AVLIS

Production Plant

Project Schedule and Milestones

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AVLIS Production Plant Project Schedule and Milestones

MARTIN MARIETTA
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Prepared by the AVLIS Program with major
contributions from Bechtel National,
Incorporated.

**Bechtel National
Incorporated**

1. EXECUTIVE SUMMARY

1.1. INTRODUCTION

An AVLIS Production Plant Deployment Schedule for the engineering, procurement, and construction for both the Initial Increment of Production and the fully Activated Plant, has been developed by the project team consisting of Lawrence Livermore National Laboratory, Martin Marietta Energy Systems, Inc. with architect-engineer support from Bechtel National, Inc., Stone & Webster Engineering Corporation, and Westinghouse Corporation. The project team has integrated the ongoing research and development activities, the AVLIS Program engineering demonstrations in the Full Scale Demonstration Facility, and the production plant design/construction schedules for the initial increment of production. The initial deployment phase consists of six separators modules and the three laser power amplifier modules consistent with the FY84 reference design with a name plate capacity of 5 million separative work units/yr followed by a full plant activation to approximately 13 million separative work units/yr.

The AVLIS Production Plant project team's strategy for deployment schedule analysis focused on three schedule options:

- o Engineering Limited Schedule -- Aggressive from an engineering and construction standpoint.
- o Authorization Limited Schedule -- Aggressive from the Department of Energy schedule standpoint.
- o Funding Limited Project Schedule -- Normal planning schedule viewpoint for a Department of Energy project.

Figure 1-1 displays the three deployment-schedule options. The three deployment schedule options developed by the AVLIS project team have been classified in ranges such as as optimistic, rapid/moderate, or moderate/pessimistic based on the probability of meeting the individual

FY	86	87	88	89	90	91	92	93	94
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"Engineering Limited Schedule"

"Authorization Limited Schedule"

"Funding Limited Project Schedule"

Fig. 1-1. Deployment Schedule Options.

schedule option's major milestones or program objectives of enriching uranium by the AVLIS process in an effective cost and schedule manner. The project team has classified each schedule option by considering the following:

- o Confidence in key assumptions/durations.
- o Optimism or conservatism.
- o Fixed price contracts for some or all construction packages.
- o Normal or accelerated review and approval cycles.
- o Major program commitment to rapid deployment.
- o Cash flow scenarios.
- o Availability of qualified personnel.
- o Technology improvements currently and planned.

The classification range of the three deployment schedule options, based on the above considerations, is as follows:

- o Engineering Limited Schedule -- Optimistic.
- o Authorization Limited Schedule -- Rapid/Moderate.
- o Funding Limited Project Schedule -- Moderate/Pessimistic Range.

1.1.1. Summary and Conclusions

During the preparation of the AVLIS Production Plant schedules, those key factors that can impact Department of Energy project schedules were evaluated to insure that the AVLIS Plant deployment could be achieved. Factors that drive Department of Energy project schedules which were included in the schedule analysis include the following:

- o Requisite research and development schedule constraints.
- o Dependency on operating funds.
- o Historical experience on design, procurement, and construction durations.
- o Procurement lead times on equipment.

- o Logical sequence of design, procurement, and construction.
- o Reasonable obligation and costing rates.
- o Reasonable manpower levels, build-up and ramp-down.
- o Shift work or overtime work requirements.
- o Work place space constraints.

Logic networks were prepared for the AVLIS Production Plant to tie all important activities and their related phases (design, procurement, construction, start-up, operation) to interrelated systems for all major AVLIS equipment/ systems. The logic networks also combine the key technology-release information from the AVLIS program demonstration facilities to the associated plant systems. The project activity durations for all project phases for key plant systems, were prepared by knowledgeable engineers of plant system specifics (design and cost), were bench-marked against similar project schedules, were reviewed/supported by respective organizational management and joint Martin Marietta Energy Systems, Inc./Lawrence Livermore National Laboratory project team, and then integrated with the logic network to establish the overall project schedule. These networks and durations were then evaluated against the Department of Energy project schedule drivers and adjusted as necessary. The detailed schedules, supporting assumptions, and back-up information establish a solid scheduling base for the AVLIS Production Plant. The realism of the schedule durations, the logic network tied to technology availability, when combined with the appropriate deployment assumptions, has resulted in an overall AVLIS Production Plant schedule that is aggressive but attainable. Further, when the overall AVLIS Production Plant schedule and specific subsystem schedules are compared against other similar project schedules, appropriate confidence is established that the AVLIS Production Plant deployment schedule will be achieved.

Department of Energy studies indicate that a delay in the deployment of AVLIS of one month will decrease the present net value of AVLIS of at least \$400 million per year. At this rate of loss, no plausible technology improvement can achieve a benefit to cost greater than unity, thus motivating delay. The additional funding needed to pursue the Engineering Limited

Schedule is less than \$100 million over FY85-86. We are strongly motivated to act on this plan.

On the other hand, in spite of the benefit, it is not likely that the conditions necessary to support the Engineering Limited Schedule will be in place when needed. This program requires clear and timely direction and adequate funding. Pragmatically, the Authorization Limited Schedule is more probable. This case is featured in our production documents.

The three schedule cases presented in this document respond to both varying levels of schedule confidence and alternative ways of meeting the deployment objectives within the constraints of cash-flow and market-demand. Unfortunately we have not received updated cash flow and market demand data. Although we believe that the options presented include the full range of schedule options, the schedules presented probably do not represent optimum deployment from a financial point of view. Given the detailed constraints, we will adjust the details of the deployment to improve the AVLIS net present value.

The major engineering, procurement, and construction activity fiscal year and quarter start dates and durations for each option are listed in Table 1-1.

Table 1-1. Milestone data and activity duration for Engineering, Authorization, and Funding Limited Schedules.

Activity	Engineering Limited Schedule	Authorization Limited Schedule	Funding Limited Schedule
<u>Milestone Data</u>			
Significant Engr. start	86-1	86-1	87-1
Procurement start	87-1	88-1	88-3
Construction start	87-1	87-1 ^a	88-1
Initial operation	90-1	91-1	92-1
Six modules operational at 95% plant capacity	92-1	93-1	95-1
<u>Activity Duration</u>			
Engr. duration	33 mo.	39 mo.	45 mo.
Procurement duration	39 mo.	42 mo.	45 mo.
Construction duration	51 mo.	63 mo.	63 mo.
Total duration from significant engr. start to the initial operation of module #6	63 mo.	75 mo.	87 mo.

^a Limited construction activities during the initial six months (mobilization, fencing, minor utility relocation, and limited site work).

The project team has selected the Authorization Limited Schedule for the most detailed analysis because it represents a reasonable and prudent pace for technology development, design engineering, procurement, construction, and start-up. This schedule requires commitment by all Department of Energy and program participants to achieve the production deployment schedule. The project team has reviewed the Authorization Limited Schedule and lower-tier schedules, and is confident that this mid-range schedule of major activities

is attainable with reasonable confidence based on present assumptions. This is based on a strong Department of Energy commitment to the development efforts and facilities needed at a basis for the plant design and equipment test.

1.2. BASIS OF THE AUTHORIZATION LIMITED SCHEDULE

Lower-tier schedules for the AVLIS Production Plant Authorization Limited Schedule are consistent with the overall master schedule (Fig. 1-2). The lower-tier schedules are based on the successful completion of several key technological objectives established by the joint Lawrence Livermore National Laboratory/Martin Marietta Energy Systems, Inc. development team. The lower-tier schedules are based on major Department of Energy decisions and/or authorizations through the project life that are critical to meet project milestones, specifically:

- o AVLIS process selection, FY85
- o Title I Engineering authorized, FY86
- o Title I and II Engineering overlap
- o Construction authorized, FY87
- o No funding restraints after management plan approval
- o High level of commitment at Department of Energy-Headquarters, Department of Energy-Oak Ridge Office, Department of Energy-San Francisco, Lawrence Livermore National Laboratory, and Martin Marietta Energy Systems, Inc. to achieve early production from the AVLIS Plant.

The lower-tier schedules were prepared on the basis of the contract work breakdown structure. The project master schedule and supporting lower-tier schedules incorporate work package summaries, milestones, intermediate milestones, logic diagrams, key design and procurement events, construction, fabrication, and production ramp-ups.

Initial increment of production

Fig. 1-2. Authorization Limited Schedule - Master Schedule.

The schedules are based on early conceptual and Title I engineering, proceeding in parallel with the development effort with a closely integrated technology/engineering team interaction. Additionally Title I preliminary design is planned to be performed in parallel with Title II detail design during part of FY86 for those design activities associated with the construction critical path, beginning with conventional facilities. The parallel Title I and Title II design activities will permit the preparation of an early construction activity bid package, the time necessary for bid response and analysis, and selection completed in sufficient time for the key milestone of Authorization/Initiation of construction as a line item at the start of FY87. The Title I design report would be completed and submitted during the first quarter of FY87.

The AVLIS Production Plant technology objectives, which closely couple with the AVLIS Production Plant engineering and construction schedule, include several key performance/cost demonstrations in the FY86-87 time frame. These demonstrations are dependent on the successful completion of three essential system projects, each of which will operate fully integrated systems to demonstrate production cycle operations and obtain life-cycle data. These are:

- o Materials Handling Demonstration Module -- fully integrated materials handling at scale.
- o High-Performance Laser Facility -- fully integrated laser life cycle at scale.
- o Full-Scale Demonstration Facility -- fully integrated process performance at scale.
 - Laser Demonstration Facility.
 - Separator Demonstration Facility.

The baseline plan for completion of the AVLIS Production Plant project for the initial increment of production will span seven years from project engineering authorization at the start of FY86 to the first year of full production at capacity achieved (5 million separative work units/yr) by FY93. This assumes that first, the modules will be put into operation individually with initial operation of the first unit scheduled early in FY91, four years

after project construction authorization, and second, the production ramp-up schedule thereafter is based on deployment of a module nominally every three months. There is an intermediate operational milestone providing three million separative work units per year by the first quarter of FY92, six years after significant engineering authorization.

As discussed above, several key development milestones established by the AVLIS Program must be accomplished to support the AVLIS Production Plant schedules. These technology milestones and the plan for deployment form the basis for the AVLIS Production Plant schedules, from conceptual design in FY85 to initial increment of production achieved by the end of FY92. During this period, many activities must be closely coordinated. These include design, procurement, construction, fabrication, training and preassembly, installation, and start-up. The AVLIS Production Plant master schedule displays the planning schedule with emphasis on major activities, starting with construction authorization in FY87. Several parallel tasks are near the critical path in order to meet schedule objectives. The most important of these are:

- o Process building construction completed in phased sections to take advantage of the laser and separator refurbishment areas for equipment preassembly and training.
- o Laser and separator major procurement issues for long lead equipment that requires vendor qualification are included on the critical path to satisfy the production rates necessary to meet the deployment buildup of the six modules.
- o Included on the critical path are the separator process vessel and laser/separator refurbishment (assembly) equipment. These items are near the critical path starting with design, initiating procurement, and finally to equipment/systems installation, checkout, and activation.

Task durations shown on the AVLIS master schedule are based on the project team's past and present experience with similar activities or equipment. Utilization of important system-design features for the special

laser isotope separation equipment for the Full Scale Demonstration Facility with later transition to the AVLIS Production Plant can best assure the success of the overall AVLIS schedule. The operational prototype for the primary AVLIS Production Plant hardware will be in the Full Scale Demonstration Facility. This prototype will establish the essential designs, vendor base, certain construction basis, system start-up information, and form a strong operational base.

One of the primary determinants in the process of planning a project schedule is the procurement cycle. As part of the conceptual engineering effort, a preliminary evaluation was made of the timing for issue of major procurement packages.

The schedules developed for the AVLIS Production Plant line-item project were based on key engineering activities in FY84-86. These engineering activities begin in FY84 with a preconceptual engineering design effort three years prior to construction project authorization. In FY86, a significant engineering only line item authorization will be required for Titles I and II designs during FY86 and FY87.

The Authorization Limited Schedule project milestones and major-element intermediate milestones were reviewed by the architect-engineers forming part of the AVLIS project team. Bechtel National, Inc., prepared a Title I and Title II engineering design schedule with design keyed to the master schedule and design release dates established to meet construction requirements. The construction lower-tier schedule logic and activity durations have been reviewed by Stone & Webster Engineering Corp., Bechtel National, Inc., and Martin Marietta Energy Systems, Inc.

1.3. AVLIS DEPLOYMENT PLAN: PLANTS 1 and 2

The continuation of Department of Energy's strong commitment to the AVLIS program, and the continuation of a low-cost enrichment process require the authorization and initiation of a second plant, that would use the AVLIS process. The second plant would be started later in the FY80s. Figure 1-3. illustrates the major activities associated with the AVLIS production plan for Plant 1 as well as the second plant (Plant 2) to be constructed, initial operations started, and expanded early in the year 2000.

Figure 1-4 displays the AVLIS deployment strategy compared to U.S. sales production of enrichment services, and establishes the best AVLIS deployment strategy to accommodate the U.S. sales projection of uranium enrichment. The current U.S. production of enriched uranium sales to domestic, foreign, and military customers is approximately 15 million separative work units in 1985. This number rises to approximately 20 million separative work units per year through the 1990s, and rises again from 20 million separative work units per year to approximately 30 million separative work units in the year 2000. The U.S. sales projection is shown on this figure as the top solid line. The AVLIS deployment strategy utilized current technology and equipment concepts being constructed in the full scale demonstration facility as the technical basis for the initial increment of deployment for the AVLIS Production Plant to permit early operation and production. The production begins in 1991 and quickly ramps-up to approximately 5 million separative work units per year. An upgrade of this production equipment performance and the addition of supplementary process equipment brings the overall plant performance from 5 million separative work units per year to approximately 13 million separative work units per year during the mid-1990 time frame. To meet the overall U.S. sales projection, a second AVLIS Plant will be constructed of the advanced performance equipment and will become operational in the mid-1990s. The total cumulative output is shown on the dashed line of the figure which matches the overall U.S. sales projection of enrichment extremely well. During the interim period, prior to significant AVLIS production, the U.S. sales can be met through the production capacity of the existing diffusion plants.

1980's					1990's										2000's										
4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9

Fig. 1-3. AVLIS Plant Deployment Schedule.

**Demand projections provided by the Office of Uranium Enrichment
on June 6, 1984**

Fig. 1-4. AVLIS plant production to meet U.S. sales projection.

2. AUTHORIZATION LIMITED SCHEDULE

This section describes the schedules and figures prepared for the Authorization Limited Schedule.

2.1. SCHEDULE AND FIGURES DESCRIPTION

The master schedule, shown in Fig. 2-1, displays the major project milestones and the Title I and Title II engineering activity and the associated intermediate milestones. The construction activity bar depicts the conventional facility which includes site work, utilities, and the process building. The procurement activity bar indicates the release of long lead general and special equipment for the six modules. A special equipment installation activity identifies the start of installing the unclassified equipment/systems followed by the installation of the classified area special equipment, the laser/separator assembly areas, and the last of the six modules construction activity completed. The operations activities includes start-up, module ramp-up operations, with the planned production achievements starting with initial operation of module number one to achievement of the initial increment of production of 5 million separative work units/yr with six modules.

The significant milestone dates, engineering, procurement, construction, and operations initiations, durations, and completions are shown below:

Table 2-1. Significant milestone dates for Authorization Limited Schedule.

Activity	Milestone
	Fiscal Year/Quarter
Engineering Initiated	86-1
Construction Authorized	87-1
Engineering Complete	89-2
Procurement Complete	91-2
Construction Complete	92-2
Production Initiated	91-1
Production Achieved	93-1

Initial increment of production

Fig. 2-1. Authorization Limited Schedule - Master Schedule.

<u>Activity</u>	<u>Month</u>
Engineering Duration	39
Procurement Duration	42
Construction Duration	63
Total duration from significant Engr. start to the initial operation of Module #6	75

2.1.1. Technology/Milestone Interrelations Schedule

The technology/milestone interrelations schedule, shown in Fig. 2-2, represents an effective and realistic plan for integration of laser and separator technology. The technology demonstration of the High-Performance Laser Facility, Full-Scale Demonstration Facility, and Materials Handling Demonstration Module provide the basis for the initial AVLIS Production Plant design. Their continuation will lead to laser and separator performance improvements, demonstration of production cycle operations, life-cycle data, and design data for the AVLIS Production Plant's planned six-module upgrade and the addition of two more upgraded modules, for a total of eight, which will constitute a fully activated plant capacity of approximately 13 million separative work units/yr.

2.1.2. Project Milestones

Figure 2-3 summarizes the major project milestones and intermediate milestones. Each milestone indicates the fiscal year and quarter needed to achieve that activity for the initial increment of production of the AVLIS Production Plant.

The major project milestones are part of the rationale for the updated AVLIS project plan, October 1984. These milestones form the basis for the planning schedules for design, fabrication, procurement, construction, and

Initial increment of production

☆ Major project milestones

Fiscal Year — Quarters	Milestones
85-1	Design documents for process selection
☆ 85-3	AVLIS process selection
☆ 86-1	Plant engineering authorized/initiated
86-1	Plant conceptual design documents
87-1	Plant Title I design reports
87-1	Plant site work (limited) design complete
☆ 87-1	Plant construction authorized/initiated
87-3	Plant conventional facilities design (0-1) primary structure
87-4	Plant general LIS equipment design comp/initiate proc (0-1) (separator chamber laser/separator assembly equip.)
88-1&2	Plant general LIS equipment design comp/initiate proc. (0-2) (laser mount assemblies, feed prep/ conv. equip., I & C computers)
88-1	Plant special LIS equipment (vendor qualification components)
88-3&4	Plant special LIS equipment design comp/initiate proc. (long lead hardware)
☆ 88-4	Plant special equipment installation initiated (unclassified)
89-1	Plant special LIS equipment assembly/fabrication details
89-2	Plant engineering complete
89-2	Plant conventional facility construction complete
89-2	Plant process building classified construction installation start
89-3	Plant gen. LIS procurement complete for module #1
90-1	Plant start-up of common systems & equipment
90-1	Plant spec. LIS procurement complete for module #1
90-1	Plant separator/laser assembly facilities construction complete
90-3	Plant central control system & support systems construction complete
90-4	Plant feed conventional/preparation facilities construction complete (initial)
90-4	Plant module #1 construction complete/start-up initiated
90-4	Plant general LIS equipment procurement complete
☆ 91-1	Plant initial operation from module #1
91-2	Plant product conversion facility construction complete (initial)
91-2	Plant module #2 initial operation
91-2	Plant special LIS equipment procurement complete
91-3	Plant module #3 initial operation
91-4	Plant module #4 initial operation
☆ 91-4	Plant production in FY 1991, 1MSWU
92-1	Plant module #5 initial operation
92-1	Plant 3MSWU/yr capacity achieved
92-2	Plant module #6 initial operation
92-2	Plant construction complete - capital project complete
92-2	Plant production in FY 1992, 4MSWU
☆ 93-1	Plant initial increment of production in FY 1993 — 5MSWU

Fig. 2-3. Authorization Limited Schedule - Project Milestones.

start-up activities for the Authorization Limited Schedule. As the design and planning effort proceeds in parallel with ongoing development activities, these fiscal-year milestones have been established to meet the overall objectives of the AVLIS Production Plant. The major project milestones, listed by their fiscal year and starting month are described below:

AVLIS Process Selection -- June 1985. The basis for the AVLIS Production Plant schedules are based on the successful analysis, evaluation, and selection of the AVLIS process by the Department of Energy for full demonstration and deployment. At the selection, it is assumed there will be clear direction, resources, and a high level of commitment at Department of Energy-Headquarters, Department of Energy-Oak Ridge Office, and Department of Energy-San Francisco to achieve early production from the AVLIS Production Plant. The selection in mid-year 1985 would permit the Contractor Project Organization (Lawrence Livermore National Laboratory/Martin Marietta Energy Systems, Inc.) to proceed with the preparation of the project management package. This management package will be prepared for the AVLIS Production Plant to establish the management approach/structure to accommodate Department of Energy requirements for a major system acquisition and at the same time assure project technical success. The project management package includes the following:

- o Project management plan.
- o Contract work breakdown structure.
- o Technical scope of work.
- o Responsibility assignment matrix.
- o Time-phased budgets.
- o Project reporting plan.
- o Major systems acquisition documentation.
- o Architect-engineer selection criteria.

Engineering Authorized/Initiated -- October 1986. A key project milestone is the initiation of Title I and II engineering design the

first of FY86 through the engineering only line item authorization. This process would result in the selection of an architect-engineer to perform Title I and limited Title II design for LIS equipment and systems and full Title II design on conventional facilities and certain long-lead equipment.

Construction Authorized/Initiated -- October 1987. A key project deployment milestone is the initiation of construction of the AVLIS Production Plant conventional facilities in the first of FY87 through the AVLIS Production Plant line-item construction authorization. This will provide approximately \$130 million in FY87 to continue Title II engineering, to initiate conventional facility construction, and to initiate long-lead procurement for certain general LIS equipment such as the separator module, vacuum vessel, and the plant control and data acquisition system central computer and software package. Only limited construction, mobilization and sitework will commence early in FY87.

Special Equipment Installation Initiated -- July 1988. The special unclassified equipment installation would be initiated for certain equipment such as laser and separator refurbishment, front end of the Uranium Processing Facilities such as Feed Preparation and Conversion Facility.

Plant Engineering Design Complete -- January 1989. The Title II detail engineering will be complete by start of the second quarter FY89. The last phase of engineering effort will conclude with the final issue of special LIS equipment assembly and fabrication details. There is a planned overlap of engineering personnel assigned to assist Title III construction on interpreting drawings and specifications and providing other construction support.

AVLIS Production Initiated -- October 1991. Start-up activation will have been completed by the end of FY89 for all equipment and systems that support the first module in the AVLIS Production Plant. The module will become operational at the first of FY91 for the initial increment of enrichment operations. All prerequisite milestones that must be accomplished from operation training/certification (the operational

safety reviews, the integrated systems testing, etc.) will be completed prior to this operational milestone.

Full Initial Increment of Production Capacity Achieved -- October 1993.

The equipment necessary to increase the AVLIS Production Plant capacity to an effective capacity of 5 million separative work units per year will have been operational to complete that phase of the AVLIS deployment strategy identified as the Initial Increment of Production. By the end of FY92 there will be six separators and three laser power amplifier modules installed and operational.

The schedule and design assumptions, shown in Fig. 2-4, itemize key elements that form the basis for the Authorization Limited Schedule. This list of schedule and design assumptions are backup for the probability classification range of the baseline schedule as rapid/moderate.

The Title I and II engineering schedule, shown in Fig. 2-5, was prepared by Bechtel and is organized by work breakdown structure and the project milestone dates. Figure 2-5 is a summary of a much more detailed schedule prepared by Bechtel's engineering organization and has supporting data of engineering only staffing to ensure that the schedule is attainable. Design assumptions were provided by Bechtel and form a portion of the schedule assumptions. The conventional facilities engineering activities were based on drawings prepared by Stone and Webster Engineering Corporation and design data for the Uranium Processing Facilities were provided by both Martin Marietta Energy Systems, Inc. and Bechtel.

Figure 2-6 illustrates that the projected laser development of ongoing technology improvements will continue to decrease laser-system cost by increasing dye-laser-chain conversion efficiency, increasing copper laser output power, increasing copper laser electrical efficiency, and extending copper laser lifetime through the 1990s.

Figure 2-7 illustrates that the projected separator development of on-going technology improvements will continue to decrease separator system cost by optimizing the separator refurbishment, optimizing the vaporizer efficiency rate and extension of separator run cycle through the 1990s.

- o Perform significant conceptual design prior to engineering authorization including extensive pre-project critical path method scheduling.
- o Highest level of commitment at Department of Energy-Headquarters, Department of Energy-Oak Ridge Office, Department of Energy-San Francisco, Livermore National Laboratory, and Martin Marietta Energy System, Inc. to achieve early production from the AVLIS Production Plant.
- o Utilize full scale demonstration facility designs to the extent possible.
- o Commence Title II prior to completing Title I design on critical path activities.
- o Utilize trained AVLIS team (Lawrence Livermore National Laboratory, Martin Marietta Energy Systems, Inc., Architect Engineers) to critical process substantial design activities.
- o Multiple shift engineering on critical path activities (selected items).
- o Utilize design-build contracts for all conventional facilities.
- o Procurement approach similar to that utilized for full scale demonstration facility (details dwgs. for copper laser and functional specifications for separator general laser isotope separation hardware) be utilized for plant.
 - Multiple vendors would be required for most hardware items.
- o Limit all bidders lists (procurement and construction) to demonstrated performers of similar activities/hardware.
- o Construction contract flexibility for critical path tasks.
- o Pay premium overtime for all construction activities.
 - Conventional facilities
 - Equipment/System installation
- o Expedite all/any phase of project activities that drive the critical path.
- o Train the start-up operations team on actual hardware in full scale demonstration facility; integrate key technical staff into the operation team.
- o During initial years start-up/operation, a key task force of technologist, analysis, engineers, operations personnel, and management focus on driving the plant availability and performance to mature operating levels.
- o One general contractor for entire construction phase.

Fig. 2-4. AVLIS Production Plant, authorization limited schedule--key schedule assumptions.

Design Assumptions

- o Title I & Title II design by same architect engineer
- o Primary engineering for selected architect engineers will be performed in architect engineers home office.
- o Significant engineering will be prepared by uncleared personnel. All key personnel will be Q cleared.

Fig. 2-4 (cont'd.).

Fig. 2-5. Authorization Limited Schedule - Title I and II.
Engineering Schedule

Fig. 2-6. Authorization Limited Schedule - Projected Laser Development.

Fig. 2-7. Authorization Limited Schedule - Projected Separator Development.

Figure 2-8 displays the planned ramp-up of the six modules. Starting in the first quarter of, FY91, the first module begins operation with each of the following five modules following nominally every three months. By the end of FY91 we will have produced 1 million separative work units, followed by approximately 4 million separative work units in FY92, and achieving the Initial Increment of Production of 5 million separative work units in FY93.

Figure 2-9 lists the major procurement issue dates and fiscal year and quarter action for elements of the separator, laser, uranium processing, and balance of plant. They form a composite list of procurement items scheduled on the lower tier schedules.

Figure 2-10 compiles the conventional facilities, special equipment/systems, and uranium processing facilities major procurement items into monthly time spans. The procurement activity starts at issue of procurement specification to vendor for quotation and spans the first to last delivery at jobsite. The basis of lead times was established by review of cost and schedule inquiries solicited for the FY84 capital costs basis document, use of similar-to lead times for conventional equipment, and on-going laser and separator technology project's purchase orders.

The Laser Procurement/Construction schedule, shown in Fig. 2-11, is a lower-tier schedule that identifies the procurement and construction activities of the major laser components required for the first module. Incremental deliveries of subsequent module requirements would be required at least every three months. Schedule durations from actual hardware deliveries associated with the Laser Demonstration Facility have been utilized to substantiate the Plant Schedule durations. The major laser element divisions portrayed are copper vapor laser, dye laser, optical system, instrumentation and controls, plus the refurbishment/test equipment. Activity bars, starting in 1987 fourth quarter identify the time spans for procurement, subassembly fabrication, installation and checkout completed by 1990 fourth quarter with system start-up following for the next three months and completing by 1991 first quarter when the first module is to be operational.

The Separator Procurement/Construction schedule, shown in Fig. 2-12, identifies the procurement and construction activities of the major separator components required for the first module. As with the laser, the separator

Fig. 2-8. Authorization Limited Schedule - Operational Ramp-up Projection.

● Separator System	
— Facilities & services	87-3
— Vacuum chambers	87-4
— Refurbishment (assembly) equipment	87-4
— Extractor power supplies	88-1
— Vaporizer power supplies	88-1
— I & C long lead equipment	88-1
— Refurbishment (recycle) equipment	88-2
— Vacuum systems	88-2
— Cooling systems	88-2
— E-gun/reflux structures	88-3
— Carriage assembly	88-3
— Chamber internals (rails-liners)	88-3
— Transport equipment	88-3
— I & C panel fabrications	88-3
— Accountability system equipment	88-3
— Extractor/product collection equipment	89-1
● Laser System	
— Facilities & services	87-3
— Refurbishment (assembly) equipment	87-4
— Mounting support structures	88-1
— CVL head qual. parts/assemblies	88-1
— CVL switch qual. parts/assemblies	88-1
— CVL power qual parts/assemblies	88-1
— I & C long lead equipment	88-1
— Optical components	88-3
— Dye laser components	88-3
— CVL head hardware	88-3
— CVL power hardware	88-3
— I & C panel fabrications	88-3
— Pointing & centering	88-3
● Uranium process facilities	
— Facilities & services	87-3
— Feed conversion — long lead equipment	88-1
— Feed preparation — long lead equipment	88-1
— Uranium recovery — long lead equipment	88-3
— Product conversion — long lead equipment	88-3
— Feed conversion — support equipment/system	88-3
— Feed preparation — support equipment/system	88-3
— Uranium recovery — support equipment/system	88-4
— Product conversion — support equipment/system	88-4
— Waste management — equipment/systems	88-4
● Balance of plant	
— Facilities & services	87-3
— Plant control — long lead	88-1
— Power — long lead	88-1
— Graphite shop — long lead	88-1
— Cooling system — long lead	88-1

Fig. 2-9. Authorization Limited Schedule - Procurement Issue Dates System/Major Equipment.

First module only

	FY		1987				1988				1989				1990			
	QTR		3	4	1	2	3	4	1	2	3	4	1	2	3	4		
Laser system																		
Copper laser																		
Dye laser																		
Optical system																		
Instrumentation and controls																		
Refurbishment																		
Separation																		
Vessel																		
Pod																		
Refurbishment																		
Instrumentation and controls																		
Uranium processing																		
Feed conversion																		
Feed preparation																		
Uranium recovery																		
Product conversion																		
Waste management facility																		

Fig. 2-10. Authorization Limited Schedule - Procurement Durations.

1st module details —

Fig. 2-11. Authorization Limited Schedule - Laser Procurement/Construction Schedule.

1st module details —

Fig. 2-12. Authorization Limited Schedule - Separator Procurement/Construction Schedule.

incremental deliveries would be required at least every three months to support the subsequent modules. A quotation provided by Chicago Bridge & Iron has indicated that the pacing item, the process vessel, first article would be one year after award and subsequent deliveries within the three month requirement. The major separator element divisions are process vessel and components, pod and components, instrumentation and controls, plus the refurbishment and test equipment. The first procurement activities start in 1987 fourth quarter and the procurement and fabrication plus construction activities continue to 1990 second and third quarters, at which time the separator equipment and instrumentation and controls are operational and followed by vessel operational and assembly of first pods. This in turn is followed by a three month activity of installing pods and start-up system that concludes by 1991 first quarter at which time the first module is to be operational.

Figure 2-13 shows the uranium processing requirement/construction schedule and identifies the procurement and construction activities of the feed conversion, feed preparation, uranium recovery, product conversion, and waste management facilities. The conventional facility construction starts in 1987 with major procurements starting in 1988 first quarter. The installation of the equipment and systems for this feed conversion and feed preparation are completed by 1990 third quarter, at which time there is a three month start-up for each facility. Key milestones that are planned to be achieved are metal product capability for the feed conversion facility and feed shape product capacity of approximately eighteen months from the feed preparation facility by the 1990 fourth quarter. Three other key milestones are to be achieved after a three month start-up for the uranium recovery, product conversion, and waste facilities and they are uranium receiving capability, UF_6 conversion capability, and waste management facility operational respectively by 1991 second quarter.

Figure 2-14 represents the project critical paths for the laser, separator, uranium processing, and conventional facilities. Several parallel activities are near the critical path in order to meet schedule objectives. A summary of these are:

Fig. 2-13. Authorization Limited Schedule - Uranium Processing Facilities.

Initial increment of production

Fig. 2-14. Authorization Limited Schedule - Critical Path.

- o Architect-engineer selection at start of 1986 to initiate the significant engineering on parallel Title I and II design activities.
- o Process building completed in sufficient time to take advantage of the laser and separator refurbishment areas for equipment preassembly and training.
- o Design data complete, award of purchase for the long lead computer based instrumentation (data acquisitions system) coupled with installation, software available and checkout completed in time for the integrated start-up of all systems.
- o Laser and separator design completed, bid and award in sufficient time to order long lead equipment/systems that require vendor qualification and receive in the necessary incremental deliveries to support the buildup of six modules.
- o Separator process vessel and laser/separator refurbishment assembly and test equipment are also on the critical path starting with design, initiating procurement and finally installation, checkout, and start-up.
- o Uranium processing facilities feed preparation and feed conversion induction furnaces are also a possibility of being on the critical path starting with the release of design specification, long lead procurement, installation, checkout, and activation. Other items that are affected by procurement times due to be a specialty item or being fabricated of monel are cold traps and fluorinators, respectively.

2.2. SCHEDULE VALIDATION

Schedule validation can be achieved with a hierarchy of schedules that represent the total project -- engineering, procurement, construction, start-up activities and, if appropriate, operations. These schedules shall contain certain key events called milestones that represent important goals to enable the scheduler, project team, management, and the client to ascertain if the project objectives and performance parameters are defined and consistent with overall program needs. The hierarchy of schedules prepared for the AVLIS

Production Plant deployment options meet this criteria. The AVLIS Production Plant master schedule reflects the major milestones and establishes the major project start and completion dates for significant activities. The master schedule also provides a time-scaled, logic diagram indicating principal constraints and interrelationships. Items considered include client activities and restraints, preliminary and detailed design, preparation of material requisitions and procurement lead times, start of construction and the subsequent installation, checkout and start-up of equipment and systems. The schedules relate from the top down and bottom up. The detailed schedules prepared for the AVLIS Production Plant during the conceptual stage were prepared in much greater detail than would be normally expected during the conceptual period on similar projects, as the additional detail was a conscious effort on the part of the AVLIS project team to allow a more in-depth schedule analysis and ensure that the schedules were attainable and realistic and also provide a sound basis for schedule validation by the Department of Energy.

2.2.1. Schedule Validation Checklist

The following items are part of a project validation checklist used by the Department of Energy to ascertain if the project schedule is credible. The AVLIS project team considered the checklist items when preparing the hierarchy of schedules for the AVLIS Production Plant deployment options. A team from Bechtel, representing the engineering, construction, and scheduling disciplines, reviewed the Technology/Project Milestone Interrelation Schedule and the Special Schedule for Process Building, Laser and Separator Installation Construction and Start-up Schedule; they provided constructive assessments and comments, which were evaluated and incorporated to provide a set of realistic logic networks for the AVLIS Production Plant. Assessments also included were impacts from outside sources such as client requirements, procurement vendor qualifications, and potential subcontract packages. The following subsections address each Department of Energy validation checklist item individually.

2.2.1.1. Budget Cycle Timing. The major milestones for the AVLIS Production Plant are keyed to the fiscal first quarter budget start (October). This key activity ensures that sufficient cost data is provided for consideration to allow the preparation of a budget for a line-item authorization and subsequent incremental fiscal year funding for the conceptual, Title I, II, or III phases of the project. The timing for the budget for the various phases of the AVLIS Production Plant are recognized and considered as part of the overall major key milestones. Major milestones that were considered as part of the budget cycle timing are as follows:

- o Engineering Authorization, October FY86.
- o Construction Authorization/Initiated, October FY87.
- o Plant Production Initiated, October FY91.

2.2.1.2. Contractor Selection Duration. The Lawrence Livermore National Laboratory/Martin Marietta Energy Systems, Inc. Project Contractor Organization acting for the Department of Energy on the AVLIS Production Plant has considered, as part of the FY85 project management plan activities, the preparation of a scope packages and select a major architect-engineer through the bid and award process. In addition, the schedule activities depict the preparation of a construction contract package during the overlap of Title I, preliminary design and Title II, detail design, to allow the bid and award cycle to select a prime contractor for the Title III construction phase. This selection and authorization/initiation of construction at the first quarter of FY87 would allow mobilization and front-end construction activities for the process building conventional facilities such as demolition, relocating structures, providing access and roads and other items shown as part of the work breakdown structure element, improvements to land.

2.2.1.3. Headquarters Reviews and Approvals. The Lawrence Livermore National Laboratory/Martin Marietta Energy Systems, Inc. Project Team has taken into consideration those items requiring Department of Energy headquarters reviews and approval. This starts with the current conceptual effort for providing the design report for review and subsequent AVLIS approval. At the Title I,

II, and III phases the reporting requirements checklist that has been reviewed and approved by both Department of Energy and Lawrence Livermore National Laboratory/Martin Marietta Energy Systems, Inc. Contractor Reporting Organization will be used as the basis for subsequent document and/or deliverables considered as receiving client reviews and approvals. Items considered in this category are management plan, contract work breakdown structure, milestone schedule and status report, change orders, Title I and II design reports and fiscal year budget estimates.

2.2.1.4. Prerequisite R&D Schedule Restraints. One of the key schedules prepared as part of this schedule section is the Technology/Major Milestone Interrelations Schedule for the Authorization Limited initial increment of production schedule. Early conceptual, Title I and II will proceed in parallel with the current laser and separator technology (research and development efforts) with closely integrated technology/engineering interaction. This interchange will allow the design team to proceed with the design of those activities on the construction critical path, beginning with the conventional facilities, while maintaining maximum flexibility for input from technology improvements on the process building special equipment work breakdown structure elements such as laser and separator systems.

2.2.1.5. Dependency Upon Timing and Amount of Operating Funds. During the conceptual stages of the AVLIS Production Plant and the preparation of the hierarchy of schedules assumptions were made that impinge on meeting certain major or intermediate milestones. These assumptions address the timing and amount of operating funds. Some of these assumptions used for the schedule preparation are as follows:

- o A high level of commitment at Department of Energy-Headquarters, Department of Energy-Oak Ridge Office, Lawrence Livermore National Laboratory, and Martin Marietta Energy Systems, Inc. to achieve early production from the AVLIS Production Plant.

- o Perform significant conceptual design prior to engineering authorization including extensive pre-project critical path method scheduling.
- o Pay premium over time for certain construction activities
 - conventional facilities
 - equipment/system installation.

2.2.1.6. Historical Experience on Design, Procurement, and Construction

Durations. One of key elements in the preparation of the AVLIS Production Plant schedule hierarchy has been the use of technology experience on design and procurement for two of the major items considered as part of the critical path, the laser and separators. The conceptual project team consisting of Lawrence Livermore National Laboratory, Martin Marietta Energy Systems, Inc., and two major architect engineers, Stone & Webster Engineering Corporation, and Bechtel National, Inc., have reviewed and established the design, procurement, and construction activity durations. Both engineering and construction from both the architect engineers have provided input for improving the validity of the schedules. Both Stone and Webster Engineering Corporation and Bechtel have provided data on craft staffing on similar new technology projects to add credance to manually staffing a project of the AVLIS Production Plant magnitude. Bechtel engineering has provided a more detailed engineering schedule encompassing the design activities for both Title I and II. Figures 2.15(a) and (b) reflect this detail. The engineering activities are by work breakdown structure element and show start and completion dates for process design work, material requisition preparation, bidding, and award of purchase orders for equipment, preparation of specifications and has included vendor print review. In addition, additional design, procurement, and construction detailed schedules were prepared for the uranium processing facilities and are shown on Figs. 2-16(a) through (h). These schedules also received a review by Bechtel's engineering and construction departments. Judicious use was made of similar-to projects historical data to provide support for schedule credibility.

COMMENTS:

NOTE A:
DESIGN INCLUDES DESIGN MATERIALS, DESIGN
BASIS, MATERIALS AND CONSTRUCTION - A
REVISION OF DESIGN REQUIREMENTS
NOTED IN BACKUP SHEET

NOTE B:
ALL IDENTIFIED STARTING DATES ARE
CONCEPTUAL DESIGN, DESIGN MATERIALS, AND
CONSTRUCTION COMPLETE

NOTE C:
FINAL COMPLETION DATE WITH BE 201
OF 100% DESIGN

NOTE D:
ENVIRONMENTAL IMPACT STUDY AND
SAFETY ANALYSIS NOT TO BE COMPLETE
PRIOR TO START OF CONSTRUCTION

NOTE E:
THE FOLLOWING OTHER STRUCTURES ARE
IN THE PROCESS ALSO: STAGE 1
1. 1. 1. STAGE 1
1. 1. 2. STAGE 2
1. 1. 3. STAGE 3
1. 1. 4. STAGE 4
1. 1. 5. STAGE 5

NOTE F:
DESIGN AND 1. 1. 1. STAGE 1
DESIGN AND 1. 1. 2. STAGE 2
DESIGN AND 1. 1. 3. STAGE 3
DESIGN AND 1. 1. 4. STAGE 4
DESIGN AND 1. 1. 5. STAGE 5

NOTE G:
DESIGN AND 1. 1. 1. STAGE 1
DESIGN AND 1. 1. 2. STAGE 2
DESIGN AND 1. 1. 3. STAGE 3
DESIGN AND 1. 1. 4. STAGE 4
DESIGN AND 1. 1. 5. STAGE 5

LEGEND

- ▽ MAJOR MILESTONES
- CRITICAL EVENT
- MINOR MILESTONE
- COMPLETE
- NOT EVALUATED COMPLETE

Lawrence Livermore
National Laboratory

JAVES PRODUCTION PLANT
AUTHORIZATION LIMITED SCHEDULE
INITIAL IMPLEMENT OF PRODUCTION

PROCESS FACILITY
ENGINEERING SUMMARY SCHEDULE

SCALE: 1" = 1 MONTH
SHEET # 1 OF 2

Fig. 2-16(a). Uranium processing, Feed Conversion Facility--detailed schedule.

Fig. 2-16(d). Uranium Processing, Uranium Recovery Facility--detailed schedule.

Fig. 2-16(g). Uranium processing, process support, Fluorine Generation Facility--detailed schedule.

Fig. 2-16(h). Uranium Processing, Waste Management and Storage Facilities--detailed schedule.

2.2.1.7. Development of Environmental Impact Report. Schedule consideration was given this potential impact for the start of construction activity. As the AVLIS Production Plant Initial Increment of Production is considered to be constructed at the Oak Ridge Gaseous Diffusion site the time for changing the existing impact report is not nearly as dramatic a lead time consideration as if it were a Greenfield Site.

2.2.1.8. Procurement Lead Times for Equipment (particularly reflecting vendor quotes). The Stone and Webster Engineering Corporation engineering group solicited cost and schedule vendor quotes on key elements of the cost and schedule drivers (laser and separator). The reflected quoted lead times were considered in the construction schedule activities. Additionally Bechtel's lead time guide for equipment and commodities was used primarily for conventional equipment found in the Uranium Processing Facilities. In addition, current technology procurements for the laser and separator projects were reviewed for schedule impacted items. Examples of vendor quoted prices and deliveries solicited by Stone and Webster Engineering Corporation are shown on Fig. 2-17(a) through (f). Figure 2-18(a) through (c) portrays Bechtel's lead-time guide and identifies (by underline), conventional equipment selected for ensuring sufficient lead time was allowed on the schedules. Bechtel's lead time guide has been in use for the last 15 to 18 years within Bechtel. It is updated quarterly or semiannually depending on lead time changes. The lead times are based on 65% of shop capacity, therefore, improvement on deliveries should present no problem.

2.2.1.9. Logical Sequence of Design, Procurement and Construction. The logic for the Technology/Milestone Interrelations schedule, Fig. 2-19, and the special schedule for process building, laser and separator installation, Fig. 2-20, are work breakdown structure oriented and have been reviewed by the AVLIS project team consisting of Lawrence Livermore National Laboratory, Martin Marietta Energy Systems Inc., Stone and Webster Energy Corporation, and Bechtel. Engineering, scheduling, and construction experience was employed to validate the logic network. Dividing the AVLIS Production Plant schedule into work breakdown structure elements permitted a focus on a greater number of subdivisions for a more detailed analysis.

Vendor	Item	Qty (ea)	Budgetary Estimate	Delivery
Continental Precision Machining San Jose, CA	Shield windows	1034	\$ 98.00 ea.	16 wks
Insulation Supply Torrance, CA	Mounting Plate	129 132 153	\$ 10.64 ea.	5 wks ARO
	Tie Down Plate	258 264 306	\$ 4.10 ea.	
	Mounting Bracket	129 132 153	\$ 9.69 ea.	
	Spacer	258 264 306	\$ 4.20 ea.	
Quartz Instruments Corp Santa Ana, CA	Quartz Tubes	702 718 846	\$ 310.00 ea.	1/2 order 6-8 wks ARO; Balance 1 wk later
Industrial Contractor Inc Idaho Falls, Idaho	Recirculating Cooling Water System (Separator Module)	1	\$3,000,000 (min) \$3,900,000 (max)	No quote
S & Q Corporation Morgan Hill, CA	Negative Air Ventilation System	1	\$1,028,000.00	240 days ARO
EPS Corporation La Mirada, CA	Oxidation Oven	2	\$185,000.00	6-9 mons after drawing approval

Fig. 2-17(a). Summary of quotes.

Vendor	Item	Qty (ea)	Budgetary Estimate	Delivery
Applied Optics Inc Pleasant Hill, CA	Injection Refl Lens	1056	\$ 150.00 ea.	200-4 mos ARO and 300/mo thereafter
		960	\$ 150.00 ea. additional 300.00 tooling	200-4 mos ARO and 300/mo thereafter
	Convex Resonator Mirror	1152	\$ 100.00 ea.	200-4 mos ARO and 300/mo thereafter
		1056	\$ 100.00	200-4 mos ARO and
		960	\$ 100.00 additional 300.00 tooling	300/mo thereafter
	Concave Resonator Mirror	2112	\$ 200.00 ea.	200-4 mos ARO and 300/mo thereafter
		1920	\$ 200.00	200-4 mos ARO and 300/mo thereafter
		2304	\$ 200.00 additional 300.00 tooling	200-4 mos ARO and 300/mo thereafter
Hogan Mfg. Inc. Escalon, CA	PFC Box with cover Oscillator	258	\$ 4,983.00 ea.	No Quote
		258	\$ 5,278.00 ea.	
Pat Patterson Assoc. San Ramon, CA	Sargent-Weich Vacuum Pump Model 8803-B	968	\$ 202.97 ea.	6 mos
		982	\$ 202.97 ea.	6 mos
		1152	\$ 197.42 ea.	7 mos
Devilbiss Inc.	Small Spray Booth	1	\$ 1,454.00 ea.	No Quote
AGF Inc.	Vacuum Furnace	6	\$276,675.00 ea.	1 unit in 6 mos
Elizabeth, NJ		7	\$271,115.00 ea.	with 1 unit each
		10	\$268,375.00 ea.	additional mo after

Fig. 2-17(b). Summary of quotes (cont'd.).

Vendor	Item	Qty (ea)	Budgetary Estimate	Delivery
McDaniel Refractory Co. Beaver Falls, PA	Alumina tubes (99.8%)	702	\$ 1,888.00 ea.	50 to 60 - 13 wks ARU, with 60/mo afterwards
		718	same	
		846	same	
Adept Manufacturing, Inc. Costa Mesa, CA	Anode #84-105422-0A	516	\$ 1,205.00 ea.	20/wk starting 60 days ARUM
		528	\$ 1,205.00 ea.	
		612	\$ 1,190.00 ea.	
	Cathode #84-105423-0A	516	\$ 940.00 ea.	20/wk starting 60 days ARUM
		528	\$ 940.00 ea.	
		612	\$ 925.00 ea.	
	Window #84-105424-0A	1034	\$ 907.00 ea.	40/wk starting 60 days ARUM
		1056	\$ 907.00 ea.	
		1224	\$ 892.00 ea.	
City Tool-Die & Mfg. Co., Inc. Santa Clara, CA	High Voltage connectors DWG 84-100706-00	258	\$ 22.50 ea.	4 to 5 wks ARU same same
		264	same	
		306	same	
Chicago Bridge and Iron Co. San Francisco, CA	Vacuum Vessel, 12' dia. X 85' long Stainless steel	4	\$2,220,000.00 ea.	1 unit, 12 mos ARU 1 unit every 2 mos thereafter
		6	\$2,100,000.00 ea.	
		8	\$2,050,000.00 ea.	
Zygo Corp Middlefield, CT	155 mm, 45 degree mirror	960	\$55.00-65.00 ea.	100/mo starting 4 mos ARU. same
		1056	same	
		1152	same	
	76mm, 45 degree mirror	960	\$185.00-195.00 ea.	100/mo starting 4 mos ARU. same
		1056	same	
		1152	same	

Fig. 2-17(c). Summary of quotes (cont'd.).

Vendor	Item	Qty (ea)	Budgetary Estimate		Delivery
Tymar Machining Santa Clara, CA	Window screw tab-01 #PY-1106687-00	4212	\$	2.31 ea.	All items 5-8 wks ARO
		4308	\$	2.29 ea.	
		5076	\$	2.19 ea.	
	Window screw tab-02 #84-106687-00	4212	\$	2.11 ea.	
		4308	\$	2.09 ea.	
		5076	\$	1.99 ea.	
	Window Clip #84-106686-00	4212	\$	2.11 ea.	
		4308	\$	2.10 ea.	
		5076	\$	2.00 ea..	
High Vacuum Equip. Corp. Hingham, MA	Vacuum Pumping System	4	\$2,415,000.00 ea.		7 mos ARO for 1st unit each additional unit would follow by 2 mos
		6	\$2,365,000.00 ea.		
		8	\$2,315,000.00 ea.		
Spellman High Voltage Electronic Corp. Plainview, NY	Switching Power Supplies, 15 kW	3168	\$	9,750.00 ea.	275 per mo for 12 mos
	Switching Power Supplies, 8 kW	1152	\$	5,200.00 ea.	100 per mo for 12 mos
Continental Optical Corp. Hauppauge, NY	Polarizer Beam Splitter	1056	\$	480.00 ea.	100/mos starting 12 wks ARO
		960	\$	480.00 ea.	
		1152	\$	480.00 ea.	
Tridecs Corp. Hayward, CA	Knurled nylon nut	258	\$	4.50 ea.	No delivery quoted
		264	\$	4.50 ea.	
		306	\$	4.25 ea.	
	Flex Vacuum Connector	258	\$	50.00 ea.	
		264	\$	49.95 ea.	
	306	\$	49.85 ea.		

Fig. 2-17(d). Summary of quotes (cont'd.).

Vendor	Item	Qty (ea)	Budgetary Estimate	Delivery
Zygo Corp. Middlefield, CT	Tab-02 CVL window (88.5mm)	960	\$185.00-\$200.00 ea.	100/mo starting 4 mo ARO
		1056	same	same
		1152	same	same
	Tab-04 CVL window	1296	\$275.00-\$295.00 ea.	100/mo starting 4 mo ARO
		1440	same	same
		1584	same	same
Pauli and Griffin Co. Vacaville, CA	Small Grit Blaster	1	\$18,500.00	8 to 10 wks
	Large Grit Blaster	1	no quote	no quote
KenLab San Leandro, CA	H.V. Connector #84-1023-0A	702	\$ 16.50 ea.	4-6 wks after receipt
		718	same	of plugs
		846	same	same
	Thyratron heater RPS connector #84-102381-0A	702	\$ 8.50 ea.	4-6 wks AROM
		718	same	same
		846	same	same
Streetman Precision Cameron Park, CA	Tube seal retainer #84-105420-0A	516	\$ 16.00 ea.	3-4 wks ARO
		528	\$ 15.75 ea.	same
		612	\$ 15.00 ea.	same
	Spacer, tube seal #84-105421-0A	516	\$ 4.50 ea.	3-4 wks ARO
		528	\$ 4.25 ea.	same
		612	\$ 4.00 ea.	same
Continental Precision Machining San Jose, CA	Window retaining washers	1034	\$ 98.00 ea.	16 wks ARO
		1056	\$ 98.00 ea.	same
		1224	\$ 98.00 ea.	same

Fig. 2-17(e). Summary of quotes (cont'd.).

Vendor	Item	Qty (ea)	Budgetary Estimate	Delivery
Maxwell Laboratories Inc. San Diego, CA	E-Beam power supply and power conditioning	24	\$ 1,312,000.00 ea.	2/mo starting 12 mos ARO
Applied Laser Electronics Framingham, MA	Switching power supplies			
	15 kW	3168	\$ 9,000.00 ea.	24 mo, total
	8 kW	1152	\$ 6,000.00 ea.	FOB-MA
EMC Controls, Inc. Cockeysville, MD	Plant I&C System as follows:			TBD
	Separator System	1	\$29,426,475.00 ea.	
	Laser System	1	\$20,087,418.00	
	Embedded Controllers	1,000	\$ 12,000.00 ea.	
	Waveform Generator	1 set	\$ 517,263.00	
	Production Operations	1 set	\$ 1,618,442.00	
	Plant Layer VAX's	1 set	\$ 1,428,806.00	
	Accountability	1 set	\$ 748,895.00	
	Refurbishment	1 set	\$ 411,578.00	
	Host Standby VAX	1 set	\$ 853,374.00	
	Distributed Stations	1 set	\$ 54,636.00	

Fig. 2-17(f). Summary of quotes (cont'd.).

Procurement

LEAD TIME REPORT

Second Half 1984

Supplier Performance Support Services Group (SFHO)

Fig. 2-18(a). Summary of quotes.

Revision Date: 07/19/84

BECKTEL
3 MINING AND METALS LEAD TIME REPORT
(IN WEEKS)

* Previous Change
** Current Change
A/RAD = After Receipt of Approved Drawings
N/A = Not Applicable
H/O = Home Office P.O.
F/O = Field Office P.O.
HSC = Home Office S/C
FSC = Field Office S/C

U. S. D O M E S T I C

LEAD TIME CODE	H/O SPEC. NO.	DESCRIPTION	Q/UTY CODE	REC. BIDS	REC. VENDOR DRAWING	TIME (SHIP A/RAD)	FROM LAST L.T.	P/O OR S/C	LEAD CHANGE				COMMENTS
									CANADA	WEST'S EUROPE	AUSTRAL/ ASIA	NORTH PACIFIC	
34-01.00		<u>CONVEYOR SYSTEMS</u>											
34-01.10		Apron	3910ED	5	N/A	30	-	H/O	30	24	18	8	
34-01.11		Belt (portable, std catalog)	3910BA	3	N/A	16	-	H/O	15	20	18	12	
34-01.12		Belt (engineered system)	3910BA	5	N/A	32	-	H/O	25	20	30	30	
34-01.13		Coal Handling System	3910BP	5	N/A	36	-	H/O	N/A	28	N/A	42	Large conveying system allow 14-18 months A.R.O.
34-01.14		Bucket	3910BG	5	N/A	21	-	H/O	14	32	35	24	
34-01.15		Pneumatic	3910BB	3	N/A	38	-	H/O	52	40	45	32	
34-01.16		Primary ore tripper	3910--	7	N/A	27	-	H/O	25	32	44	32	
34-01.17		Screw	3910BA	3	N/A	24	-	H/O	15	32	30	24	
34-01.20		Flow Type	3910C--		N/A	52	-	H/O	50	60	60	36	
		Loading areas-marine (gasoline or diesel fuel)	3910--	10	N/A	52	-	H/O	N/A	42	40	52	
34-01.40		Car handling/dumping equip.	2200BA	5	N/A	52	-	H/O	50	60	60	36	
<u>34-01.50</u>		Platemwork: bins, chutes, hoppers	9515DA	4	N/A	18	-	H/O	20	16	18	18	

Fig. 2-18(b). Summary of quotes (cont'd.).

Revision Date: 07/19/84

MINING AND METALS LEAD TIME REPORT
(IN WEEKS)

* Previous Change
** Current Change
ABD = After Receipt of Approved Drawings
N/A = Not Applicable
HFO = Home Office P.O.
PFO = Field Office P.O.
HOC = Home Office O/C
FSC = Field Office O/C

LEAD TIME CODE	QPM SPEC. NO.	DESCRIPTION	CHRY CODE	REC. RIDS	REC. VENDOR DRAWING	LEAD CHANGE TIME FROM (SHIP LAST AND) L.T.		CHRY CODE	HIST. N C/TYPE	ASIA	NORTH PACIFIC	COMMENTS
						P/O OR S/C						
U. S. DOMESTIC												
MILLS AND CRUSHERS												
34-02.00		MILLS										
34-02.10		MILLS										
34-02.11	**	Mills - autogenous	3660-	8	8	52 (-12)	HFO	48	44	50	52	
34-02.12	**	Mills - ball	3660-	8	N/A	44 (-4)	HFO	39	44	46	52	
34-02.13	**	Mills - pebble	3660-	9	N/A	44 (-4)	HFO	44	40	45	54	
34-02.14	**	Mills - rod	3660-	8	N/A	40 (-6)	HFO	44	48	15	50	Small rod mills 22-30 wh
34-02.15		Screens, vibrating	3620B	2	N/A	18 -	HFO	14	24	16	24	
34-02.20		CRUSHERS										
34-02.21		Crus (25-100 ton per hr)	3620A	5	N/A	50 -	HFO	36	48	16	38	
34-02.22	**	Double roll (15 ton per hr)	3620B	5	N/A	47 -	HFO	52	56	26	**39	
34-02.23		Jaw (40" to 60")	3620D	5	N/A	49 -	HFO	46	40	34	52	
34-02.24		Gyratory (54"-102")	3620C	5	N/A	54 -	HFO	50	56	40	52	
34-04.00		ASH HANDLING										
34-04.10	**	Ash handling system	3699A	7	12	32 (-10)	HFO	60	50	52	38	
34-04.11		Dust suppression system	3695-	1	N/A	13 -	HFO	13	N/A	18	26	
34-05.00		CLASSIFIERS/SEPARATORS										
34-05.11		Cyclones (20 to 6000 GPM)	3680A	4	N/A	26 -	HFO	N/A	N/A	28	25	
34-05.12		Spiral (60" to 120" dia)	4340A	4	N/A	23 -	HFO	N/A	50	30	26	
34-05.20		Separators, air	3655B	8	N/A	30 -	HFO	19	N/A	30	30	Erection time 20 weeks
34-05.30		Separators-glycol dehydration	4330B	4	N/A	39 -	HFO	N/A	52	45	40	
34-05.50		Precipitators, electrostatic	4460B	8	N/A	52 -	HFO	60	64	18	52	Does not include installation
34-05.60		Scrubbers, sulfur dioxide	4450B	8	N/A	26 -	HFO	16	N/A	13	40	Erection time 12 weeks
34-05.70		Separators-magnetic (cobber)	3680D	8	N/A	52 -	HFO	N/A	N/A	25	40	

Fig. 2-18(c). Summary of quotes (cont'd.).

Fig. 2-20.
Authorization
limited schedule,
initial increment
of production,
special schedule
for Process Building,
laser and separator
installation,
construction and
start-up.

2.2.1.10. Reasonable Manpower Levels, Buildup and Ramp Down. Both engineer and manual-craft staffing were considered as part of the schedule preparation. Realistic engineering and construction staffing levels, including buildup and ramp down, were determined. Bechtel engineering providing design engineering staffing for the detailed engineering schedules and they were considered to be realistic and attainable. Construction staffing considerations provided for the AVLIS March, 1984 Deployment Schedule were utilized to determine that this 1985 smaller plant requirements could be realistically manually buildup and ramped down.

2.2.1.11. Reasonable Obligation and Costing Rates. The capital cost estimate for the AVLIS Production Plant utilized current cost data developed at Oak Ridge by Martin Marietta Energy Systems, Inc. to present reasonable craft labor rates. Both Stone and Webster Engineering Corporation and Bechtel provided equipment quantities and cost with labor requirements and crew-mix. Factors were input at Oak Ridge based on historical data for reasonable cost rates.

2.2.1.12. Shift Work or Overtime Requirements. Shift work and overtime requirements were considered in the development of the hierarchy of schedules for the AVLIS Production Plant. These considerations form a part of the schedule assumptions for the Authorization Limited Schedule and are:

- o Pay premium overtime for certain construction activities
 - conventional facilities
 - equipment/system installation
 - expedite all/any phase of project activities that drive the critical path.

2.2.1.13. Work Place Space Constraints. The more detailed Special Schedule for Process Building, Laser and Separator Installation monthly schedule did take the work place space constraints into consideration when developing the construction activity logic. Items considered were working the process

building by discrete areas and also accomplishing different craft work at various levels of the process building.

2.2.1.14. Exposure Constraints. There will be no constraints on the construction, installation, and equipment checkout of the initial increment of the AVLIS Production Plant due to exposure of construction personnel to ionizing radiation. All construction activities will be carried out in areas with no radionuclide contamination. There is the potential for operating personnel to be exposed to radiation during the startup and operation of the AVLIS Production Plant. The design of the plant equipment will incorporate features to mitigate this potential utilizing development activity experience from current technology demonstration projects (i.e., Full Scale Demonstration Facility, Materials Handling Demonstration Module, and High-Power Laser Facility) and existing operating production facilities (i.e., Oak Ridge Gaseous Diffusion Plant and Portsmouth Gaseous Diffusion Plant). The startup and operating schedules for the AVLIS Production Plant reflect the radiation exposure potential.

When the AVLIS Production Plant is upgraded to a fully activated plant, the several uranium processing facilities will be expanded to provide the additional production capacity. While this construction effort is underway, physical barriers will be in place to completely segregate construction personnel from areas of the several facilities undergoing expansion which contain uranium for safeguard reasons. Therefore, there will be no constraints on these construction operations due to an exposure potential.

The operation of the AVLIS Production Plant will be performed by trained and experienced personnel. Operation will be in strict accordance to procedures to prevent unnecessary exposure of plant personnel to radiation. Any constraints imposed on plant operations to avoid exposure to operating personnel are reflected in the scheduling of activities.

2.3. SCHEDULE CONSIDERATIONS/DETAIL BACKUP

In addition to a review of the DOE schedule validation checklist items the AVLIS Production Plant project team schedulers prepared and used a

checklist of items titled Schedule Considerations. The purpose of this checklist was to enumerate items that should be considered in the preparation of project schedules in order to provide sufficient detail backup for a viable schedule. The list was prepared by the Bechtel schedule team, who have an average of 30 years experience in the industry. In addition, Bechtel historical scheduling records and scheduling procedures were utilized to a comprehensive list and provide an alternate source of questions.

The Schedule Consideration checklist is divided into three major categories, engineering, procurement, and construction. Standard checklists for schedule preparation were used in developing the schedules for the AVLIS Production Plant. Examples of typical considerations for each category are as follows:

Engineering

- o The documents or reports required in addition to the Environmental Impact Report to allow construction to start at the first quarter of FY87.
- o Requirements for a physical model of the process facility.
- o The procurement critical path items.
- o Resident engineering representatives will be required in some vendor shops for critical equipment/hardware.
- o Q clearance for key personnel to alleviate the time delay at the front-end.
- o Large ring forgings required for the separator process vessel.
- o Procurement lead times from potential suppliers to support the deployment schedule.
- o Soils and geology data available from prior Oak Ridge projects.

Procurement

- o The location of vendors (proposed/selected) on major procurement equipment versus the site location (Oak Ridge).
- o The expected production rates on critical laser items.

- o Expeditors and/or quality control representatives in vendor shops for critical procurement items through the first lot shipment and periodically thereafter.
- o Q-cleared facilities and manual personnel to handle the items that require them.
- o Client review and approval cycles during procurement.

Construction

- o Field fabrication shops.
- o Provisions made for preassembly of critical items.
- o Winter excavations and foundation pourings.
- o Manpower densities for craft labor (about 5 men/1000 sq ft).
- o Equipment weight and crane usage or equipment size and use of building block-outs during building erection.
- o Chemical cleaning of piping systems and hydrotesting.
- o Time for construction drawing reviews.

3. FULLY ACTIVATED SCHEDULE

3.1. FULLY ACTIVATED PLANT DEPLOYMENT SCHEDULE

The fully activated plant scenario, based on the Authorization Limit Schedule, includes the addition of two more modules to the six installed for the initial increment of production for the AVLIS Production Plant. Module number seven would start initial operation the first quarter FY95 and for module number eight, initial operation would start the second quarter FY95. The six initial-increment modules would be upgraded in pairs in three-month upgrade periods to enhance performance capabilities. The fully activated AVLIS Production Plant would consist of eight separators and four laser amplifier modules, and the plant capacity would be 13 million separative work units/YR. Figures 3-1 through 3-4 depict the deployment schedule and production ramp-up.

Fig. 3-1. Fully Activated Plant - Supplement Deployment Schedule.

Fig. 3-2. AVLIS Production Plant--fully activated plant supplement production ramp-up.

Major project milestones

Fiscal year - Quarters

Milestones

90-4	Engineering authorized/initiated
91-4	Engineering Title I report
92-3	Construction authorized/initiated
92-3	Construction Uranium Processing Facilities initiated
93-1	Construction Conventional Facilities initiated
93-1	Construction separators 7 & 8 & Laser PAM 4 initiated
94-1	Construction upgrade separators 6-1 & Laser PAM 3-1 initiated
94-4	Startup Module #7
95-1	Engineering complete
95-1	Construction Conventional Facilities complete
95-1	Construction separators 7 & 8 & Laser PAM 4 complete
95-1	Initial Operation Module #7
95-2	Initial Operation Module #8
95-3	Construction Uranium Processing Facilities completed
95-4	Plant production in FY 1995 - 8 MWSU
95-4	Complete construction Modules #5 & #6, initial operation
96-1	Complete construction Modules #3 & #4, initial operation
96-2	Complete construction Modules #1 & #2, initial operation
96-2	Construction full activated plant complete
96-4	Plant production in FY 1996 - 11 MSWU
97-4	Plant production in FY 1997 - 13 MWSU

Fig. 3-3. Fully Activated Plant - Project Milestones.

Fig. 3-4. Fully Activated Plant - Deployment and Ramp-up Logic Network.

4. SCHEDULE UNCERTAINTY

The AVLIS Production Plant line-item project planning schedules, from start of construction to full-plant deployment, are based on preliminary conceptual design definition within a framework of major AVLIS program milestones. As expected, such schedules carry an inherent degree of uncertainty and it should be recognized that additional scheduling effort will be performed during the conceptual and Title I engineering phase to prepare the necessary, more detailed engineering, procurement, and construction schedules. Of primary importance to minimize uncertainty is early DOE concurrence and support of the funding schedule. Other areas of uncertainty that could directly impact the AVLIS Production Plant schedule are discussed in the following paragraphs.

Commitment by Lawrence Livermore National Laboratory, Martin Marietta Energy Systems, Inc., and the architect-engineers of the engineering and technical staff required to perform design tasks in a timely fashion is critical for the engineering design to be on schedule.

Delays or problems in the performance objectives of Material Handling Demonstration Module, Full-Scale Demonstration Facility or High-Power Laser Facility will impact the design and subsequent procurement and construction completion dates for the plant. Since many of the Full-Scale Demonstration Facility development components are to be prototypic of components conceived for the plant, the potential exists for AVLIS Production Plant design schedule impacts if the Full-Scale Demonstration Facility components undergo major design modification.

Several key elements in the process-support-systems power supplies, refurbishment equipment, and instrumentation and controls require special and early attention to ensure that these long lead components do not become the overall schedule driver.

Input from the joint Lawrence Livermore National Laboratory/Martin Marietta Energy Systems, Inc. technology team was used to establish the laser system schedules and, although preliminary, it is considered appropriate at this stage of the project. However, the critical path schedule, through both

the laser and separator engineering procurement/installation activities has minimum contingency for completion of the engineering phases. The schedule assumes that the laser specifications are developed, and detailed procurement planning is completed by the fourth quarter of FY87. This will permit an aggressive start of the procurement activities for the laser system and allow adequate time for the initial procurement activities of the copper laser subassemblies/components bought from functional specifications to assure performance prior to placing major plant subcontracts in FY87. A successful laser development program focused through the Laser Demonstration Facility is a key to meeting the laser acquisition schedules for the plant. A similar schedule scenario is envisioned for the separator module design and procurement.

The availability of the architect-engineer at the beginning of the project is necessary to permit early work on the design package for site grading, underground utilities, and building foundations. This will help ensure that the project schedule will not be limited by the building construction schedule. This requires design criteria development and the start of the architect-engineer selection process in FY85 prior to authorization of the engineering only line item.

The AVLIS Production Plant is modular, permitting early operation of the initial laser module/separator module, while the final units are still in the procurement/installation cycle. This early operation places increased pressure on the schedule for support facilities such as the refurbishment facility and the graphite shop.

There are management options that could result in a project schedule of shorter durations than presented. An example is to procure lasers from more vendors to accelerate the total laser deliveries. To realize an overall project acceleration, multiple vendors would be required for both separator and laser components and support facilities would have to be completed early. This would increase the unit cost of lasers and separator modules, but would reduce the escalation. An important requirement to accommodate this type of multiple-source procurement is the need for sufficient obligational authority in the early project years. Options for multiple-source procurement will be evaluated during the preliminary engineering phase.

5. MAJOR PROJECT MILESTONES

The major project milestones described below were established for the AVLIS Production Plant and are part of the rationale for the updated AVLIS Project Plan, May 1984. These milestones form the basis for the planning schedules for design, fabrication, procurement, construction, and start-up activities for the Authorization Limited Schedule. As the design and planning effort proceeds in parallel with ongoing development activities, these fiscal year milestones have been established to meet the overall objectives and mission of the AVLIS Production Plant. The major project milestones with fiscal year and month starting quarter scheduled event are described as follows:

Schedule information presented in this section is consistent with the current AVLIS project plan milestones, and is dependent on the accomplishment of the ongoing development program to support the key design information release requirements and the key engineering milestones shown in Fig. 5-1. Figure 5-1 identifies the FY85 engineering milestones, AVLIS documentation, and process selection leading to the establishment of the Contractor Project Organization. The Contractor Project Organization would initiate major elements of the project management plan. Key activities in the next five months would include: the assessment package preparation; architect-engineer bid and selection package and subsequent notification on a letter-of-intent; the submittal of the 90% review of the conceptual-design report, and by the first quarter of FY86 the significant engineering initiated, and the submittal of the preliminary operations/maintenance plan for review. The major project milestones, listed with their respective starting month and fiscal year, are described in the following paragraphs.

Design Documents for Process Selection (October 1985). A design package will be prepared for the AVLIS Production Plant to establish process/project deployment options, major systems requirements, preliminary equipment layouts, a uranium materials management approach, operations/maintenance planning, cost estimates, and schedules. The

Fig. 5-1. 1985 Engineering Milestones.

report will also describe the conceptual design for all major equipment and systems, including the separator module, laser system, refurbishment, plant control and data acquisition system, and the uranium processing facilities.

Plant Engineering Authorized/Initiated (October 1986). A key milestone is the initiation of Title I and II engineering design the first of FY86 through the engineering only line item authorization. This process would result in the selection of an architect-engineer to perform Title I and limited Title II design for LIS equipment and systems and full Title II design on conventional facilities and certain long lead equipment.

Plant Conceptual Design Documents (October 1986). A project conceptual design report will be prepared for the AVLIS Production Plant to establish the basis for project deployment and the engineering backup for the construction project data sheet. The conceptual design will emphasize system requirements for all key equipment and systems, the alternatives and uncertainties for all high-leverage cost drivers, and areas of technical risk, and the cost estimate based on the bottoms-up conceptual design basis. The design will also include a schedule that ties technology availability to design starts, reasonable time frames for design, procurement, and construction startup. This will be coupled with an operational perspective of the phased production ramp-up and a design basis of all major equipment, systems, conventional facilities, and support systems to the conceptual design level of detail.

Plant Title I Design Reports (October 1987). A project Title I engineering report will be prepared for the AVLIS Production Plant to establish the design basis that serves as the baseline to initiate the remaining detailed Title II engineering for conventional facilities and certain long lead procurement for general LIS equipment. The Title I design report will extend the level of engineering for conventional facilities between the Titles I and II levels of detail, for general LIS equipment and process support facilities to the Title I level of detail, and for special LIS equipment between the conceptual and Title I level of detail.

Plant Site Work (Limited) Design Complete (October 1987). The architect-engineer selected to form a part of the Lawrence Livermore National Laboratory/Martin Marietta Energy Systems, Inc. project team during the first quarter of FY86 and working on the Title I, Preliminary Design, will also perform a limited amount of Title II, Final design, during that period to form a construction scope package for a construction contractor to initiate work during this first quarter of FY87. The construction contractor, in addition to mobilizing and erecting temporary facilities, would initiate the limited process building conventional facilities improvements to land such as demolition; clearing/grading, access roads, relocating structures and utilities.

Plant Construction Authorized/Initiated (October 1987). A key project deployment milestone is the initiation of construction of the AVLIS Production Plant conventional facilities in the first of FY87 through the AVLIS Plant line item construction authorization. This will provide approximately \$130 million in FY87 to continue Title II engineering, to initiate conventional facility construction, and to initiate long-lead procurement for certain general LIS equipment such as the separator module, vacuum vessel, and the plant control and data-acquisition system central computer and software package.

Plant Conventional Facilities Design - Primary Structure (April 1987). The Title II design for the process building conventional facilities primary building structure will be completed with sufficient design data to have the building excavation, concrete, and structural steel design and specification issued to construction for the critical path construction activities associated with the AVLIS Production Plant process building and uranium processing facilities.

Plant General LIS Equipment Design Complete/Initiate Procurement -- (separator chamber laser/separator assembly equipment) (July 1987). The design and specifications will be completed and procurement will be initiated in the last quarter of FY87 on critical path procurements for the AVLIS Production Plant process building special equipment. Specific hardware procurements will include separator module long-lead power supplies and separator refurbishment (assembly) equipment and laser

system components that are procured from a functional specification where appropriate vendor qualification is required. Procurement will also include certain equipment associated with the front end of the uranium processing facilities such as for the toll facility, feed preparation (foundry), and the graphite shop.

Plant General LIS Equipment Design Complete/Initiate Procurement -- laser mount assemblies, feed prep./conv. equip., instrumentation and controls computers (October and January 1988). The design and specifications will be completed and procurement will be initiated during the first and second quarter of FY88 for additional critical path procurement items for the AVLIS Production Plant. Specific hardware requirements will include the copper laser oscillator, amplifier, and herriott cell equipment as well as dye laser waveform generators and amplifier chain components. This procurement activity also include feed preparation, conventional equipment, and the instrumentation and controls computers.

Plant Special LIS Equipment -- vendor qualification components (October 1988). Procurement will start in the first quarter of FY88 on critical-path procurement systems/equipment for the AVLIS Production Plant. Specific hardware procurements that require vendor qualification of components include copper laser oscillator and copper laser oscillator heads, power and switch equipment; dye laser components; laser instrumentation and controls computer main frame and software, beam diagnostics, pointing and centering electronics; separator graphite materials, local control hardware and software, pod system vaporizer subsystem and extractor collector/system equipment.

Plant Special LIS Equipment Design Complete/Initiate Procurement -- long lead hardware (April/July 1988). Title II design and specifications will be completed and procurement will start on the remainder of the long lead hardware for the AVLIS Production Plant. Specific hardware procurements will include separator system E-gun/reflux structures, carriage assemblies, chamber internals (rails-liners), transport components, dye laser components, copper vapor laser head and power hardware. instrumentation and controls panel fabrications, and additional pointing and centering components; uranium processing facilities uranium recovery,

product conversion, feed conversion, feed preparation, and waste management long lead equipment and support equipment/system hardware.

Plant Special Equipment Installation Initiated -- unclassified (July 1988).

The special unclassified equipment installation would be initiated for certain equipment such as laser and separator refurbishment, front end of the uranium processing facilities such as toll facility, feed preparation (foundry), and the graphite shop.

Plant Special LIS Equipment Assembly/Fabrication Details (October 1989).

The AVLIS Production Plant special LIS equipment assembly and fabrication design detailed drawings will be completed and available for final procurement and construction planning by the first quarter of FY89. Specific hardware requirements include separator system extractor collector system components for the enclosure assembly; ion extractor, withdrawal system, alignment system, and thermal system.

Plant Engineering Design Complete (January 1989). The Title II detail engineering will be complete by start of the second quarter FY89. The last phase of engineering effort will conclude with the final issue of special LIS equipment assembly and fabrication details. There is a planned overlap of engineering personnel assigned to assist Title III construction on interpreting drawings and specifications and providing other construction support.

Plant Conventional Facility Construction Complete (January 1989).

Construction will be completed in the second quarter of FY89 on all conventional facilities for the AVLIS Production Plant, including the main process building, toll facility, and the feed-preparation facility. Also included will be the graphite shop, the wet chemical facility, the conversion facilities (both feed and product if required), and other miscellaneous support facilities such as the electrical switch house, dye pumping facility, etc. Conventional facilities include all improvements to land, outside utilities, new building construction and building modifications, ventilation systems, lighting and normal electrical systems and utility distribution systems.

Plant Process Building Classified Construction Installation Start

(January 1989). Construction will be started by the second quarter of

FY89 on the AVLIS Production Plant process building special equipment considered as classified. This installation includes such equipment as the laser and separator refurbishment and test equipment as the initial assembly of components within the process will be accomplished within these areas. The installation and checkout of this equipment will combine training while assembling the copper vapor laser components.

Plant General LIS Procurement Complete for Module #1 (April 1989).

Procurement of all AVLIS Production Plant general equipment required for the start-up of Module #1 will be complete by April 1989. Specific hardware procurement and fabrication details include remaining details on the separator module extractors/product collectors and the final support equipment for the uranium processing wet chemical recovery and product conversion facility portion of the uranium processing facility.

Plant Start-Up of Common Systems and Equipment (October 1990). Start-up activation will be initiated at the first of FY90 on the process equipment/system associated with the first process module in the AVLIS Production Plant. The initial plan is to provide approximately three-month startup for individual systems and an additional three months for the integrated system startup, specifically:

Separator vessel operational	07/90
Separator local control operational	04/90
Integrated separator operational	10/90
CVL system operational	07/90
Dye system operational	07/90
Optics system operational	07/90
Laser local control operational	04/90
Integrated laser systems operational	10/91

A number of support facilities will be operational at earlier dates to support this first module startup plan, such as the graphite shop, separator module assembly, and copper-vapor laser assembly and checkout. This will allow the requisite operator training and assembly of the LIS hardware system elements.

Plant Special LIS Equipment Procurement Complete For Module #1 (October 1990). Procurement will be completed for the special LIS equipment by the first quarter of FY90 for module #1. Specific hardware items included in this category include separator system E-gun/reflux structures, carriage assemblies, chamber internals (rails-liners), transport equipment, and instrumentation and controls panel fabrications; laser systems optical components, dye laser components, copper vapor laser head and power hardware, instrumentation and controls panel fabrications, and pointing and centering components; uranium processing facilities uranium recovery, product conversion, feed conversion, feed preparation, and waste management long lead equipment and support equipment/system hardware.

Plant Separator/Laser Assembly Facilities Construction Complete (October 1990). An important aspect of the AVLIS Production Plant initial module operation is the completion of the construction portion of the separator/laser assembly facilities by the first quarter of FY90. The construction completion is extremely important to allow adequate time for equipment/system pre-operation training, and laser assembly stations to be activated which leads to the copper vapor laser, dye laser, and optics to be installed prior to system start-up. The separator system follows to also allow pre-operation assembly, check parts/components, which leads to the assembly of the first pods.

Plant Central Control System and Support Construction Completed (April 1990). Construction is planned to be completed on the AVLIS Production Plant control system and support system by the third quarter of FY90. The completion of these auxiliary and support systems is required to allow an orderly transition to the laser/separator systems pre-operation startup.

Plant Feed Conventional/Preparation Facilities Construction Complete -- initial (July 1990). Initial construction for the uranium processing feed conversion facility and feed preparation facility are to be complete by the fourth quarter of FY90. This construction activity includes the three month startup activity on both facilities. The startup will result in a metal product capability for the feed conversion facility and

a feed-shape production capacity built up for the feed preparation facility to support the Module #1 system startup and subsequent initial operation.

Plant Module #1 Construction Complete/Start-Up Initiated (July 1990).

Construction will be completed by the fourth quarter of FY90 on all equipment/systems required for the AVLIS Production Plant first process module. The final equipment installation activation will include the separator module pods, pod instrumentation, module optics, the dye lasers and optics, and the final copper vapor heads and electronics package. This construction completion date is extremely important in order to allow adequate time for equipment/system start-up prior to the operational milestone on the first quarter of FY91.

Plant General LIS Equipment Procurement Complete (July 1990).

Procurement will be completed for the AVLIS Production Plant general LIS equipment by the fourth quarter of FY90. Specific hardware procurement and fabricated details include the remaining separator module extractors/product collectors and the final support equipment for the uranium processing wet chemical recovery and product conversion facilities.

Plant Initial Operation From Module #1 (October 1991). Start-up activation will have been completed by the end of FY90 for all equipment and systems that support the first module in the AVLIS Production Plant. The module will become operational at the first quarter of FY91 for the initial increment of enriched operations. All prerequisite milestones that must be accomplished from operation training/certification (the operational safety reviews, the integrated systems testing, etc.) will be completed prior to this operational milestone.

Initial Plant Product Conversion Facility Construction Complete (January 1991). Construction will be completed on the uranium processing product conversion facility, initial portion, by the second quarter of FY91.

This construction activity includes the three month start up period where the enriched uranium-alloy product castings and mixed assay refurbishment

oxides have been received as part of the initial increment of production products from Module #1.

Plant Module #2 Initial Operation (January 1991). The startup activation for Module #2 for the AVLIS Production Plant will be initiated at the second quarter of FY91. This startup is part of the overall operational planning where modules are put into operation every three months.

Plant Special LIS Equipment Procurement Complete (January 1991).

Procurement will be complete for the AVLIS Production Plant special LIS equipment by the second quarter of FY91. The special hardware items include the remaining separator system E-gun/reflux structures, carriage assemblies, chamber internals (rails-liners), transport equipment, and instrumentation and controls panel fabrications; laser systems optical components, dye laser components, copper vapor laser head and power hardware, instrumentation and controls panel fabrications, and pointing and centering components.

Plant Module #3 Initial Operation (April 1991). The startup activation for Module #3 for the AVLIS Production Plant will be initiated at the third quarter of FY91.

Plant Module #4 Initial Operation (July 1991). The startup activation for Module #4 for the AVLIS Production Plant will be initiated at the fourth quarter of FY91. This module initiation constitutes the planned modules to be operational during FY91. By the end of the fiscal year there is a planned installed nameplate capacity of approximately 2 million separative work units/yr.

Plant Production in FY91, 1 MSWU (July 1991). The planned AVLIS Production Plant production by the fourth quarter of FY91 is approximately 1 million separative work units/yr. Individual separator/laser modules will begin operation approximately every three months, beginning with the first quarter of FY91, and the second beginning at the second quarter of FY91, and the third in the third quarter of FY91. By the end of FY91 and the first separator/laser module will have been operational for approximately 12 months and the second separator/laser module will have been operational for approximately nine months.

Although the operational capacity factors will be significantly less than mature plant operations, it is anticipated that the approximately 1 million separative work units-per-year production rate can be sustained by the end of FY91.

Plant Module #5 Initial Operation (October 1992). The startup activation of Module #5 for the AVLIS Production Plant will be initiated at the first quarter of FY92.

Plant 3 MSWU/Yr Capacity Achieved (October 1992). By the first quarter of FY92 there will be five separator/laser modules installed in the AVLIS Production Plant. Although the operational capacity factor will be somewhat less than in a mature plant operation, it is anticipated that approximately three million separative work units/yr, can be sustained by the first quarter of FY92 with a high confidence since the installed nameplate capacity from the full five modules is approximately 4.2 million separative work units/yr at mature plant operations.

Plant Module #6 Initial Operation (January 1992). The last startup activation of Module #6 for the AVLIS Production Plant at the second quarter of FY92 concludes the planned number of modules to satisfy the Authorization Limited Schedule initial increment of operation. The installation of the sixth module achieves an installed nameplate capacity of approximately 4.6 million separative work units/yr and through FY92 will achieve an effective capacity of approximately 4 million separative work units/yr. All prerequisite milestones that must be accomplished from an operation training/ certification. (The operational safety reviews, the integrated systems testing, etc.) will have been completed prior to this operational deployment milestone. The average module (both laser and separator) operational capacity factor (effective availability) during this second year of deployment will be considerably less than that planned for the mature plant operations for the initial increment of production.

Plant Construction Complete - Capital Project Complete (January 1992).

The AVLIS Production Plant Authorization Limited Schedule for the initial increment of production construction portion of the capital project will be complete by the second quarter of FY92. This includes all

equipment and systems necessary to increase the plant production capacity to achieving a production capacity of approximately 5 million separative work units/yr.

Plant Production in FY92 4 MSWU (July 1992). The AVLIS Production Plant initial increment of production will achieve approximately 4 million separative work units/yr by the fourth quarter of FY92. This operational capacity is less than the installed nameplate capacity of approximately 4.6 million separative work units/yr for the six installed modules.

Plant Initial Increment of Production in FY93 (October 1993). The equipment necessary to increase the AVLIS Production Plant capacity to an effective capacity of 5 million separative work units per year will have been operational to complete that phase of the AVLIS deployment strategy identified as the initial increment of production. By the end of FY92 there will be six separators and three laser power amplifier modules installed and operational that are consistent with the FY84 Reference Design.

6. ENGINEERING LIMITED SCHEDULE

This schedule option is an optimistic deployment of the AVLIS Production Plant. In order to meet the major milestones would require the engineering team to develop and issue process building drawings for the construction start in the first quarter of FY87.

Department of Energy studies indicate that a delay in the deployment of AVLIS of one month causes a decrease in net present value of the enterprise of at least \$400 million per year. At this rate of loss, no plausible argument be made for delay. In addition the additional funding needed to pursue the Engineering Limited scenario is less than \$100 million over FY85-86. We are strongly motivated to act on this plan.

On the other hand, in spite of the benefit, it is not likely that the conditions necessary to support the Engineering Limited schedule will be in place when needed. This program requires clear and timely direction and adequate funding. Pragmatically, the Authorization Limited schedule is more probable. This case is featured in our production documents.

The milestones also dictate early design freezes on equipment/systems for the lasers and separators in order to initiate long lead procurement in the first quarter of FY87, thereby, not accommodating full utilization of the laser and separator technology development until later upgrades.

The schedule requires the highest commitment at Department of Energy Headquarter, Department of Energy Oak Ridge Office, Department of Energy San Francisco, Lawrence Livermore National Laboratory, and Martin Marietta Energy Systems, Inc. to achieve early production from the AVLIS Production Plant.

The significant milestone dates, engineering, procurement, construction, and operation initiations, durations, and completions are shown in Table 6-1.

Table 6-1. Significant milestone dates for the Engineering Limited Schedule.

<u>Activity</u>	<u>Milestone</u>
	<u>Fiscal Year/Quarter</u>
Engineering Initiated	86-1
Construction Authorized	87-1
Engineering Complete	88-4
Procurement Complete	90-4
Construction Complete	91-2
Production Initiated	90-1
Production Achieved	92-1
	<u>Month</u>
Engineering Duration	33
Procurement Duration	39
Construction Duration	51
Total duration	63

6.1. SCHEDULE AND FIGURES

Figure 6-1 through 6-8 display the major activities for the Engineering Limited Schedule.

Initial increment of production

Fig. 6-1. Engineering Limited Schedule - Master Schedule.

Initial increment of production

☆ **Major project milestones**

Fiscal year - quarters

Milestones

85-1	Design documents for process selection
☆ 35-3	AVLIS process selection
☆ 86-1	Plant engineering authorized/initiated
86-1	Plant conceptual design documents
86-4	Plant Title I design reports
86-4	Plant site work (limited) design complete
☆ 87-1	Plant construction authorized/initiated
87-1	Plant conventional facilities design (0-1) primary structure
87-2	Plant general LIS equipment design comp/initiate proc (0-1) (separator chamber laser/separator assembly equip.)
87-3&4	Plant general LIS equipment design comp/initiate proc. (0-2) (laser mount assemblies, feed prep/conv. equip., I & C computers)
87-3	Plant special LIS equipment (vendor qualification components)
88-1&2	Plant special LIS equipment design comp/initiate proc. (long lead hardware)
☆ 88-2	Plant special equipment installation initiated (unclassified)
88-3	Plant special LIS equipment assembly/fabrication details
88-4	Plant engineering complete
88-4	Plant conventional facility construction complete
88-4	Plant process building classified construction installation start
88-4	Plant gen. LIS procurement complete for module #1
89-1	Plant start-up of common systems & equipment
89-2	Plant spec. LIS procurement complete for module #1
89-2	Plant separator/laser assembly facilities construction complete

Fig. 6-2. Engineering Limited Schedule - Project Milestones.

Initial increment of production

☆ Major project milestones

<u>Fiscal year - quarters</u>	<u>Milestones</u>
89-3	Plant central control system & support systems construction complete
89-4	Plant feed conventional/preparation facilities construction complete (initial)
89-4	Plant module #1 construction complete/start-up initiated
☆ 90-1	Plant initial operation from module #1
90-1	Plant general LIS equipment procurement complete
90-2	Plant product conversion facility construction complete (initial)
90-2	Plant module #2 initial operation
90-3	Plant special LIS equipment procurement complete
90-3	Plant module #3 initial operation
90-4	Plant module #4 initial operation
☆ 90-4	Plant production in FY 1990, 1MSWU
91-1	Plant module #5 initial operation
91-1	Plant 3MSWU/yr capacity achieved
91-2	Plant module #6 initial operation
91-2	Plant construction complete — capital project complete
91-4	Plant production in FY 1991, 4MSWU
☆ 92-1	Plant full production capacity achieved — 5MSWU

Fig. 6-2. Engineering Limited Schedule - Project Milestones (cont'd.).

● Separator system	
— Facilities & services	87-1
— Vacuum chambers	87-2
— Refurbishment (assembly) equipment	87-2
— Extractor power supplies	87-3
— Vaporizer power supplies	87-3
— I & C long lead equipment	87-3
— Refurbishment (recycle) equipment	87-4
— Vacuum systems	87-4
— Cooling systems	87-4
— E-gun/reflux structures	88-1
— Carriage assembly	88-1
— Chamber internals (rails-line's)	88-1
— Transport equipment	88-1
— I & C panel fabrications	88-1
— Accountability system equipment	88-1
— Extractor/product collection equipment	88-3
● Laser system	
— Facilities & services	87-1
— Refurbishment (assembly) equipment	87-2
— Mounting support structures	87-3
— CVL head qual. parts/assemblies	87-3
— CVL switch qual. parts/assemblies	87-3
— CVL power qual. parts/assemblies	87-3
— I & C long lead equipment	87-3
— Optical components	88-1
— Dye laser components	88-1
— CVL head hardware	88-1
— CVL power hardware	88-1
— I & C panel fabrications	88-1
— Pointing & centering	88-1
● Uranium process facilities	87-1
— Facilities & services	87-3
— Feed conversion — long lead equipment	87-3
— Feed preparation — long lead equipment	88-1
— Uranium recovery — long lead equipment	88-1
— Product conversion — long lead equipment	88-1
— Feed conversion — support equipment/system	88-1
— Feed preparation — support equipment/system	88-2
— Uranium recovery — support equipment/system	88-2
— Product conversion — support equipment/system	88-2
— Waste management — equipment/systems	
● Balance of plant	87-1
— Facilities & services	87-3
— Plant control — long lead	87-3
— Power — long lead	87-3
— Graphite shop — long lead	87-3
— Cooling system — long lead	

Fig. 6-3. Engineering Limited Schedule - Procurement Issue Dates
System/Major Equipment (Initial Increment of Production).

[illegible]

93

Fig. 6-5. Engineering Limited Schedule - Separator Procurement/Construction Schedule.

Fig. 6-7. Engineering Limited Schedule - Operational Ramp-up Projection.

AVLIS Production Plant
-Engineering Limited Schedule-
-Key Schedule Assumptions-

- o Perform significant conceptual design prior to engineering authorization including extensive pre-project critical path method scheduling.
- o Highest level of commitment at Department of Energy Headquarter, Department of Energy Oak Ridge Office, Department of Energy San Francisco, Livermore National Laboratory and Martin Marietta Energy Systems, Inc. to achieve early production from the AVLIS plant.
- o Utilize full scale demonstration facility designs to the extent possible.
- o Commence Title II prior to completing Title I design on critical path activities.
- o Utilize trained AVLIS team (Lawrence Livermore National Laboratory, Martin Marietta Energy Systems, Inc., architect-engineer's) to critical process substantial design activities.
- o Multiple shift engineering on critical path activities (selected items).
- o Utilize design-build contracts for all conventional facilities.
- o Procurement approach similar to that utilized for full scale demonstration facility (details dwgs. for copper laser and functional specifications for separator general LIS hardware) be utilized for plant.
 - Multiple vendors would be required for most hardware items.
- o Limit all bidders lists (procurement and construction) to demonstrated performers of similar activities/hardware.
- o Construction contract flexibility for critical path tasks.
- o Pay premium overtime for all construction activities.
 - Conventional facilities
 - Equipment/System installation
- o Expedite all/any phase of project activities that drive the critical path.
- o Train the start-up operations team on actual hardware in full scale demonstration facility; integrate key technical staff into the operation team.
- o During initial years start-up/operation, a key task force of technologist, analysis, engineers, operations personnel, and management focus on driving the plant availability and performance to mature operating levels.
- o One general contractor for entire construction phase.

Fig. 6-B. Engineering Limited Schedule - Key Schedule Assumptions.

Design Assumptions

- o Title I & Title II design by same architect-engineer
- o Primary engineering for selected architect-engineers will be performed in architect-engineers home office.
- o Significant engineering will be prepared by uncleared personnel. All key personnel will be Q cleared.

Fig. 6-8 (Cont'd.)

7. FUNDING LIMITED SCHEDULE

This schedule option has been evaluated as a moderate/pessimistic schedule in that the significant engineering for Title I design would not be initiated until one year later than either the Engineering Limit Schedule or Authorization Limited Schedule. In addition, the Funding Limited Schedule allows six months more for engineering and three months more for procurement versus the Authorization Limited Schedule. The startup and initial operation of the six modules is two years versus eighteen months on the Authorization Limited Schedule.

The significant milestone dates, engineering, procurement, construction, and operation initiations, durations, and completions for the Funding Limited Schedule are shown in Table 7-1.

Table 7-1. Significant milestone dates for the Funding Limited Schedule.

<u>Activity</u>	<u>Milestone</u>
	<u>Fiscal Year/Quarter</u>
Engineering Initiated	87-1
Construction Authorized	88-1
Engineering Complete	90-2
Procurement Complete	92-2
Construction Complete	93-2
Production Initiated	92-1
Production Achieved	94-3
	<u>Month</u>
Engineering Duration	39
Procurement Duration	45
Construction Duration	63
Total duration	87

7.1. SCHEDULE AND FIGURES

Schedules and milestones for the Funding Limited Schedule are shown in Figs. 7-1 through 7-3.

Initial increment of production

Fig. 7-1. Funding Limited Schedule - Master Schedule.

Initial increment of production

☆ **Major project milestones**

<u>Fiscal year - quarter</u>	<u>Milestones</u>
85-1	Design documents for process selection
☆ 85-3	AVLIS process selection
86-3	Plant conceptual design documents
☆ 87-1	Plant engineering authorized/initiated
87-3	Plant Title I design reports
88-1	Plant site work (limited) design complete
☆ 88-1	Plant construction authorized/initiated
88-3	Plant conventional facilities design (0-1) primary structure
88-4	Plant general LIS equipment design comp/initiate proc. (0-1) (separator chamber laser/separator assembly equip.)
89-1&2	Plant general LIS equipment design comp/initiate proc. (0-2) (laser mount assemblies, feed prep/conv. equip., I & C computers)
89-1	Plant special LIS equipment (vendor qualification components)
89-3&4	Plant special LIS equipment design comp/initiate proc. (long lead hardware)
☆ 89-3	Plant special equipment installation initiated (unclassified)
90-1	Plant special LIS equipment assembly/fabrication details
90-2	Plant engineering complete
90-3	Plant conventional facility construction complete
90-3	Plant process building classified construction installation start
90-2	Plant gen. LIS procurement complete for module #1
90-4	Plant spec. LIS procurement complete for module #1
91-1	Plant start-up of common systems & equipment
91-2	Plant separator/laser assembly facilities construction complete
91-3	Plant central control system & support systems construction complete
91-3	Plant general LIS equipment procurement complete
91-4	Plant feed conventional/preparation facilities construction complete (initial)
91-4	Plant module #1 construction complete/start-up initiated
☆ 92-1	Plant initial operation from module #1
92-1	Plant special LIS equipment procurement complete
92-2	Plant product conversion facility construction complete (initial)
92-2	Plant module #2 initial operation
92-3	Plant module #3 initial operation
☆ 92-4	Plant production in FY 1992, 1MSWU
93-1	Plant module #4 initial operation
93-2	Plant module #5 initial operation
93-2	Plant construction complete — capital project complete
93-3	Plant module #6 initial operation
93-4	Plant production in FY 1993, 3MSWU
94-3	Plant full production capacity achieved — 5MSWU

Fig. 7-2. Funding Limited Schedule - Project Milestones.

AVLIS Production Plant
-Funding Limited Schedule-
-Key Schedule Assumption-

- o Perform normal level conceptual design prior to engineering authorization.
- o Minimum overlap of title I & II design activities.
- o Utilize certain Full Scale Demonstration Facility designs with normal plant related adjustments to accommodate value engineering, system's engineering, and technology improvements.
- o Utilize trained AVLIS team (Lawrence Livermore National Laboratory, Martin Marietta Energy Systems, Inc., Architect-Engineers) to perform certain design activities, but select new architect engineers to support plant designs.
- o Utilize fixed price contracts for all conventional facilities.
- o More complete design prior to initiating procurements on special process equipment through functional specifications.
- o Single vendors could be used for most hardware items.
- o Open bidders lists (procurement and construction).
- o Fixed price construction for most items.
- o Premium overtime for all construction activities to be the exception.
 - Conventional facilities (none planned)
 - Equipment/System installation (only limited-unplanned)
- o Training or operating personnel through standard classroom techniques followed by production on-job-training/handwork (in plant) experience.
- o Production problems (performance shortfalls, availability, etc) handled on an occurrence basis. Task forces formed after problems occur for corrective action recommendation.

Fig. 7-3. Funding Limited Schedule - Key Schedule Assumptions.

8. SCHEDULE COMPARISONS

8.1. CONSTRUCTION PROJECT COMPARISONS

Figure 8-1 is comprised of four charts that are the result of data furnished by both Stone and Webster Engineering Corporation and Bechtel. The basis for the data was recently completed, planned, or on-going projects that required craft labor or subcontractors ramping-up to over one thousand men within 12-18 months from authorization/initiation of construction. Part of the basis was that construction be of an advanced technology rather than conventional facilities. In summary the two charts of data provided by Stone and Webster Engineering Corporation on the Clinch River and Solvent Refined Coal Projects and the two charts of data provided by Bechtel on the Defense Waste Pilot Facility and Belle River Units 1 and 2 provide sufficient validity that staffing-up to a project such as the AVLIS Production Plant to be located at Oak Ridge should present no problem. The four charts show that at four diverse locations sufficient manpower can be marshalled and there should not be a problem to obtain sufficient labor to construct the AVLIS Plant. The four charts indicate that 1000-2000 manpower within 12 to 18 months falls within the probability range for the Department of Energy Project Limit Schedule of optimistic/realistic. The best estimate for craft labor and subcontractors ramp-up for the AVLIS Production Plant falls within the above parameters.

8.2. SCHEDULE COMPARISONS OF LASER CONSTRUCTION PROJECTS AND AVLIS PRODUCTION PLANT

A comparison between the schedule for large laser construction projects and the AVLIS Production Plant laser construction is given in Fig. 8-2. The design start to procurement duration includes Title I and Title II design and preparation of procurement packages up to the issuance of the first procurement packages. The procurement start to system completion duration includes the full procurement, fabrication, assembly, installation and component check-out of whole laser systems. In the case of the AVLIS Production Plant, the construction of modular sections is staged; the time to

Hours (000)

Contractor: SWEC Year Project: Clinch River

The Clinch River Breeder Reactor plant construction master schedule depicts the planned craft labor.

The schedule was based on 8-hour shift operations and alternating 4-day 10-hour shift operations in the second year.

The schedule was based on funding restraints through the first year.

The manual labor hours were developed by the contractor, reviewed by construction and project management and approved as reasonable.

Leveling of the craft labor was not accomplished at this time.

Fig. 8-1 (a). Construction Projects Craft Staffing Comparisons.

Hours (000)

Contractor: SWEC

Project: *SRC—Unit 1

The Solvent Refined Coal unit #1 project construction master schedule displays the planned craft labor to be used. Staffing planned at a five (5) day forty hour week.

Total plant costs were estimated \$846 million plus.

The labor hours were developed by the contractor, reviewed by both construction and project management and it was determined to be reasonable and approved for use.

*Solvent Refined Coal

Fig. 8-1 (b). Construction Projects Craft Staffing Comparisons.

Hours (000)

Contractor: Bechtel

Project: Defense Waste
Pilot Facility

The Defense Waste Pilot Facility is an Advanced Technology project.

The construction planned staffing of direct hires and subcontractors is based on no restraint on manpower availability.

Construction would be conducted with the bulk of the work effort on an unclassified basis.

A forty-hour work week for construction and engineering support was considered with casual overtime.

On subcontract package that required schedule relief the project would go out with an initial construction release package for bidding and issue final construction package prior to award.

Fig. 8-1 (c). Construction Projects Craft Staffing Comparisons.

Contractor: Bechtel

Project: Belle River
Units 1 & 2

The Belle River coal fired power units number 1 and number 2 are being constructed for the Detroit Edison Company.

Actuals and planned construction staffing is shown.

The chart displays total direct plus subcontractors.

Fig. 8-1 (d). Construction Projects Craft Staffing Comparisons.

Laser system	Approx laser units	Month duration			
		Design start to procurement start	Procurement start to system completion	System completion to operation	Operation started
Argus	20	3	8	5	June, 76
Shiva	150	9	23	5	Nov, 77
LDF	54	9	8	2	Jan, 85
AVLIS Full Plant	250	24	26	8	March, 90
AVLIS Plant (First Mod)	1000	—	37	—	—

Fig. 8-2. Laser Comparison Other Projects vs AVLIS Authorization Limited Schedule.

complete the first section is the shorter time given; the longer for completed construction of the laser system. System completion to operation includes the time required to go from checked and operable components and subsystems to full operational capability.

In all cases the durations for the AVLIS Production Plant are substantially longer than those experienced with any prior system. The plant's laser modules are each somewhat larger than the Shiva system which is the closest equivalent example. The Laser Demonstration Facility uses virtually identical equipment, but is a smaller system. The Nova system, not listed, received incremental funding and was delayed by funding limitations; it is not comparable for this reason. The Novette system, built while waiting for Nova funding, was equal to about 20% of an AVLIS module, and was built on a schedule comparable to that listed for Argus, much faster than Shiva or Nova or the AVLIS plant system. However, it used existent Nova designs and equipment already procured for Nova; it is not comparable.

In summary, the durations chosen for the AVLIS Production Plant schedule are based on directly comparable activities experienced with the Laser Demonstration Facility or on similar experience with comparable lasers. In all cases, the AVLIS Production Plant durations for the Authorization Limited Schedule are substantially more conservative than those of our experience base.

8.3. SCHEDULE COMPARISON OF THE AVLIS SEPARATOR CONSTRUCTION PROJECTS AND THE AVLIS PRODUCTION PLANT

The schedule comparison of the AVLIS Production Plant and AVLIS separator projects is given in Fig. 8-3. The Separator Demonstration Facility is very similar to the plant separator. Due to funding limitations in FY85, the installation of the pod requiring six months will be accomplished after a three month abeyance in FY85. The same funding limitations caused the facility completion to take 19 months instead of the scheduled 16 months. The overall procurement start to complete installation without funding delays would have required 22 months.

Separator system	No. of pods	Month duration			Operation start
		Design start to procurement start	Procurement start to complete installation	Complete installation to start operation	
Mars	1	5	17	9	Jul, 81
SDF	1-3	4	25	3	Jun, 86
AVLIS (first module)	4	12	31	10	Oct, 90
AVLIS full plant	24	—	49	—	—

Fig. 8-3. Separator Comparison FSDF vs AVLIS Authorization Limited Schedule.

The first plant module will be procured and installed in 31 months; the last of 6 modules, in a total of 49 months.

The MARS facility was completed in 17 months through vaporizer operation. The extractor assembly design awaited the outcome of MARS vapor characterization measurements and has actually taken 3 years to complete. However, the equivalent time to activate the vapor characterization apparatus was 9 months.

The Materials Handling Demonstration Module facility has been built slowly with facility vessel systems and separator systems being designed and fabricated in series with interspersed system tests. This facility's schedule durations are not comparable with those of the Separator Demonstration Facility.

In summary, again the specific activity durations for the AVLIS Production Plant separator are conservatively longer than those experienced in the construction of comparable systems.

9. SCHEDULE ANALYSIS

9.1. SCHEDULE ANALYSIS OBJECTIVES

The overall master schedule network for the technology program and production plant project was introduced in Section 2 and discussed in detail in Section 5. In analyzing this schedule to establish confidence levels, two techniques have been used. First, experienced construction engineering staff who provided the baseline durations (expected values) traced the critical path and took measures to distribute the schedule stress as uniformly as possible. This led to a baseline schedule with minimum risk and highest overall confidence based on experience with similar construction projects (Section 8). The most probable critical path was discussed in Section 2.

To improve the quantitative assessment of confidence and risk, a Monte-Carlo analytic method for schedule analysis is also being used. This method establishes the duration for each activity in accordance with an expected distribution for durations for that activity. As a result, the critical path is not unique, but varies dependent on the network dependencies and durations chosen.

The strong advantage of this technique is that it examines every possible critical path, utilizes them in accordance with the assign probability distributions, and derives an overall schedule duration which is more realistic in that the schedule logic responds to the full set of probable schedule realizations. The result is a quantitative assessment of overall confidence and a detailed analysis of "off critical path" activity influences on the realized schedule. This analysis has been particularly revealing in examining the interaction of "off critical path" activities. The following sections describe the analysis technique and the results.

9.2. VENTURE EVALUATION AND REVIEW TECHNIQUE

The Venture Evaluation and Review Technique is a simulation network technique design to model decisions under risk. Venture Evaluation and Review Technique network modeling dates back to the early 1970s when it was developed

and applied to assess risks of major U.S. Army weapon system development projects. Many unique applications of the Venture Evaluation and Review Technique philosophy have materialized since that time and enhancements to the model have resulted in adaptations of Venture Evaluation and Review Technique to these applications. Version 4 of the Venture Evaluation and Review Technique is the most recent in this series and represents the most comprehensive capability of any model of its type. It is a tool with a comprehensive array of logical, statistical and mathematical features which makes it possible to deterministically or stochastically model and analyze a program.

The Venture Evaluation and Review Technique-4 analytical process utilizes a network similar to that used in deterministic scheduling. The principal differences are in the statistical determination of each activity duration, in the options for redirection of the logic flow at each node, and in the inclusion of cost and performance parameters as well as schedule.

The activity durations, as well as cost and performance parameters, are randomly chosen for each activity in accordance with one of 14 standard distributions. The distributions which we use most often are triangular, uniform, and normal. The distributions can be skewed to reflect unequal short and long side certainty.

The redirection of logic flow at nodes can be either the typical longest of incoming durations initiating several dependent activities or a more complex decision ranging from Monte-Carlo selection of the outgoing path to deterministic thresholding based on schedule cost or performance achieved on the incoming arcs. Twenty node types are available. We have utilized for the schedule analysis very straightforward deterministic logic flow through the nodes.

Similarly in analyzing the schedule per se cost and performance parameters are assumed constant for the initial analysis.

In summary, Venture Evaluation and Review Technique-4 is a powerful program analysis tool which we have used to analyze the AVLIS Development Program and Production Plant project schedules. We are continuing to elaborate our analysis, including schedule sensitivities, cost, and performance effects.

9.3. MONTE CARLO SCHEDULE ANALYSIS

The AVLIS program schedule for development activities starting in mid FY84 through deployment of the first increment of the first plant has been modelled using VERT-4. The starting activities are those involved in the process and equipment demonstrations to be completed in FY85 for process selection. The development activities needed to support plant conceptual design, final design, procurement, operations and training have been included and tied into the plant design, procurement, construction, assembly, installation, and phased activation and operation.

The schedule model covers more than 8 years from 1984 to 1992. About 1100 activities are scheduled with about 200 dependencies. The development activities include laser, separator, uranium processing, and operations technology and training. The plant construction includes all conventional facilities, laser and separator systems, supporting systems and facilities, uranium processing systems and facilities, site facilities and site improvements. All activities are initiated by the program logic out of the Development Program and eventually flow logically to the completion of the first plant increment's 6 separation modules. The program master network was presented in a previous section but is reproduced here to illustrate the scope of this analysis (see Fig. 9-1).

The most probable activity durations are based on the Authorization Limited schedule. The actual durations are randomly chosen for each network realization according to a specified distribution appropriate to the activity. The uncertainty of the activity is modeled by choosing the width and skewness of the duration probability distribution. We have used both symmetric distributions and distributions skewed to longer durations. Typically the uncertainty is in the range of plus or minus 20% to 30% of the most probable duration. The specific distribution width and skewness are chosen based on the experience of our construction engineering staff.

Typical activity arcs for the initial development activities are shown in Table 9.3-1. The inputs include the arc designation, the initial and terminal nodes, the probability of completion, the activity name, the parameter to be analyzed (time, cost, or performance), the distribution function, and the distribution specifiers. The durations are specified in months.

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TABLE 9.3-1. Typical Arc and Node Specifications.

Typical Activity Arc's

d111	d11a	d11b		1.0 modify facility	
d111	utime 1		3.0	3	7
					5
d113	d11b	d11c		1.0 1000 hour tests	
d113	utime 1		3.0	5	7
					6
d115	d11c	d11d		1.0 2500 hour tests	
d115	utime 1		3.0	8	10
					9

Typical Dependency Arc's

d1r15	d1/y	d18e	1.0
d1r16	d18f	d18x	1.0
d1r17	d18v	d18x	1.0
d1r18	d17x	d18x	1.0

Typical Node Specifications

mod od	2	2
mod 6e	2	2
mod of	2	21

The dependencies are modelled as simple transport arcs. Table 9.3-1 gives examples of such arcs. These arcs are defined simply by a designator, the initial and final nodes, and a probability of completion of 1.0.

The nodes are specified simply by a designator, a node type, and a priority if the node is a terminal node. Examples of such nodes are also shown in Table 9.3-1.

The code is being used for schedule analysis only at this point. Cost and performance analyses will be used later. The code chooses durations for each of the activities and computes the schedule for the overall program and to each significant internal node. Then new durations are chosen according to the specified distributions and a second schedule computation is completed. This process is repeated typically 100 times during the setup phase. When it is determined that the logic is correct for the specific objective of the analysis and that the appropriate diagnostics are operative, the network is run typically 200-1000 times to generate smoothly distributed statistics.

By the nature of this analysis the critical path and slack paths are not unique, but differ with each generation of the network. As a result the criticality and slackness are specified in terms of probable values and ranges. The activities with the most slack are reported as shown in Table 9.3-2. The report includes the arc designation and the average, minimum and maximum slack times experienced for that activity.

The critical path report is presented as a histogram such as that shown for the development activities and nodes listed in Fig. 9-2 and 9-3. The report gives the arc designation and the probability that the arc is on the critical path both numerically and graphically.

The total duration to the final nodes for the entire network is specified in terms of the average, minimum and maximum durations. The planned duration of the Authorization Limited Program is 99 months (8.25 years). When symmetric activity duration distributions are used, the overall average program duration is approximately as planned. The program duration to full operation of the first plant increment is 98.4 months + 1.8 months (90% confidence) -1.3 months (10% confidence). The minimum and maximum durations found in 200 trials are 94.0 months and 102.8 months. The distribution for the program duration is shown in Figure 9-4. Finally, the average durations to the completion of each activity are shown in Table 9.3-3 for the final 20 activities.

TABLE 9.3-2. Slack Time Report for Paths with Maximum Slack.

slack time for arc s45

no obs =	100 ave =	5.427366
min =	0.559890 max =	13.448905

slack time for arc srl1

no obs =	100 ave =	4.469820
min =	0.000000 max =	8.508880

Table 9.3-3. Typical Activity Completion Time Reports.

nodes	Mean Completion time
U18r	82.7044
U1r3e	83.9311
U18y	84.7526
Umod5u	84.8889
Umod4w	84.9559
Umod6c	85.7167
U1r1f	85.8414
U18n	87.7629
Umod2f	87.8386
Umod5e	87.8532
usr1e	88.2321
Umod3f	88.2922
U54e	88.4776
Umod6d	89.1365
U55f	89.7504
Umod4r	91.2287
Umod6e	92.3753
Umod1r	93.5633
Umod5t	93.8111
Umod6f	98.4151

largest critical path index - no. paths = 288											
		0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
d131	0.0200	*									
d133	0.0200	*	+	+	+	+	+	+	+	+	+
d141	0.1050	*****									
d143	0.1050	*****	+	+	+	+	+	+	+	+	+
d151	0.0050	****									
d153	0.1750	*****	+	+	+	+	+	+	+	+	+
d155	0.0200	*									
d157	0.0200	*	+	+	+	+	+	+	+	+	+
d159	0.0200	*									
d1511	0.0200	*	+	+	+	+	+	+	+	+	+
d1513	0.0150	*									
d161	0.3200	*****	+	+	+	+	+	+	+	+	+
d163	0.4150	*****	+	+	+	+	+	+	+	+	+
d165	0.0200	*									
d167	0.0200	*	+	+	+	+	+	+	+	+	+
d169	0.0200	*									
d1611	0.0200	*	+	+	+	+	+	+	+	+	+
d171	0.0150	*									
d173	0.0150	*	+	+	+	+	+	+	+	+	+
d175	0.0150	*									
d177	0.0050	*	+	+	+	+	+	+	+	+	+
d181	0.1350	*****	+	+	+	+	+	+	+	+	+
d183	0.1350	*****									
d185	0.0450	**									
d187	0.0450	**	+	+	+	+	+	+	+	+	+
d188	0.0450	**									
d189	0.0450	**	+	+	+	+	+	+	+	+	+

Figure 9-2. Typical Activity Critical Path Frequency Report

```

nodes critical path index - no. paths = 188
      0.1  0.2  0.3  0.4  0.5  0.6  0.7  0.8  0.9  1.0
-----
d13a  0.0200  *
d13b  0.0200  * + + + + + + + +
d13c  0.0200  * + + + + + + + +
d14a  0.2300  * + + + + + + + +
d14b  0.2300  * + + + + + + + +
d14c  0.2300  * + + + + + + + +
d15a  0.0800  * + + + + + + + +
d15b  0.2000  * + + + + + + + +
d15c  0.2000  * + + + + + + + +
d15z  0.0200  *
d15d  0.0200  * + + + + + + + +
d15e  0.0200  * + + + + + + + +
d15y  0.0200  * + + + + + + + +
d15x  0.0200  * + + + + + + + +
d16a  0.3000  * + + + + + + + +
d16b  0.4100  * + + + + + + + +
d16c  0.4100  * + + + + + + + +
d16z  0.0200  * + + + + + + + +
d16d  0.0200  * + + + + + + + +
d16y  0.0200  * + + + + + + + +
d16x  0.0200  * + + + + + + + +
d17a  0.0100  *
d17b  0.0100  * + + + + + + + +
d17c  0.0100  * + + + + + + + +
d17z  0.0100  * + + + + + + + +
d18a  0.1200  * + + + + + + + +
d18b  0.1200  * + + + + + + + +
d18c  0.6900  * + + + + + + + +
d18d  0.0300  *

```

Figure 9-3. Typical Node Critical Path Frequency Report

network time										
for node modif										
cfid	B.1	B.2	B.3	B.4	B.5	B.6	B.7	B.8	B.9	1.0
93.9893										min
93.9893										0.000
94.3085										0.010
94.7877										0.010
95.1870										0.010
95.5868										0.025
95.9852										0.045
96.3844										0.076
96.7826										0.130
97.1820										0.195
97.5819										0.260
97.9811										0.340
98.3803										0.495
98.7795										0.615
99.1787										0.730
99.5778										0.815
99.9778										0.885
100.3762										0.915
100.7754										0.940
101.1746										0.965
101.5738										0.980
101.9729										0.990
102.3721										0.990
102.7713										1.000

no obs										max
std error										1.4417
coef of variation										98.4151
kurtosis (beta 2)										3.49

pearsonian skew										0.3928
median										98.2532
mode										98.2532

min	5%	10%	15%	20%	25%	30%	35%	40%	45%	50%
93.989	96.052	96.566	96.986	97.213	97.521	97.762	98.007	98.126	98.264	98.397
55%	60%	65%	70%	75%	80%	85%	90%	95%	max	
98.563	98.730	98.901	99.075	99.273	99.507	99.777	100.177	100.935	102.771	

Figure 9-4. Network Completion Distribution Report

In summary, we have obtained the initial results of VERT-4's Monte Carlo schedule analysis and have begun to exercise its computational power to optimize the schedule for deployment. In general, the analysis verifies our deterministic schedule analysis indicating that the network logic is accurate and that the critical path is not subject to strong off-critical-path effects. In addition, the analysis indicates that significant uncertainties can be tolerated in each activity without resulting in either an excessively long or uncertain overall schedule. With specific uncertainties in the range of $\pm 30\%$, the overall program uncertainty is $\pm 5\%$.

In the near term we will exercise several schedule effects of which we have not taken advantage. First, we will analyze the critical path to see how the schedule can be shortened by logic changes (parallel or work-around techniques) and by trading schedule risk for schedule acceleration (shorten selected activities, but accept a wider or more skewed distribution of these durations). Second, we will begin to employ learning to the schedule. For the most part we have used the same durations for repetitive activities, preserving the durations estimated for initial activities for all succeeding exercises of that activity. Clearly succeeding repetitions will be completed more efficiently. Initial results indicate that this procedure will allow significant shortening of this schedule or the inclusion of schedule contingency (slack) on the most critical path. In addition, activities which are often repeated can receive development effort early in the program to ensure their expeditions completion for the plant.

The Monte Carlo schedule analysis is proving to be a practical and useful tool for analyzing and planning the overall program schedule.

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