycle Programs of the Bechtel Corporation, a leading builder of nuclear fuel cycle facilities. We also met with Martin Marietta's Vice President for Enrichment Operations.

Our work was conducted between December 1989 and March 1991 in accordance with generally accepted government auditing standards. DOE and NRC provided written comments on a draft of this report. These comments are evaluated in chapters 2 and 3 and are included in appendixes I and II.

AVLIS Technical and Program Uncertainties Are Likely to Delay Deployment

LLNL scientists and members of an independent technical evaluation review group (TERG)[1] are confident that the ongoing AVLIS demonstration program will be successful. However, the independent experts generally believe that the demonstration will not provide specific cost information needed for a complete evaluation of deployment options by the scheduled end of the demonstration project—November 1992. Further, additional time will be needed to fully resolve some technical issues. For example, additional development, which LLNL calls technical support, will be needed after 1992 to achieve projected performance levels for the lasers and fully test separator components to determine the costs of materials and maintenance. Further, by November 1992 DOE will not have fully demonstrated the processes needed to effectively integrate AVLIS into the existing nuclear fuel cycle. LLNL scientists and the independent technical experts believe that if there is a decision in 1992 to build an AVLIS plant, these remaining technical concerns can be resolved while initial construction occurs and before the lasers and separator equipment are installed.

Although some technical and cost questions may remain at the end of 1992, program activities such as plant licensing will almost surely delay construction of an AVLIS plant beyond 1993. DOE's January 1990 plan recognized that long lead times would be needed to select a plant site, obtain an NRC license review, and complete needed environmental studies; however, DOE did not meet the plan's milestones in these areas. Further, DOE stopped most of these program activities following the preparation of its fiscal year 1992 budget proposal. This means that a government corporation, if created, will have to restart and complete these activities before beginning to build a plant. Finally, DOE has not developed any contingency plan for deploying the AVLIS technology should a government corporation not be formed. DOE also ended its industrial access program, which was designed to obtain the private sector's expertise in building an AVLIS plant. This action reduced the program's ability to identify and attract private investment in the future.

[1] In 1986, DOE established TERG, an independent panel of experts, to continuously monitor and oversee the AVLIS program. The panel meets periodically and has issued several reports on various AVLIS technical issues.

The AVLIS Demonstration Project Will Not Resolve All Technical Uncertainties

DOE's January 1990 plan states that LLNL will demonstrate a nearly commercial-scale laser and separator system and develop technical and economic data needed to make a sound business decision by November 1992 on the commercial feasibility of AVLIS. Although the demonstration is expected to show the feasibility of the AVLIS process, technical experts do not expect the demonstration to provide reliable cost information needed to project plant performance because (1) demonstration lasers and the related optical system will not be fully tested at expected plant performance levels and (2) separator components will not be fully tested during the demonstration to establish the cost of plant maintenance and materials. In addition, because plant-scale equipment will not actually enrich uranium until 1992, unexpected engineering problems could occur late in the program.

Demonstration Lasers Will Not Operate at Production Levels

Since 1989, LLNL has been developing the advanced copper vapor laser it expects to use in the AVLIS plant. LLNL expects this laser will be more cost-effective than previous lasers; therefore, it will produce more power at less cost. LLNL will continue to develop this laser throughout the demonstration project and expects to achieve about 70 percent of projected plant power levels by November 1992. However, the advanced lasers will not be used during the demonstration's enrichment runs, scheduled to begin in June 1992. Instead, to produce the power to energize the dye lasers for the 1992 enrichment runs, LLNL will use two corridors[2] of copper vapor lasers built during earlier AVLIS research and development efforts. These lasers will produce laser light with the necessary characteristics for uranium enrichment, but not as efficiently as the advanced lasers. A 9-million-SWU AVLIS plant is expected to require 24 corridors of advanced copper vapor lasers.

On the basis of their past success, LLNL officials are confident that they will continue to improve the advanced laser after the scheduled end of the demonstration project in order to meet expectations for an AVLIS production plant. However, because DOE will not fully demonstrate the advanced laser during the project, any current analysis of the projected cost of the AVLIS plant will have to make certain assumptions about the production efficiency of the plant's laser system. LLNL's 1989 cost projections assumed that the advanced laser would be developed to meet projected power levels for the plant by the time the plant is built.

[2]A copper vapor laser corridor consists of six copper vapor laser chains packaged in a series of individual self-contained modular boxes that contain the support systems necessary for their operation.

Likewise, DOE analysts will have to make certain assumptions about the capability of the copper vapor and dye lasers to illuminate and separate the uranium vapor produced in the separator. During the demonstration, the two corridors of lasers at the LLNL facility will only generate enough laser light to illuminate and enrich a fraction of the vapor generated in the separator. According to LLNL scientists, achieving full illumination would require significantly more lasers than they have and would dramatically increase demonstration costs with very marginal benefits. The scientists are confident that they can accurately predict the plant's performance by extrapolating or adjusting from the results of the demonstration. However, technical experts we talked to are concerned about the adjustment process used to predict the plant's performance because it could have a significant impact on plant economics. For example, if the process underestimates the lasers' performance and more lasers are needed for the plant to operate efficiently, costs would increase. After our October 1990 visit to LLNL, DOE told us that the LLNL scientists had conducted experiments to show that the illumination rates in the demonstration can be significantly increased to more closely approach those required for a production plant.

Finally, DOE officials do not expect the demonstration project to achieve anticipated plant performance levels for the optical system used to deliver the laser light to the separator. The demonstration will use a series of mirrors and mechanical devices to direct the light to the separators. LLNL expects to improve this system, in part, through the use of fiber optics. Like the advanced laser program, LLNL is developing the new optic system "off-line"—that is, LLNL will not use the new system during the enrichment test scheduled to begin in 1992. By the end of the scheduled demonstration in 1992, LLNL expects to have achieved 80 percent of expected plant optical efficiency. Again, LLNL scientists are confident they will meet expected plant levels through continued technical support after 1992.

Separators May Not Be Adequately Tested

Although LLNL is conducting many rigorous tests of the AVLIS separator, LLNL will not produce enriched uranium using a commercial prototype of the separator before the 1992 demonstration. LLNL and independent technical experts are confident the separators will operate as anticipated, but NRC officials told us that unforseen engineering problems often arise when uranium distribution systems like those contained in the AVLIS separator are scaled up to plant levels. Further, only a limited

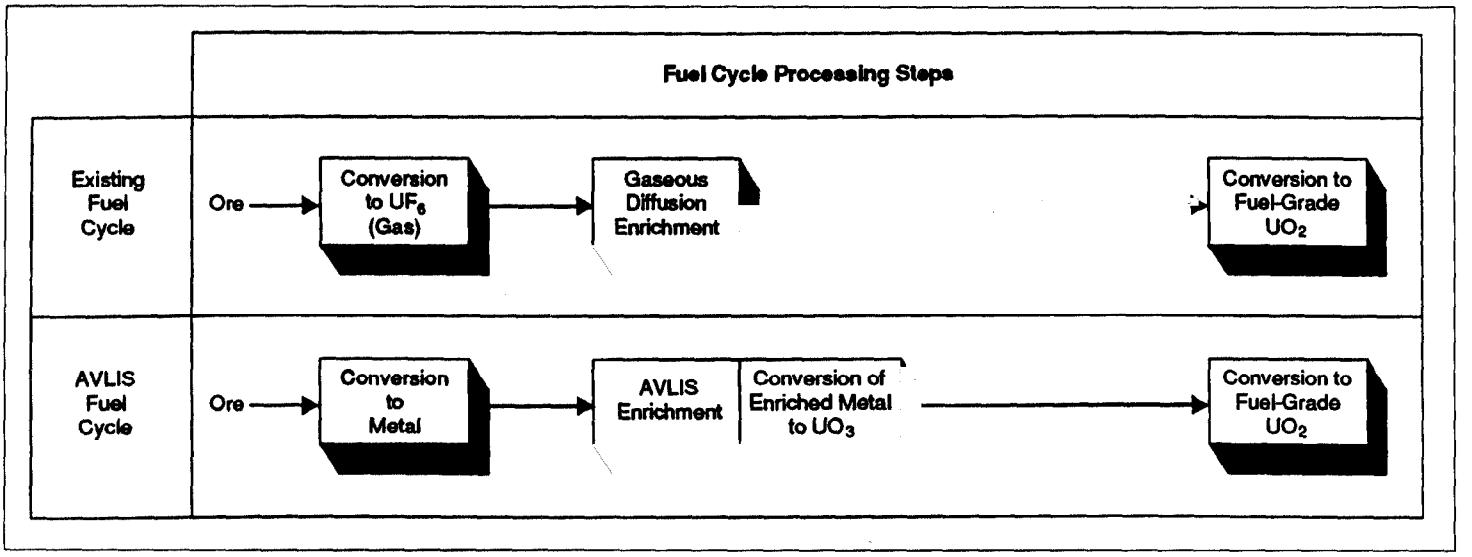
number of actual enrichment runs will be conducted before the scheduled November 1992 deployment decision date. According to DOE's January 1990 plan, the first single-pod separator and first three-pod separator will be demonstrated in March 1992 and September 1992, respectively. According to LLNL scientists, extended runs of several hundred hours will be needed to fully resolve questions about the corrosion of materials and related maintenance requirements—important factors in determining production costs. LLNL expects these runs will take place in 1993 and 1994, after the demonstration project is completed.

Fuel Cycle Changes Will Require Continued Development

Because AVLIS is a metal-based technology—using metal uranium ore as feedstock and producing enriched uranium in a metal form—the current nuclear fuel cycle will need to be changed to accommodate an AVLIS plant. At present, the nuclear fuel cycle is well established for DOE's gaseous diffusion plants. Two private NRC-licensed companies produce uranium hexafluoride (UF_6) from natural uranium after it has been initially processed at uranium mills. Uranium hexafluoride, in a gaseous form, is enriched at DOE's diffusion plants and then shipped to fuel fabricators, which convert it into uranium dioxide powder (UO_2), used to produce nuclear fuel.

DOE has identified new processes that could convert uranium ore into a metal form before it enters an AVLIS plant and then convert the enriched uranium metal into uranium trioxide powder (UO_3), which could be converted to uranium dioxide at the fuel fabricators. These steps would eliminate the need to produce and handle uranium hexafluoride gas before and after enrichment at an AVLIS plant. Figure 2.1 compares the existing and proposed fuel cycles.

Figure 2.1: Comparison of Existing and AVLIS Fuel Cycles



DOE officials believe that its proposed new fuel cycle processes, when fully implemented before and after enrichment at an AVLIS plant, or, in other words, on the front and back ends of the AVLIS plant, will reduce environmental concerns and overall production costs. LLNL estimates that total fuel cycle costs will be reduced between $6 and $13 per SWU if the new processes are used. However, DOE is several years away from demonstrating these processes and has been slow to coordinate their development with existing fuel cycle companies. Further, DOE has not yet decided where the new processes will be performed—at the AVLIS plant or at private plants. Finally, DOE has not evaluated the cost of changes needed at existing fuel cycle companies.

AVLIS Will Require Front-end Uranium Processing Changes

Currently, uranium ore goes through a four-step process to convert it to uranium hexafluoride for DOE's gaseous diffusion plants. Although an accepted and proven chemical, uranium hexafluoride is difficult to handle and very volatile, and it poses health and safety concerns. DOE originally expected that the uranium processing steps for AVLIS would be the same as for the gaseous diffusion process, with uranium hexafluoride converted to metal feed at the AVLIS plant.

However, Martin Marietta Energy Systems, a DOE contractor located in Oak Ridge, Tennessee, which became responsible for the AVLIS fuel cycle process after the 1985 decision to abandon the gas centrifuge program,

conducted studies to identify a more economic and reliable process to convert uranium ore to a metal feed. In June 1990, DOE selected for further development and demonstration a process that converts uranium ore directly into uranium metal. DOE concluded that this process would eliminate converting uranium ore to a gas, reduce the amount of waste material generated, reduce safety and environmental concerns, and be cheaper than the existing steps in the fuel cycle.

During fiscal year 1991, Oak Ridge plans to perform engineering tests needed to design and construct a prototype facility that would demonstrate this conversion process. According to DOE planning documents, design of the facility will be completed in fiscal year 1991, after which construction of a demonstration facility will begin. DOE expects to operate the facility from March 1992 through the first half of fiscal year 1994. By then, DOE expects to have enough information to determine the acceptability of this process for AVLIS. Although this time frame extends well beyond 1992, DOE officials insist that the prototype demonstration will provide sufficient performance and cost information by 1992 to make a deployment decision.

Industry officials told us they only became aware during the summer of 1990 that a different process for feed conversion would be used for AVLIS. Oak Ridge officials did not begin to meet with the industry until late September 1990 to explain the technology involved in the new process. When we contacted industry representatives in August 1990, they did not know what the AVLIS feed conversion process was or what would be required technically. They also told us that they wish to remain competitive as uranium feed converters even though they realize changing their processes will affect their operations.

DOE officials told us that they plan to eventually transfer the conversion technology to the private sector, but as of January 1991, they had not determined when and how this would be accomplished. In commenting on our draft report, DOE stated that the first AVLIS plant would initially use uranium metal produced by private uranium metal producers. According to DOE, these producers have a limited production capacity, but could support an initial AVLIS plant.

AVLIS Will Require Back-end Process Changes

At the back end of the fuel cycle, enriched uranium is converted by fuel fabricators into reactor fuel rod assemblies for nuclear power plants. Under the current industry standard, fuel fabricators chemically convert enriched uranium hexafluoride into uranium dioxide, then into pellets that go into the reactor fuel rod assemblies. If this standard is maintained for the AVLIS process, an additional chemical processing step will be needed to convert AVLIS enriched uranium metal back to uranium hexafluoride in order for the industry to continue with the same chemical process it now uses. To reduce fuel cycle costs, DOE proposes to avoid producing uranium hexafluoride and provide uranium trioxide in a powder form to fuel fabricators. Oak Ridge has identified a process to produce uranium trioxide from the uranium metal enriched at an AVLIS plant and plans to build a prototype processing facility by June 1991 and begin production by June 1992.

Although all five of the fuel fabricating companies would rather continue to handle uranium hexafluoride, they have agreed to evaluate how uranium trioxide could be processed in their facilities under a two-phased contract initiated by DOE in 1989. Phase one of the contract is intended to (1) assess specific issues regarding the industry's interface with the AVLIS product and (2) develop an overall strategy for the industry's acceptance of that product. Under phase two, the fabricators will implement the strategy and report their results to DOE. All of the companies had completed phase-one activities by June 1991.

Industry officials told us that handling both uranium hexafluoride and uranium trioxide in the same facility would complicate their operations. According to the fuel fabricators, accepting uranium trioxide powder rather than enriched uranium hexafluoride gas would require them to change certain processes—just which would depend on their current production methods. In addition, they said that significant capital investments would be needed for new shipping containers, protected storage areas, feeding and processing equipment, and new procedures for handling waste.

Despite these concerns, the five fabricators see long-term environmental and economic advantages in changing to a metal-based process for AVLIS. However, all five fabricators are not as optimistic as LLNL about the projected savings for nuclear utilities, nor are they confident that an AVLIS plant will be built soon. As a result, the companies told LLNL they are not willing to commit significant resources or modify their plants until after DOE completes the demonstration project and a decision to build an AVLIS plant has been made. Further, the five fuel fabricators told us that some

type of reactor testing of the metal-based AVLIS product would probably be needed before utilities completely accept it. The companies estimated this testing could take up to 10 years.

Because of concerns about integrating AVLIS into the fuel cycle, DOE officials told us in September 1990 that they had started to reexamine the possibility and costs of continuing to use a uranium hexafluoride interface with fuel fabricators at least for initial plant operations. DOE estimates that such an interface would increase total costs by about $10 per SWU. As of January 1991, DOE had not decided what fuel cycle interface would be used for the first AVLIS plant. However, in commenting on our draft report, DOE stated in May 1991, that it had decided that the initial plant would convert enriched uranium metal to uranium hexafluoride for fuel fabricators, if they so desired. DOE also believes that the new, improved steps will be integrated into the fuel cycle as the AVLIS plant matures and expands.

Program and Legislative Uncertainties Cloud the Future of AVLIS

The future of AVLIS is clouded by legislative and program uncertainties and the lack of a contingency plan. DOE's revised AVLIS deployment strategy focuses solely on a new corporation, which the Congress may or may not create. DOE has not examined or developed other options for an AVLIS plant, such as making the technology available to the private sector. In addition, DOE's AVLIS demonstration plan recognized that certain program objectives, such as selecting a site, obtaining an NRC license, and performing environmental studies must be accomplished before construction can begin. However, DOE did not begin to address these issues until late 1989, and its fiscal year 1992 budget request does not include funding to complete these program activities. Therefore, a new government corporation, if and when it is formed, will have to restart and complete these activities before a plant is built. In particular, an NRC licensing review could delay construction for several years. Because of these program uncertainties, neither DOE, a new government corporation, or a private company will be able to begin building a plant in 1993, as DOE originally planned.

DOE Has Not Developed a Contingency Plan Should a Government Corporation Not Be Created

DOE's uranium enrichment program has faced many problems since the mid-1980s. In response, DOE initiated several steps to improve the competitiveness of its program, and proposed legislation that would restructure the program into a government corporation so that the program might better function as a business entity. We have supported such legislation in the previously cited October 1987 report and several testimonies because we believe a government corporation would have the flexibility to better manage the program in today's competitive business environment. Although various congressional committees have considered restructuring proposals, the Congress has not acted on such legislation.

As noted previously, DOE decided in February 1991 that it would not build a plant or fund certain deployment activities that it believes should be the responsibility of a new government corporation or the private sector. However, DOE has not developed any contingency plan for the AVLIS program should the Congress decide not to create a new government corporation. In particular, DOE has not examined the possibility of making the technology available to the private sector under the National Competitiveness Technology Transfer Act of 1989 (15 U.S.C. 3701). That act recognized that (1) government-owned laboratories, such as DOE'S LLNL, possess technology that could enhance the private sector's ability to compete with foreign companies and (2) much more could be done to encourage or enhance such technology transfers.

Accordingly, the act authorized cooperative research and development agreements between government laboratories and private companies for the purpose of promoting the private sector's use of new technology developed at the laboratories. DOE has begun to use these agreements in other areas, but at the time of our review had not considered how it might develop such an agreement for AVLIS or otherwise promote private investment in a AVLIS plant. On the contrary, as a result of the 1992 budget request, DOE stopped its planned industrial access program, which was originally intended to promote and develop the private sector's interest in the AVLIS technology. Further, DOE has not examined the question of how to preserve the AVLIS technology should the demonstration end before a new corporation is formed or a technology transfer to the private sector is arranged.

DOE's Site Selection Program Delayed

The National Environmental Policy Act of 1969 (P.L. 91-190) (NEPA) requires federal agencies to prepare a detailed environmental impact statement for every proposed major action significantly affecting the

quality of the human environment. This would include the construction of an AVLIS plant. Under the 1990 plan, DOE expected to identify two or three potential AVLIS sites and prepare a general environmental impact statement for all potential sites by June 1992, and a site-specific statement by March 1993. Typically, this site selection process precedes licensing activities by NRC. However, under its 1990 plan, DOE hoped to expedite plant deployment by simultaneously selecting the site and submitting a license application to NRC.

In October 1989, DOE requested its Argonne National Laboratory to conduct AVLIS site selection activities.[3] DOE had expected to issue site selection criteria in April 1990, develop a preliminary list of site alternatives by December 1990, and select a preferred site by November 1992—the planned deployment decision date. DOE issued siting criteria in June 1990—2 months after the planned milestone and did not develop a list of preliminary sites by the December 1990 planned date. A DOE official said the delay was due to internal review problems and efforts to comply with a July 1990 Senate Appropriations Committee report directing DOE to consider non-DOE nonradioactively contaminated (greenfield) sites.

In April 1991, DOE's Assistant Secretary for Nuclear Energy testified before a House Subcommittee that DOE had identified the three existing gaseous diffusion plant sites—Oak Ridge, Tennessee; Paducah, Kentucky; and Portsmouth, Ohio—as candidate sites. An agency official told us that DOE considered greenfield sites and that such sites failed to meet the June 1990 site selection criteria. DOE officials also said that for the three sites they will proceed with environmental studies, which can productively be used later, but that these studies will be discontinued after September 30, 1991, because DOE's fiscal year 1992 budget request did not ask for funding for this or other predeployment activities. If and when a corporation is formed, it will have to complete siting activities, such as an environmental impact statement, before beginning to build a plant. We also note that the environmental assessment process for nuclear facilities has traditionally been lengthy and contentious. Private interest groups often intervene in the process, extending it even longer than it would otherwise take.

[3]Argonne previously developed the site selection process for DOE's Superconducting Super Collider Program.

NRC Licensing Could Substantially Delay an AVLIS Plant

The Atomic Energy Act does not require DOE to obtain a license from NRC before DOE constructs and operates any facility, including an AVLIS plant. Further, NRC does not have the authority to license and regulate an AVLIS plant built and operated by DOE. However, reacting to criticism that the lack of independent oversight contributed to many of the health and safety problems at its defense facilities, DOE has for several years sought NRC health and safety license reviews for its new facilities. As a result, DOE, in its 1990 demonstration plan, anticipated having NRC conduct a safety and health review of the AVLIS plant even if DOE did not obtain a formal NRC license. Further, DOE hoped and still anticipates that the Congress will pass proposed legislation to structure DOE's uranium enrichment program as a separate government corporation. The proposed legislation would require an AVLIS plant to obtain an NRC license before it is constructed. If a private company were to build an AVLIS plant, it would also need to obtain an NRC license.

In August 1990, DOE requested NRC to prepare for an AVLIS license review and to help develop a plan and schedule for performing safety and licensing reviews. When we spoke to NRC staff within the Office of Nuclear Materials, Safety, and Safeguards in November 1990, they told us that they had not reacted to DOE's request for several reasons. They explained that NRC does not have resources to review a multisite application, which DOE anticipated sending to NRC; that many safety concerns are site-specific; and that a review of multiple plant sites would be a waste of time and money. DOE, according to its plan, did not anticipate identifying a preferred AVLIS site until November 1992, only 4 months before the plan called for NRC to complete its review.

In addition, NRC staff were not convinced that the demonstration will work smoothly and that all final design changes will be made by early 1991. Past experience tells them that plant demonstrations often uncover engineering problems that are not apparent at laboratory scale. They pointed out that DOE has only enriched very small amounts of uranium using the AVLIS technology and that demonstration production runs usually lead to design changes that could affect safety analysis and licensing activities. NRC staff also added in the agency's official comments on this report that legislation passed in November 1990 (P.L. 101-575) establishes a one-step licensing review process for enrichment plants. This means that a complete, final design will be needed at the beginning of the licensing process. In its January 23, 1991, formal response to DOE's request, NRC officials stated that they would adjust their budget request to provide needed resources to conduct an AVLIS licensing review only if the Congress enacts legislation requiring DOE or a

government corporation to obtain a license, or if the applicant is from the private sector.

When we asked the NRC staff how long it might take to license an AVLIS plant, they emphasized that AVLIS is a very novel technology and that very little performance or safety data exist for many of its processes. Further, on the basis of initial information, the staff pointed out that the technology presents several unique, serious safety concerns. Because NRC does not have expertise available to properly evaluate some of these safety questions, a full-scale license review is likely to require NRC to contract with outside experts, which could further lengthen the review process. Finally, given the unique new technology involved, the NRC staff expect private interest groups to oppose the licensing process—raising the prospect of even longer delays. Therefore, the staff concluded that a full-scale NRC review will require considerable time and effort, and possibly take much longer than DOE's original estimate of 2 years.

Conclusions

Because of the potential benefits of the AVLIS program, we believe DOE should continue to demonstrate and develop the technology in order to preserve and enhance deployment options. However, we do not believe the demonstration will provide all of the information needed to make a deployment decision in 1992 as DOE originally planned. In particular, remaining technical issues will hinder completion of an independent cost review of AVLIS deployment options. Such a review will be needed before a decision on building an AVLIS plant is made. In addition, DOE's current strategy is limited to completing the technology demonstration, with little effort directed toward those program activities that must be completed before a plant is built. Thus, a new corporation, if and when it is created, will have to delay construction until these activities, including site selection and an NRC licensing review, are completed.

More importantly, DOE has no contingency plan for AVLIS should the Congress not create a government corporation. Such a plan could identify what steps DOE could take to transfer the technology to the private sector if a corporation is not formed. It could also identify steps and costs to close out the AVLIS technology demonstration and maintain the technology for future use if a plant is not built in the near future. At a minimum, the plan could identify steps to determine how much more research and development is needed beyond 1992 and how best to preserve the technology and related expertise if a corporation is not formed.

Recommendations to the Secretary of Energy

GAO recommends that the Secretary of Energy update the AVLIS demonstration plan to realistically reflect revised program goals and remaining technical development work. The plan should also provide for an independent cost analysis and allow and promote private industry's access and participation in the development program to enhance future deployment options. Finally, the updated plan should identify other deployment options should a government corporation not be established. In particular, DOE should examine options encouraged by the National Competitiveness Technology Transfer Act of 1989.

Agency Comments and Our Evaluation

We sent a copy of our draft report to NRC and DOE for official comments at about the same time the administration submitted its proposed 1992 budget to the Congress. As discussed in chapter 1, the proposed budget substantially changed DOE's 1990 demonstration plan. Therefore, several of DOE's and NRC's comments were directed at the need to change our report to reflect DOE's revised strategy, as established by the budget request. We have made changes throughout our final report to take into account DOE's revised plan and reflect several other specific comments by NRC and DOE. In addition, as noted below, we revised the report's recommendations because of DOE's changed deployment strategy. DOE and NRC also made several general observations or comments on our report, which we discuss in the following sections and at the end of chapter 3. See appendixes I and II for the complete text of DOE's and NRC's comments, respectively.

NRC

In its comments, NRC highlighted several points concerning a potential license review of an AVLIS plant. In particular, NRC noted that P.L. 101-575, passed in November 1990, added to the Atomic Energy Act a requirement that private uranium enrichment plants obtain a license from NRC. This would involve a single licensing proceeding, rather than a two-step (operating and construction) license review process. NRC pointed out that this change has the effect of requiring a single, complete license application containing a final plant design at the outset of the license review, rather than permitting a substantial evolution of the design throughout the licensing process. NRC also pointed out that analysis of the unique safety issues associated with an AVLIS plant will require knowledge of the final design. The report's discussion of licensing issues has been revised to include NRC's views.

NRC also commented on a proposed recommendation in our draft report calling for a formal agreement between DOE and NRC that would establish

a license review schedule. NRC generally opposed such an agreement because of uncertainties associated with an AVLIS license review. Our final report does not contain this recommendation, because DOE decided not to build a plant or fund licensing activities. NRC also commented that our report inaccurately refers to uranium hexafluoride as a gas, when it is a solid at room temperature and atmospheric pressure. We made appropriate changes in the report; however, we note that uranium hexafluoride is often processed as a gas at various points in the nuclear fuel cycle.

DOE

DOE disagreed with how our draft report addressed two major areas. The first involved our discussion of technical issues that will remain unresolved when DOE completes its ongoing demonstration in 1992. DOE commented that it will generate a sufficient body of reliable technical and economic data to validate the performance of the AVLIS plant and that our report leads the reader to erroneously conclude that whoever builds an AVLIS plant should take a zero-risk approach. DOE argues that the remaining risks are acceptable and that resolving all such risks is cost-prohibitive. In an analysis of the remaining technical uncertainties, DOE concludes that at most these uncertainties could increase the cost per SWU to about $50.

Our report clearly states that technical experts are confident that (1) the ongoing project will successfully demonstrate the AVLIS technology and (2) remaining plant performance objectives can be met through continued development after 1992. However, these same experts also believe that the demonstration project will not answer all of the technical questions needed to provide the specific cost data necessary for a deployment decision by the end of 1992. This view was supported by the findings of a recently issued Edison Electric Institute report entitled The DOE AVLIS Program: An Industry Assessment. The report contained a cost analysis concluding that DOE's current AVLIS SWU cost estimates could double if a number of technical uncertainties are not favorably resolved. Therefore, we continue to doubt whether the current project, scheduled to end in 1992, will adequately address all remaining technical issues needed to make a deployment decision. However, nowhere in the report do we suggest a costly "zero-risk" approach be taken. In any event, now that the administration has determined that an AVLIS plant will be built with private funds, a detailed discussion in this report of what risks are or are not acceptable would not be productive. DOE, or the corporation, will ultimately have to convince private investors that the technical and economic risks of an AVLIS plant are acceptable.

DOE's second major area of disagreement with our draft report concerned our discussion of fuel cycle integration activities. Although DOE commented that our draft report incorrectly concluded that DOE has not adequately addressed this issue, DOE's comment letter to us addressed two major fuel cycle issues that had not been resolved at the time we sent our draft report to the agency for comment. Our draft report stated that changes must be made to the existing fuel cycle to accommodate an AVLIS plant and that DOE had not yet determined what these changes would be or where they would be made—at the AVLIS plant or at existing nuclear fuel convertors or fabricators. While our report was with the agency for comment, DOE determined that the initial AVLIS plant would use uranium metal feedstock produced by existing suppliers. DOE also determined that the enriched uranium metal produced by the plant would be converted to uranium hexafluoride for fuel fabrication companies that desire enriched uranium in that form for processing into nuclear fuel. Our report has been revised to reflect DOE's new policies. DOE's comments also expressed strong confidence in the new fuel cycle technologies the agency is developing. DOE expects them to be cost-effective and phased into the fuel cycle as the plant matures.

DOE also questioned our statement that plant licensing could take longer than 2 years. DOE stands firm in its estimate that NRC can perform a 2-year AVLIS license review, especially in light of recent changes that will eliminate the need for a two-step license review. For a number of reasons, we continue to believe that the licensing process could take much longer. For example, NRC officials point out that AVLIS will present many unique safety questions for which little historical data exist. Further, these questions may require NRC to contract for outside expertise, which could delay its review. Finally, an AVLIS plant licensing procedure could generate considerable public interest, further delaying the process. An NRC staff member testified during an April 10, 1991, House Subcommittee hearing that he could not estimate how long a license review might take, but that it would take several months just to determine what health and safety issues exist and devise ways to address them.

Market Risks Need to Be Addressed Before AVLIS Deployed

Existing uranium enrichment capacity in Europe and the United States exceeds current demand by over 25 percent, and if DOE's estimate of Soviet capacity available for production for Western sales is considered, capacity exceeds demand by over 60 percent. This condition will continue because demand for enrichment services is expected to grow slowly until well past the year 2000 and because few nuclear plants are under construction or planned. Further, future growth in demand for enrichment services will not occur for 8 to 10 years after new nuclear plants are ordered because construction of a nuclear plant generally takes at least that long.

Because demand is not growing and excess capacity exists, a new AVLIS plant will have to be able to attract existing demand with low prices while still recovering construction and operating costs. LLNL reports that an AVLIS plant would be a good investment because the Laboratory expects the plant's production costs to be the lowest in the world and at least 50 percent less than DOE's gaseous diffusion plants' costs. However, as pointed out in chapter 2, definitive AVLIS cost information will not be available for several years. Further, some experts believe LLNL's cost estimates are optimistic. In addition, LLNL's analysis does not consider certain dynamic enrichment market factors, such as customers' tendency to buy from domestic sources and foreign competitors' sales strategies, particularly the Soviet Union's current practice of selling excess production to Western utilities for hard currency[1] at prices significantly below competitors'.

DOE's initial efforts to model these and other market factors have led to mixed conclusions about the advisability of building an AVLIS plant. Some scenarios show that an AVLIS plant would be a prudent investment, while others indicate that under certain conditions, an AVLIS plant might not recover its costs. These initial scenarios were developed prior to the May 1990 Smith Barney study, which concluded that total AVLIS construction costs could double and that an AVLIS plant will probably be delayed by 5 years because of licensing and site selection problems. The March 1991 Edison Electric Institute report, The DOE AVLIS Program: An Industry Assessment, also concluded that production costs are likely to be twice DOE's estimates. Further, the longer an AVLIS plant is delayed, the more it will depend on the uncertain demand from new plants to recover its costs. The mixed results of these initial market studies lead us to conclude that DOE needs to conduct an extensive, updated analysis to help

[1]Hard currency is a national currency that can be freely converted into gold or the currencies of other countries.

assess deployment strategies and/or convince private investors to support an AVLIS plant.

Excess Enrichment Capacity Exists Throughout the World

Until 1974, the United States supplied practically all of the enrichment services available outside of the Soviet bloc. In 1990, DOE sold about the same amount of enrichment services as it sold in 1974, but met only about 45 percent of the market's needs. Foreign competitors began to erode DOE's market share in the mid-1970s following DOE's decision not to accept orders above what it could produce with its existing capacity. Foreign competition also grew as European countries built enrichment plants to ensure their own domestic sources of supply.

Today, the United States still possesses the world's largest capability to produce enriched uranium and the largest single share of the market. However, other competitors have gained significant proportions of the market, especially outside of the United States. Currently, only about 33 percent of DOE's sales are to foreign utilities. DOE has several main competitors:

- Eurodif: A French-led European consortium capable of producing 10.8 million SWU per year from a gaseous diffusion plant. Eurodif charges partners relatively high prices ($180 to $200 per SWU), but is willing to sell excess production to U.S. customers at much lower prices.
- Urenco: A German, Dutch, and United Kingdom consortium with a centrifuge plant located in each member country. Urenco can produce about 2.7 million SWU per year and can expand its capacity. Urenco also charges partner countries relatively high prices ($160 to $190 per SWU), but has offered enriched uranium at substantially lower prices to U.S. customers in order to capture a share of the U.S. market.
- Soviet Union: Using centrifuge and diffusion technology, the Soviet Union has historically offered about 3 million SWU annually to Western customers. However, in the last few years, the Soviet Union has reduced both its military and civilian nuclear programs and dramatically increased its attempts to sell enrichment services in order to generate hard currency. Estimates of the Soviet Union's excess capacity available to produce enriched uranium for foreign sales range up to 10 million SWU per year. As a result, the Soviets have recently dominated the short-term enrichment market. Further, the Soviets have been selling enriched uranium at very low prices—less than 50 percent of DOE's current contract price of $117 per SWU.

Table 3.1 shows the current capacity of the world's leading enriched uranium producers.

Table 3.1: Existing Uranium Enrichment Capacity

Capacity in Millions of SWU per Year

Producer	Capacity
DOE	19.2
Eurodif	10.8
Urenco	2.7
Soviet Union	10.0[a]
Total	**42.7**

[a]Estimates of excess capacity that could produce enriched uranium for sale to Western countries range up to 10 million SWU.

Other countries, such as Japan and China, are also emerging as future competitors. Japan is building a centrifuge plant and pursuing laser technology as it seeks to reduce its dependency on outside sources. DOE officials also expect China, which they believe has large uranium reserves, will develop an enrichment technology for foreign trade objectives. China's and Japan's progress will have a significant impact on DOE's program, since the Far East is DOE's last remaining foreign market with significant sales and an area where new nuclear power plants have been ordered and are under construction. In addition, DOE faces the prospect of a competitor located within the U.S. market. In 1988, Urenco entered into a partnership with several U.S. companies and utilities to build a gas centrifuge plant in Louisiana. According to announced plans, the consortium expects to obtain a license and build a plant capable of producing 1.5 million SWU per year by 1997.

In the late 1970s and early 1980s, following the Three Mile Island accident and the Chernobyl disaster, the construction of nuclear plants slowed dramatically. U.S. utilities have not ordered a new nuclear power plant since 1978; further, many experts do not expect any new plants to be ordered until past the year 2000, although DOE and private nuclear industry groups are promoting new plant designs and other initiatives to revitalize nuclear power. In this regard, the Nuclear Power Oversight Committee, composed of senior executives representing eight nuclear utility organizations, issued A Strategic Plan for Building Nuclear Energy Plants. The November 1990 plan proposes several actions to overcome the institutional, technical, and financial impediments to the planning and construction of new nuclear plants in order to generate orders for new plants by the mid-1990s for operation by the year 2000. Unless such initiatives are successful, it is unlikely that any new U.S.

plants will be operating until after 2010 at the earliest, because historically construction has taken 8 to 10 years or longer.

Because few nuclear plants throughout the world are under construction or planned, nuclear capacity is expected to grow slowly through the year 2005. As shown in table 3.2, total worldwide demand (excluding that of the Soviet Union and other communist countries) is projected to be about 26 million SWU in 1990, or about 17 million SWU less than existing capacity can produce. By 2005, demand will still be 7 million SWU less than existing capacity, not counting possible additions to capacity within the United States, Japan, and China.

Table 3.2: Projected Worldwide Enrichment Demand

Demand in Millions of SWU

	Demand			
	1990	**1995**	**2000**	**2005**
United States	9.6	11.0	10.8	11.4
Europe	10.6	12.4	13.0	13.2
Far East	5.3	7.0	7.2	9.1
Others	0.3	0.8	1.2	1.7
Total	**25.8**	**31.2**	**32.2**	**35.4**

Source: Smith Barney Harris Upham & Co., Inc., United States Uranium Enterprise: An Independent Financial Assessment (May 1990).

The oversupply of enrichment capacity has created a very competitive market, which will become even more so as long-term DOE contracts expire or are terminated. Through 1995, almost all of the demand in Western countries is under contract. However, in 1996, "uncommitted" demand—demand not currently under contract—jumps to 12 million SWU and increases thereafter. About one-third of this demand will come from U.S. utilities that are expected to terminate their long-term contract commitments to DOE, in anticipation of more competitive prices elsewhere.

Market experts expect that this so-called "buyers' market" will result in short-term contracts and competitive bidding throughout the world. However, these same experts point out that even with foreign supplies available at cheap prices, it is unlikely that large segments of U.S. utilities' demand will shift from DOE to other sources of supply. These experts conclude that domestic utilities will purchase some portion of their needs from foreign suppliers but that it is unlikely a large number of utilities will purchase all of their needs overseas because such action would strain existing foreign capacity and drive up prices. Further,

experts believe that domestic utilities are likely to purchase some portion of their needs from DOE to maintain an assured source of supply. Just how many utilities will purchase foreign enrichment services is a key variable in evaluating whether or not to build an AVLIS plant.

Current Market Analyses of AVLIS Deployment Are Not Conclusive

Any analysis of whether or not an AVLIS plant should be built has to consider a number of complex, interrelated factors. These factors include

- the size of the plant and when it will begin production;
- the cost of constructing and operating the plant;
- the cost of operating the existing gaseous diffusion plants;
- the cost of meeting environmental requirements at the existing plants compared to the cost of meeting these requirements at an AVLIS plant;
- competitors' market strategies, especially the Soviet Union's; and
- future demand, including customers' preferences for domestic production.

The range of assumptions made about these key factors will affect the results of any AVLIS deployment analysis. For example, some of DOE's scenarios, discussed below, assume that most of DOE's customers will not buy from other suppliers after long-term contracts expire because of Urenco's lack of excess capacity, Eurodif's high prices, and customers' need to maintain an assured source of supply. Other scenarios by DOE assume that most utilities will automatically buy the cheapest enrichment services available. These two sets of scenarios lead to conflicting conclusions on the viability of an AVLIS plant, thereby illustrating the potential impact of certain hard-to-predict market factors.

Three separate AVLIS deployment studies have been initiated, including some preliminary analyses by DOE, which it plans to update and expand as more information is generated by the demonstration project. In addition, the Edison Electric Institute's recently published assessment of the AVLIS program contains an analysis of the possible future operating costs of an AVLIS plant. However, the lack of definitive cost information and the impact of certain market assumptions have led to mixed results. Some of the scenarios support the conclusion that an AVLIS plant should be built as soon as possible, while others lead to questions about the plant's ability to pay for itself if demand does not increase. The following sections describe the existing studies.

Lawrence Livermore

In a November 1989 report, LLNL analyzed the financial benefits of an AVLIS plant. Using its general design model, which incorporates the latest AVLIS design requirements to predict construction and operating costs, LLNL predicted that an AVLIS plant would cost between $570 million and about $1 billion, depending on whether a small (3-million-SWU) or large (9-million-SWU) plant was built. The report also projected that costs per SWU would range between $21 and $31, depending on the size of the plant. A larger plant would reduce average production costs. These projected costs compare very favorably with DOE's current selling price of $117 per SWU and the approximate production cost of $65 per SWU from its gaseous diffusion plants.

LLNL has also developed a model that predicts the financial impact of building an AVLIS plant. This model, termed the enterprise model, uses cost data from the design model and DOE's estimate of enrichment demand to predict the program's financial performance based on given plant deployment strategies and demand assumptions. LLNL predicted in its 1989 report that an AVLIS plant could save DOE's enrichment program $500 million to $800 million a year, if it built a 9-million-SWU AVLIS plant. The model predicted that savings would result because of an AVLIS plant's low production costs compared to those of the gaseous diffusion plants. The LLNL report did not evaluate the return on investment of an AVLIS plant delayed past 1997, since this would force the analysis to project demand from nuclear plants not yet ordered.

When LLNL prepared the 1989 analysis, it did not have the detailed cost information that it expects to obtain from the ongoing demonstration and technical support it plans after 1992. Key cost factors yet to be defined include separator maintenance requirements, and the production and maintenance costs of advanced lasers and related optical systems yet to be fully developed. Further, LLNL's 1989 cost analysis used what it called "plant performance criteria" even though certain equipment has not yet been developed or operated at expected plant performance levels. Nevertheless, LLNL officials are confident the performance targets predicted in their 1989 plan will be met by the time plant construction begins. In addition, they argue that two-thirds of the capital costs are easily predicted because they would be for standard construction materials; therefore, the officials feel confident that their cost figures are reasonably accurate.

Smith Barney

In January 1990, DOE entered into a contract with Smith Barney Harris Upham and Co., Inc., to assess the feasibility of restructuring the enrichment program. DOE wanted an objective review of the program and an independent opinion concerning the best option to maximize the program's financial value. Smith Barney delivered the report to DOE on May 15, 1990.

Smith Barney evaluated AVLIS with the help of a panel of experts and concluded that the technology is sound and could be a significant factor affecting the program's ability to compete. However, the Smith Barney report expressed concern about whether the technology can be deployed in a timely manner to achieve its potential. The panel concluded that existing cost estimates are highly uncertain and predicted that an independent cost estimate might increase expected capital costs by 50 percent and production costs by 25 percent. Further, the panel went on to state that a doubling of plant capital costs and a 50-percent increase in SWU production costs above LLNL's current estimates would not be unexpected. The panel did not develop these estimates through any specific analyses, but rather based them on its collective review of available cost data and experience with DOE's large research and development projects.

The panel also stated that DOE's planned deployment schedule was too optimistic and ambitious. According to the panel, a 5-year delay could occur, due largely to expected difficulties in obtaining environmental and regulatory approvals. The report concluded that the potential for repeating the gas centrifuge program mistake—continuing to invest capital in an adverse, declining market—would be substantially reduced by transferring the decision of whether or not to construct a plant to a new government corporation, where commercial considerations would determine the decision.

DOE Headquarters

DOE did not complete the detailed market and financial analysis of AVLIS deployment issues it originally anticipated needing before making a decision on building a plant. However, DOE included some initial analyses as an addendum to LLNL's 1989 report in an effort to "extend" LLNL's cost analyses. In the addendum, DOE attempted to determine the impact of several dynamic market factors, such as the Soviet Union's future market strategies and the number of U.S. customers that would purchase foreign enrichment services because of their lower price.

DOE used a market model called Allocate for its preliminary analyses of an AVLIS plant's sales. Allocate uses known production capacities,

demand, and production costs to project annual sales for each of the world's suppliers. The model computes a market price and allocates uncommitted demand to the supplier with the lowest cost of production. The model assumed that a new AVLIS plant would supply DOE's existing demand first, since the plant will enrich uranium at a lower cost than a gaseous diffusion plant. Therefore, production from DOE's gaseous diffusion plants would be available for sale to new markets.

DOE evaluated several market scenarios with and without an AVLIS plant to determine the impact of several key market variables identified by its market experts: (1) the amount of price-sensitive demand; (2) the Soviet Union's sales; and (3) Urenco's future expansion. For analytical purposes, DOE varied the amount of future U.S. demand that would be influenced by future price changes between 100 million and 200 million SWU over the next 20 years. Urenco's capacity was assumed to be 3 million or 6 million SWU per year and Soviet production available for sales to the West ranged from 3 million to 9 million SWU per year.

The model predicted that for many market scenarios, an AVLIS plant would generate significant new sales; however, for some scenarios, new sales are small or nonexistent. For example, the model predicted that if the Soviets sell 9 million SWU per year to Western customers, Urenco expands to sell 6 million SWU per year, and only a small part of the market proves to be price-sensitive, a new AVLIS plant would not increase sales at all. Further, DOE's analyses lead to questions about whether an AVLIS plant's sales would result in revenues sufficient to cover investment costs, since prices would be expected to drop in a competitive market after AVLIS is deployed. For example, some DOE officials told us that (1) the analyses suggest that in some cases, most of AVLIS' cost benefits could be passed on to utilities in the form of lower prices and (2) DOE would have trouble recouping its investment.

Edison Electric Institute

In March 1991, the Edison Electric Institute, a professional organization representing electric power companies, issued a report entitled The DOE AVLIS Program: An Industry Assessment. The report included of analysis of an AVLIS plant's potential to produce enriched uranium at costs lower than current facilities'. Using sophisticated statistical techniques, the report concluded that production costs twice DOE's estimates are likely, but that production costs significantly lower than those of gaseous diffusion plants and at least competitive with those of a centrifuge plant

are still achievable. The report also identified those operating parameters most critical to realizing low AVLIS costs. All of the parameters concerned the maintenance and operation of the separators, for which, according to the report, DOE has no substantial experience. The report concluded that the future of the program depends on how quickly and how inexpensively DOE can bring the technology to a deployable state.

Conclusions

We recognize that DOE's uranium enrichment program has, over the past 20 years, provided many benefits to the United States. For example, the program has (1) annually contributed up to $500 million to the U.S. balance of trade; (2) provided an assured source of energy supply; and (3) contributed to the nation's nonproliferation goals. Currently, however, the program is facing financial problems because of potentially high environmental and decommissioning costs, growing foreign competition, and the need to pay back a portion of the government's investment. An AVLIS plant is projected to be more efficient than existing production facilities, thereby creating a competitive advantage that experts believe the United States can ill-afford to lose to another country.

We believe that the AVLIS technology offers potential technical, cost, and related market benefits; however, we do not believe that DOE, a government corporation, or a private company will be adequately prepared to make an AVLIS deployment decision in 1992 as planned. As we pointed out in chapter 2, technical questions will remain and related cost information will need to be developed and analyzed. Further, site selection and plant licensing requirements will most certainly delay construction beyond 1993, especially now that DOE has decided not to pursue certain predeployment activities.

This means that an AVLIS plant will not be able to take immediate advantage of the large amount of uncommitted demand that will develop in the mid-1990s when DOE's long-term contracts expire. AVLIS will in effect miss the "window of opportunity" to generate an optimum return on investment. Further, the longer a plant is delayed, the greater the financial risk because long-term demand growth is tied to a resurgence in nuclear power. Currently, the United States' enrichment capacity can supply U.S. needs for years. Also, because it takes 8 to 10 years to construct new nuclear plants, but only 5 to 6 years to construct an AVLIS plant, plenty of time exists to build an AVLIS plant if it is needed to ensure an adequate supply.

LLNL reports that AVLIS would make an excellent investment even if demand does not increase because of the plant's projected low production costs. However, DOE's preliminary analyses including dynamic market factors, such as the Soviet Union's aggressive sales strategy and the extent that potential customers value price over other factors like an assured supply, are less conclusive. DOE's analyses show that under certain circumstances, an AVLIS plant may not generate enough new sales to recover its construction costs. Further, the longer AVLIS is delayed, the more dependent it becomes on demand effected by a resurgence of nuclear power.

As we stated in chapter 2, because of the potential benefits of the AVLIS program, we believe DOE should continue its demonstration efforts to keep deployment options alive. However, we also believe that an updated market analysis of the impact of AVLIS will be needed to assess deployment strategies and/or convince private investors to support an AVLIS plant.

Recommendation to the Secretary of Energy

We recommend that the Secretary of Energy include a market analysis in the revised AVLIS demonstration plan.

Matters for Consideration by the Congress

As the Congress considers proposed legislation that would restructure DOE's uranium enrichment program as a government corporation, it could also consider transferring responsibility for AVLIS to the new corporation. This would require the new corporation to convince private financiers to invest in AVLIS and could reduce the government's financial risk. It would also help ensure that the decision on building an AVLIS plant is based on commercial concerns.

Agency Comments and Our Evaluation

DOE took issue with our statement in chapter 3 that AVLIS may have already missed its "window of opportunity" to reap maximum financial returns since it will not be built by 1995, when large blocks of uncommitted demand develop. DOE contends that AVLIS will be very competitive because of its cost advantages and that building an AVLIS plant as soon as possible is the best way to generate high returns. DOE also contends that large amounts of uncommitted demand will be available on a continuing basis beyond 1997.

We agree that market conditions indicate utilities are not likely to commit to long-term contracts; therefore, uncommitted demand is likely to exist for some time. We point out, however, that the longer AVLIS is delayed, the more investors will need to depend on the demand from aging power plants and new power plants not yet ordered to recover their investment. Also, further delays jeopardize the current lead this country has on foreign competitors pursuing the AVLIS technology. Our statement on missing "a window of opportunity" merely points out that if AVLIS could have been brought on-line by 1995, as DOE originally planned, it might have taken immediate advantage of new uncommitted demand and therefore maximized returns. We also note that DOE often used this argument when it requested funds for AVLIS in the 1980s.

Comments From the Nuclear Regulatory Commission

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

March 11, 1991

Mr. J. Dexter Peach
Assistant Comptroller General
Resources, Community, and Economic
Development Division
U.S. General Accounting Office
Washington, D.C. 20548

Dear Mr. Peach:

I am responding to your letter of March 1, 1991, which requested the Nuclear Regulatory Commission (NRC) review and comment on the General Accounting Office's (GAO) draft report entitled "Uranium Enrichment: DOE Should Delay Decision on Building an AVLIS Plant" (GAO/RCED-91-88). The staff has reviewed the draft report and offers the following comments:

1. In the Executive Summary and on page 25, the report states that NRC staff told GAO that unforeseen difficulties often occur when new processes are scaled up from laboratory demonstrations. On page 39, the report states that NRC staff said that design changes usually result from scale-up. It is important to note that these staff comments are not merely observations about difficulties in deploying a new technology, they have significance in safety analysis and licensing. The staff has remarked upon the many unique safety issues evident in atomic vapor laser isotope separation (AVLIS) process. Analysis of these safety issues requires knowledge of the final design configuration that evolves from the scale-up. In addition, recently enacted legislation (P.L. 101-575) amended the Atomic Energy Act to require a single license for uranium enrichment plants under NRC's materials licensing regulations. This change has the effect of requiring a single, complete application containing a final design at the outset, rather than permitting substantial design evolution through the licensing process. The GAO report should clarify the safety and licensing basis for NRC's expressed concerns.

2. Congress must enact appropriate legislation before NRC has the authority to license and regulate the Department of Energy's (DOE) construction and operation of an AVLIS plant. Absent legislation requiring DOE to secure an NRC license, DOE may proceed without a license from NRC.

3. On pages 7 and 41, the report recommends that DOE enter into a formal agreement with NRC to establish a license review schedule. The purpose of the agreement is not explicitly stated, although it is implied that the agreement would guarantee a fixed review schedule. Such an agreement would not be an appropriate arrangement for a technology with no previous NRC staff review experience. NRC's reluctance to setting a fixed review schedule is also related to the lack of a sufficiently clear definition of the activities that would be subject to licensing, the uncertainty of the Government's commitment to the program, and the inability to predict the duration of a mandatory, adjudicatory hearing. Although a tentative review schedule could be prepared, its effectiveness for planning would depend on the nature, completeness, and definitiveness of a license application.

Mr. J. Dexter Peach - 2 -

4. With respect to the statements on the NRC's licensing process (pages 5 and 33), the procedures for licensing uranium enrichment plants are now well defined. As stated in our recent (January 23, 1991) letter to DOE, a uranium enrichment plant would be licensed pursuant to 10 CFR Parts 40 and 70 and other requirements that result from the Solar, Wind, Waste, and Geothermal Power Production Incentives Act of 1990. However, the uncertainties associated with any first-time review could easily cause deviations from even the most carefully conceived review plan.

5. Because over one year has passed since DOE submitted the AVLIS deployment plan referred to throughout the GAO report, the schedule is now obsolete. The GAO report should be updated to take into account recent activities, and the report should make clear that the comments, conclusions, and recommendations would apply to any updated schedule if, indeed, they do.

6. The report extensively refers to UF_6 as "UF_6 gas." This statement is not accurate, since UF_6 is a gas under specific conditions. At room temperature and atmospheric pressure, UF_6 is a subliming solid.

Specific comments are directly marked on the enclosed copy of GAO/RCED-91-88. NRC has no comment on the recommendation to delay the decision on building an AVLIS plant. This is a policy and economic decision, which is not within the purview of the NRC mandate to protect the public health and safety.

Sincerely,

James M. Taylor
Executive Director
for Operations

Enclosure:
Marked Copy of
GAO/RCED-91-88

Comments From the Department of Energy

The Under Secretary of Energy
Washington, DC 20585

May 7, 1991

Mr. Victor S. Rezendes
Director, Energy Issues
Resources, Community, and
Economic Development Division
U.S. General Accounting Office
Washington, D.C. 20548

Dear Mr. Rezendes:

The Department of Energy (DOE) appreciates the opportunity to review and comment on the General Accounting Office (GAO) draft report entitled "Uranium Enrichment: DOE Should Delay The Decision on Building an AVLIS Plant (GAO/RCED-91-88)."

We disagree with GAO's position on two fundamental issues. The first issue involves GAO's premise that all Uranium-Atomic Vapor Laser Isotope Separation (U-AVLIS) process variables must be demonstrated at full plant conditions before a deployment decision can be made. Based upon this position, GAO concluded that significant technical uncertainties and concerns will not be resolved when DOE's technology demonstration program is completed in 1992 and, thus, a decision should not be made at that time. GAO's basic premise is not sound, and, therefore, their conclusion is not valid.

For example, development and commercial organizations do not take the zero risk approach suggested by GAO where all parameters are tested at full production levels before a technology is commercialized. Rather, testing is conducted at near plant-scale conditions where a few uncertainties and risks remain. Our technology demonstration program will involve tests at plant-like conditions using plant-scale components for prolonged periods of time that closely approximate production requirements. Therefore, it is our position that the U-AVLIS program plan that DOE forwarded to Congress in January 1990 (Enclosure 1) will generate a sufficient body of reliable data to validate the technical performance of the U-AVLIS process.

Economic assessments will be conducted based on performance of plant-scale equipment, the costs of procuring that equipment, and a conceptual design for a production plant. We consider that these technical and economic data, in combination, will comprise an appropriate basis for a deployment decision. A more detailed

critique of the technical concerns raised in your report is enclosed (Enclosure 2).

The second issue involves GAO's statement that the Department's plan does not adequately address the integration of a U-AVLIS production plant with nuclear fuel convertors and fabricators. This is not the case. We have carefully identified means by which the U-AVLIS enrichment process can be integrated into the nuclear fuel industry. These include the use of existing industry capacity in the near term that is sufficient to provide feed to an initial U-AVLIS plant. Also, our plan includes the installation of equipment using well-understood technology as part of an initial U-AVLIS plant that would convert uranium metal product to the uranium hexafluoride form that is currently used by the industry to fabricate nuclear fuel. The cost of this product conversion equipment has already been factored into our cost estimate for a U-AVLIS production plant. Therefore, both the integration and timing of an initial U-AVLIS plant with the existing nuclear fuel industry can be readily accomplished.

As a future alternative to the use of existing capacity and technical capabilities, we plan to demonstrate improved feed and product conversion processes that offer significant economic and environmental benefits. This demonstration will be completed by September 1992 and made available at that time for potential use by the private sector in the post-2000 timeframe. These parallel activities are expected to provide an efficient integration of U-AVLIS technology with the nuclear fuel industry in both the near and long term.

The GAO report also commented on the need for independent technical and cost analyses. The experimental results generated to date have been exhaustively reviewed by the independent Technology and Engineering Review Group (TERG) that is comprised of individuals from industry, universities, and the national laboratories who have experience in developing and deploying state-of-the-art technologies. Based on these reviews, TERG concluded that enrichment performance uncertainties have been reduced to less than 25 percent and that the planned integrated demonstration program will reduce these potential uncertainties even further. Currently, we project that the enrichment performance uncertainties following technology demonstration will be less than 10 percent.

We have long planned to subject the results of the demonstration program to independent reviews by both the TERG and a Senior Industrial Review Group (SIRG) that includes individuals from industry (e.g., International Business Machines) and the utility community. The objective is for TERG to continue to carefully evaluate the demonstrated technical performance and to verify economic projections. By having both TERG and SIRG review the experimental results and economic analyses that will be performed,

we will be able to assure that detailed consideration is given to all aspects of the program when the technology demonstration program is completed in 1992. In addition to these independent technical and economic analyses, we have long planned to obtain independent assessments of the market impact of the U-AVLIS technology and the timing for deployment that will result in the greatest business value.

It should also be pointed out that the GAO report is not current in that it does not reflect recent decisions by DOE regarding future deployment of U-AVLIS technology. GAO recommended revision of the U-AVLIS deployment plan to allow additional time to resolve outstanding technical and program issues and submission of a U-AVLIS deployment report to Congress at the conclusion of the technology demonstration program indicating that these issues have been resolved. As stated previously, the U-AVLIS technology demonstration will address all relevant technical issues through the demonstration of the process in full-scale equipment. Any remaining issues related to investments in U-AVLIS deployment should be addressed by the entity that would build and operate a future U-AVLIS production plant.

In this regard, the Administration has determined, based on policy considerations, that the Government should avoid investment in the uranium enrichment enterprise that could more appropriately be made by the private sector. Therefore, our plans for U-AVLIS deployment have been revised to reflect this determination as indicated in the Administration's FY 1992 budget submission to Congress. Basically, Government expenditures for U-AVLIS predeployment activities to support eventual plant deployment were not included in the FY 1992 budget.

The Administration is also actively supporting the establishment of a Government corporation as an interim step for eventual privatization for uranium enrichment at the earliest possible time. Such a corporation represents the best means to assure timely investment in, and deployment of, the U-AVLIS technology. An enrichment corporation with access to private sector funds for U-AVLIS deployment will be better able to apply commercial investment criteria with the appropriate assurances that any remaining U-AVLIS issues are resolved. These inherent practices for private sector investments will more than adequately address GAO's concerns about deployment readiness.

GAO also raised concerns about the duration that may be required for a Nuclear Regulatory Commission (NRC) licensing process for AVLIS. Since the GAO draft report was prepared, NRC has indicated that it will require the identification of an applicant before commencing any licensing activities. Further, Public Law 101-575, which established new licensing procedures under 10 CFR Part 70 applicable to uranium enrichment plants, provides for receipt of a

combined construction and operating license and, therefore, completion of more detailed design at the time of license application. These developments make it essential that a Government corporation that can be an applicant be formed as soon as possible and commence the design and safety analysis work required. If that is accomplished by the start of FY 1992, DOE estimates that a license application submittal could now occur by early 1994. Assuming NRC review in two years, which DOE still considers a viable and appropriate duration, an initial AVLIS production plant could commence operation by 1999-2000, depending upon the size of the plant built. DOE plans to work with NRC to develop the earliest schedule for licensing and deployment of a commercial U-AVLIS production plant.

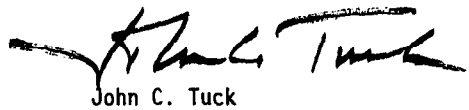
Finally, GAO believes that because delays are likely in the earliest possible operation of a production plant, the decision to commit to construction should be delayed. GAO goes on to make the statement that, if delayed, AVLIS will miss the "window of opportunity" to capture the large amount of uncommitted demand that will develop in the post-1995 time period. We strongly disagree with this logic.

The AVLIS technology has a very high probability of commercial success, because the cost of production from an AVLIS plant continues to be projected to be about half of the production cost from any other enrichment process being used in the world. This cost can effectively provide a significant competitive advantage that can result in greater sales and increased earnings to the enrichment enterprise. Deployment of the AVLIS technology as soon as market conditions allow is the most effective means to generate higher returns on an early basis. We expect that a large amount of uncommitted demand will be available in the future on a continuing basis, and AVLIS can be successfully applied to capture these sales. Therefore, the need to complete technology demonstration as soon as possible to support a deployment determination is vital to the future business interests of the enrichment enterprise.

In conclusion, it would be appropriate for GAO to revise its report to reflect the comments we have made and recent policy changes by the Administration that affect the U-AVLIS program.

Minor editorial changes have been presented to GAO under separate cover. We hope that the comments in both letters will be helpful to GAO in their preparation of the final report.

Sincerely,



John C. Tuck

Enclosures

Enclosure 2

Critique of General Accounting Office's (GAO) Technical Concerns

The following presents the Department of Energy's (DOE) review of the technical concerns about the Uranium-Atomic Vapor Laser Isotope Separation (U-AVLIS) program raised in Chapter 2 of the GAO report "Uranium Enrichment: DOE Should Delay The Decision on Building an AVLIS Plant."

The U-AVLIS Demonstration Project Will Not Resolve Technical Uncertainties

As stated in the "Plan for Demonstration, Transition and Deployment of U-AVLIS Technology," the primary goal of the 1992 demonstration is to reduce the technical and cost uncertainties to a level that supports a credible projection to plant cost, schedule, and performance. To fully demonstrate all aspects of plant performance prior to a determination to deploy would represent a very costly and nonproductive approach of total risk avoidance. We estimate that to do so would cost an additional $150 million to $200 million to maintain a large technical program and staff in support of a continued full-scale development and demonstration test program. This would delay a deployment determination by 2 years and constrain timely introduction of the U-AVLIS technology in a market where cost competitiveness is essential for future sales success. It should be noted that our 1990 U-AVLIS plan did allow for additional component testing of lasers, separators, and other special equipment on a limited, selective basis for another 2 years after September 1992 to verify performance and reliability prior to the final design freeze in 1994. After a careful evaluation of all of the issues, we developed a technology demonstration program that was designed to address all technical and economic issues on the most prudent, balanced basis.

By September 1992, full-scale separators, lasers, and product processing equipment will be tested in both integrated and off-line demonstration facilities. The feed processing effort will utilize less than full-scale equipment but of such a size that extrapolations to full scale are reasonable. As described below, the technology demonstration test that will be completed in 1992 will firmly establish the technical performance of the process in full-scale equipment for prolonged periods of time. In addition, a sound basis for extrapolating plant economics will be possible based on demonstrated performance, purchase of plant-scale components for the technology demonstration, and completion of a detailed conceptual design.

As part of the evaluation of the economics of the U-AVLIS process, we have considered the impact on plant costs even if there were no further improvements made in component performance and reliability beyond that demonstrated by the end of FY 1992. This would be equivalent to estimating the cost in a zero risk environment. For example, the following table compares the projected goals for the 1992 demonstration in terms of the plant requirements and the Separative Work Unit (SWU) cost impact if values demonstrated in 1992 were the best that could be achieved in a production environment.

TECHNICAL PARAMETER	DEMONSTRATED VALUE (% OF PLANT)	PERCENT INCREASE IN SWU COST USING DEMONSTRATED VALUE
Copper Laser Power	80	3
Optical System Efficiency	80	3
Separator Run Time	50	16
Copper Laser Capital Cost	200	7

If the demonstrated value for the above parameters were the best ever achieved, the estimated cost of producing separative work using the U-AVLIS technology could potentially increase to about $50 per SWU. Even at this higher cost, U-AVLIS would be a highly competitive uranium enrichment process.

However, we have sound reason to believe that there will be further improvement in component performance and reliability beyond the values firmly demonstrated. In fact, we are confident that continued improvement beyond the demonstrated values can be achieved in a relatively short period of time. Basically, no major technological barriers exist, and improvements through standard engineering practices are expected. The extrapolation from demonstrated values to production conditions is highly probable, because all but 2 of about 10 critical factors will be demonstrated at at least 80 percent of plant requirements by the end of 1992. One of these parameters, the separator run time, will be demonstrated prior to submitting a license to the Nuclear Regulatory Commission (NRC). The other, the laser illumination rate, has been the subject of detailed review for the past 6 years, and the uncertainties associated with the parameter are small.

Reference is made in the GAO report to NRC staff comments that point out that U-AVLIS has not yet enriched uranium using full-scale equipment and that unforeseen difficulties usually occur in equipment scaleup. We would like to highlight the fact that large-scale enrichment demonstrations of the U-AVLIS separator and laser equipment were carried out in the 1987 through 1988 timeframe. The results were then exhaustively reviewed by the independent DOE Technology and Engineering Review Group (TERG) with the general conclusion that enrichment performance uncertainties had been reduced to less than 25 percent. While unforeseen difficulties should always be anticipated in the deployment of new technologies, we believe that large-scale demonstration tests involving the U-AVLIS technology have been sufficient to date to make it unlikely that these difficulties will be of major significance. Finally, the integrated technology demonstration program that is planned for completion in 1992 will reduce the potential uncertainty in enrichment performance to less than 10 percent. The major performance issue that will not be completely demonstrated relates to the laser illumination rate. The scaling laws for that parameter have been obtained using detailed process physics codes that are considered to be accurate to within 10 percent. As part of the demonstration effort, further confirmation by September 1992 of these scaling laws will be obtained by conducting enrichment experiments at various illumination rates.

Demonstration Lasers Will Not Operate At Production Levels

Copper Lasers

DOE's laser program has two major goals related to testing and demonstration that will be accomplished by the end of FY 1992. The first of these is to supply laser light with the appropriate plant-scale characteristics such as wavelength, beam quality, etc., to the separator for enrichment experiments. The characteristics of the supplied laser light, which are measurable, must be identical with those projected for the plant. The existing laser system installed and operating in the Laser Demonstration Facility (LDF) will provide this laser light at levels needed in a plant-scale environment.

The second goal is to demonstrate the operation of the plant prototype laser system, a more advanced technology level than is currently being used in the LDF. Testing of a development unit of the advanced copper laser has recently achieved plant power levels for short periods of time (approximately 24 hours). Additional testing on the development unit is scheduled for the remainder of FY 1991. Experience from the startup of the existing laser system indicates that as newly engineered systems are brought up to operating conditions, it takes about 12 months of operational time to achieve the power level demonstrated in developmental units. By November 1992, the advanced laser system will have been subjected to about 6 months of testing at 80 percent or greater of that projected for plant requirements. If the power levels of the advanced copper lasers installed in the plant were limited to the 1992 demonstration goal (i.e., 80 percent of plant goal), then the plant SWU cost would increase by only about $1 per SWU.

Laser Illumination Rate

GAO criticized the Department for planning to make a decision on deploying the U-AVLIS technology based on demonstrations at illumination rates significantly below plant requirements. Outside, independent experts have reviewed this issue periodically over the last 6 years and have concluded that the scaling relationships are straightforward and would represent only a minimal risk to full plant projections. The GAO report indicates that as of October 1990, the Lawrence Livermore National Laboratory (LLNL) was considering options to increase the illumination rate. This consideration was merely the result of a continuing effort by LLNL to seek means to more closely approximate plant illumination rates. In fact, since the October meetings with GAO, LLNL has conducted experiments to show that illumination rates in the demonstration tests will be significantly increased to more closely approach those required for a plant. The installation of additional lasers in the demonstration system would be needed to increase illumination rates to levels needed in a production plant. The additional cost and time required to accomplish this is unwarranted, because, as stated previously, the scaling for extrapolation uncertainties from the demonstration test results of illumination rates are small.

Optical System Efficiency

We believe that the expected demonstrations of optical system efficiency of 80 percent is sufficient to estimate plant economics. In fact, if the plant optical system efficiency was limited to the 1992 demonstration goals, the plant SWU cost would increase by only about $1 per SWU. Also, the use of the optical fiber technology that LLNL is pursuing to achieve production plant

goals does not require a major development effort since the components of the fiber optics systems are available and are being engineered to meet the specific U-AVLIS requirements.

Off-line Laser Demonstrations

GAO highlighted that certain laser testing is to be conducted off line, but did not clarify whether this is good or bad. The demonstration plan recognizes the fact that testing of laser systems, without using the light to enrich uranium, does provide valid demonstration of the lasers. This is because characteristics of the laser light required to efficiently ionize uranium-235 are known, and these characteristics are easily measured. Thus, the off-line demonstrations of the laser will provide data that enable projections of enrichment performance while avoiding the cost of constructing and operating the laser system and integrating the light with the separator.

Separators May Not Be Adequately Tested

GAO states that LLNL will not produce enriched uranium using a commercial prototype of the U-AVLIS separator before the 1992 demonstration, and that only a limited amount of separator testing time will be available at the end of FY 1992. We disagree with this statement, since a plant-scale separator is currently being tested in an off-line test facility. Based on these tests, the separator system is undergoing design iterations before the first separator is installed in the mainline demonstration system, the Uranium Demonstration System (UDS), within the next few months. Approximately 6 months of separator testing in the UDS separator will precede the enrichment tests that are planned to occur between December 1991 and March 1992. Demonstrations using three of these separator units are planned to begin in May 1992 and have a goal of demonstrating 50 percent of the projected plant separator run time. The engineering and operational feasibility of the separator pod will be clearly established by the end of FY 1992. Additional separator testing will verify the projected run times and reliability and validate production plant economics.

However, even if the separator run time were limited to the 50 percent value projected for the demonstration effort, then the plant SWU cost would increase by only about $6 per SWU.

DOE Has Only Recently Begun To Address Needed Fuel Cycle Changes

The GAO report indicates that DOE has only recently begun to address needed fuel cycle changes. This is not the case. In the summer and fall of 1985, shortly after the DOE decision to select U-AVLIS as the enrichment technology for the future, DOE hosted meetings with converters and fuel fabricators. The purpose of these meetings was to acquaint industry with the U-AVLIS process and to discuss whether future modifications, if any, in the fuel cycle would be needed. These initial meetings led to a series of site visits and discussions with all of the domestic and foreign converters and fuel fabricators. Based on the information gathered in these meetings and an evaluation of alternative processes for converting uranium ore to metal and enriched metal product to fuel, we prepared a strategy for integrating U-AVLIS production into the nuclear fuel cycle. This strategy is designed to minimize the impact on utilities, feed convertors, and fuel fabricators during the initial deployment, while promoting the long-term objective of feed and product interfaces that

maximize the economic and environmental benefits of a mature U-AVLIS technology.

For feed conversion, the entry strategy is for utilities to continue their current practice of purchasing uranium ore and for DOE to arrange for conversion to metal utilizing existing industry capability. There is sufficient existing domestic and Canadian production capacity to supply feed to a nominal 6 million SWU AVLIS plant. For U-AVLIS production levels beyond 6 million SWUs, the existing feed conversion capacity would have to be expanded. Such an expansion by feed converters is expected to represent a low risk investment that the existing industry could easily make. As an alternative, we plan to demonstrate an improved feed conversion process by September 1992 that would have potential economic and environmental advantages compared to the current process. After demonstration, this improved process would be made available for transfer and use by the private sector.

The strategy for product conversion is for the U-AVLIS plant to include the capability to convert uranium metal to uranium hexafluoride for those who require it and to provide uranium trioxide directly to those who will accept it. For the longer term, the goal is to provide the technology and the demonstrations that would permit the delivery of uranium trioxide product to the fuel fabricators.

Although feed and product development and demonstration have lagged behind laser and separator efforts, this is in part because the issue is not feasibility but optimization. The economics of AVLIS are not expected to depend on feed and product conversion costs, although there are indications that successful efforts can further reduce AVLIS' projected low cost.

The GAO report criticizes DOE for not deciding where the fuel cycle processes will be performed. It is DOE's position that it is premature to make such decisions without carefully considering the various options available and, most important of all, to have inputs from both the utilities and the companies that provide fuel cycle services. It would be inappropriate to make any decisions as to the placement of the facilities to provide these services without consulting with those companies.

U-AVLIS Will Require Front-End Uranium Processing Changes

Feed conversion operating facilities currently exist in the industry that can provide feed for an initial 6 million SWU U-AVLIS plant. Also, the existing feed conversion industry could expand this capacity with a low risk investment to provide feed for additional U-AVLIS plant production. Therefore, no major changes will be required for the feed conversion industry to support an initial U-AVLIS plant.

The advanced technology we are developing for feed conversion to a U-AVLIS plant can potentially provide significant cost and environmental benefits. While this advanced technology is desirable, it is not necessary for initial U-AVLIS deployment. Nevertheless, sufficient data will be available from the on-going experimental program to allow a detailed evaluation of the process and its economics by the end of FY 1992. DOE has long planned to initiate a formal relationship with the domestic fuel conversion industry in 1991 in order to identify prior to September 1992 whether the industry would prefer to expand existing capacity or invest in the advanced feed conversion process.

Because industry today has the capability to provide uranium metal, it is clear that providing feed for an initial U-AVLIS plant will not be an issue. Schedules have been developed that would allow for expansion of this capacity with the improved technology to meet the requirements for increased U-AVLIS production. However, industry would make their own decisions on whether to expand existing capacity or implement the improved process that DOE will demonstrate by September 1992.

U-AVLIS Will Require Back-End Conversion Changes

Our plan for back-end conversion of U-AVLIS product includes the installation of equipment using well understood technology as part of an initial U-AVLIS plant that would convert uranium metal product to the uranium hexafluoride form that is currently used by the industry to fabricate nuclear fuel. The cost of this product conversion equipment has already been factored into our cost estimate for a U-AVLIS production plant. We also intend to demonstrate an improved product conversion process by September 1992 that offers economic and environmental advantages that the industry could utilize in the future. Thus, no change will be required by the industry for the back-end conversion of product from an initial U-AVLIS plant. Also, the availability of an improved product conversion product in the long term will be an option that industry can exercise at its discretion to support additional U-AVLIS production capacity.

We also intend to use existing industry capabilities to the maximum extent possible in order to integrate the U-AVLIS product into the nuclear fuel cycle. A cooperative program has been in place since 1989 with fuel fabricators that have focused on the identification of the best means to do this. As a result of this program, we found that the existing industry capacity is limited and can only support a 2 million SWU U-AVLIS plant. About 50 percent of this capability exists in the United States, and the remainder is available from foreign companies. Therefore, our plan includes a commitment to install process equipment at the initial U-AVLIS plant to convert uranium metal (the product from U-AVLIS enrichment) to uranium hexafluoride, which is the standard enrichment product form used today by fuel fabricators. This process is well understood and used in industry today for the conversion of natural uranium, and its application to enriched uranium conversion should be easily achieved. Even though we are prepared to install this product conversion process equipment as part of an initial U-AVLIS production facility complex, as part of our cooperative program with the fuel fabricators, we will offer industry the opportunity to install this equipment and provide this capability in the private sector. In either case, the integration of U-AVLIS product into the nuclear fuel cycle will be adequately addressed for the initial U-AVLIS production plant.

Another element of our plan to integrate U-AVLIS product into the nuclear fuel cycle involves the development of an improved process in terms of economics and environmental factors that would generate reactor-grade uranium oxide directly from uranium metal product. We plan to fully demonstrate this improved process in plant-scale equipment by September 1992. The reactor-grade uranium oxide generated by the demonstration program would undergo in-reactor testing in order to confirm that it meets existing industry standards and requirements for reactor fuel. At this time, we do not know how extensive the testing program will have to be in order to satisfy fuel fabricator warranty requirements. It is currently estimated that the most rigorous testing program, if required, could be accomplished in 6 to 8 years with full implementation of this product conversion process in the nuclear fuel cycle within 8 to 10 years. However, as

part of our cooperative program with the fuel fabricators, they will identify the exact requirements and schedule needed for in-reactor testing by the end of September 1992.

NRC Licensing Could Substantially Delay U-AVLIS

GAO reported that NRC stated that a serious safety concern is control of enriched uranium vapor in case of a rupture in the vacuum vessel. This concern represents a misunderstanding by NRC or the GAO. The total vapor inventory of an entire U-AVLIS plant is less than one gram of uranium.

GAO also raised concerns about the duration that may be required for a Nuclear Regulatory Commission (NRC) licensing process for AVLIS. Since the GAO draft report was prepared, NRC has indicated that it will require the identification of an applicant before commencing any licensing activities. Further, H.R.4808, which established new licensing procedures under 10 CFR Part 70 applicable to uranium enrichment plants, provides for receipt of a combined construction and operating license and, therefore, completion of more detailed design at the time of license application. These developments make it essential that a Government corporation that can be an applicant be formed as soon as possible and commence the design and safety analysis work required. If that is accomplished by the start of FY 1992, DOE estimates that a license application submittal could now occur by early 1994. Assuming NRC review in two years, which DOE still considers a viable and appropriate duration, an initial AVLIS production plant could commence operation by 1999-2000, depending upon the size of the plant built. DOE plans to work with NRC to develop the earliest schedule for licensing and deployment of a commercial U-AVLIS production plant.

The remainder of Chapter 2 is no longer relevant because of program decisions reflected in DOE's FY 1992 budget submission.

Major Contributors to This Report

Resources, Community, and Economic Development Division, Washington, D.C.

Judy A. England-Joseph, Associate Director
Robert E. Allen, Jr., Assistant Director
Mary Ann Kruslicky, Assistant Director
Ronald E. Stouffer, Assignment Manager
William J. Mohan, Evaluator-in-Charge

Related GAO Products

Comments on Proposed Legislation to Restructure DOE's Uranium Enrichment Program (GAO/T-RCED-91-33, Apr. 10, 1990).

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