Needs Analysis and Project Schedule for the Los Alamos National Laboratory (LANL) Health Physics Analysis Laboratory (HPAL) Upgrade

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Executive Summary

This report is a needs assessment and project schedule for the Health Physics Analysis Laboratory (HPAL) upgrade project at Los Alamos National Laboratory (LANL). After reviewing current and projected HPAL operations, two custom-developed laboratory information management systems (LIMS) for similar facilities were reviewed; four commercially available LIMS products were also evaluated.

This project is motivated by new regulations for radiation protection and training and by increased emphasis on quality assurance (QA). HPAL data are used to:

- protect the health of radiation workers;
- document contamination levels for transportation of radioactive materials and for release of materials to the public for uncontrolled use; and
- verify compliance with environmental emission regulations.

The HPAL program suffers from extreme shortages of staff, equipment, and space. The ability of a LIMS to effect increased quality, productivity, and improved customer responsiveness will be minimized or even negated until these problems are substantially addressed. Programmatic documentation and upgrades are required to ensure that existing, manual HPAL operations run smoothly with adequate QA. These program upgrades are principally in the areas of standardized forms and reports, sample accountability, quality control (QC) and blind-audit sample processing, and technical documentation of data reduction algorithms. Documented agreement on these fundamental issues must *precede* any computerization effort.

Development of a LIMS tailored to LANL's needs will be a major undertaking requiring several years. Therefore, a temporary, off-the-shelf LIMS should be implemented quickly to promote efficiency, support QA programs, and reduce the risk of a major funding cut in the middle of a multi-year custom LIMS development effort. Once the low-cost, prototype LIMS is operating, lessons learned from that startup will be incorporated into the software requirements specification for the final, custom LIMS.

Phase I of the HPAL upgrade project concentrates on four types of counting instruments which support in excess of 90% of the sample workload at the existing central laboratories. Phase II is a refinement phase and also integrates summary-level databases on the central Health, Safety, and Environment (HSE) VAX. Phase III incorporates additional instrument types and integrates satellite laboratories into the HPAL LIMS.

Phase I will be a multi-year, multimillion dollar project. The temptation to approach the upgrade of the HPAL program in a piece meal fashion should be avoided. This is a major project, with clearly-defined goals and priorities, and should be approached as such. Major programmatic and operational impacts will be felt throughout HSE as a result of this upgrade, so effective coordination with key customer contacts will be critical.

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1 Introduction

1.1 Background

Los Alamos National Laboratory (LANL), Health Safety and Environment Division (HSE), Radiation Protection Group (HSE-1), Radiation Protection Measurements Section, operates central labs and other satellite labs for analysis of various types of samples in support of the LANL operational health physics groups. These samples are collected to demonstrate compliance in three areas:

- stack filters for comparison against environmental release standards;
- room air filters, contamination smears (swipes), and nasal smears for contamination control and personnel protection measures as required by Department of Energy (DOE) Order 5480.11; and
- miscellaneous swipes and other sampling media to support decisions on transportation and release of equipment to the public for unrestricted use.

The users of the Health Physics Analysis Laboratory (HPAL) analysis services, referred to here as HPAL "customers," are all within the HSE organization at LANL.

Current support activities require that HSE programs process more than 500,000 samples per year, many of which are high priority samples requiring immediate turnaround of verified and approved results. HSE management anticipates significant increases in sample load and longer counting times since the promulgation of DOE Order 5480.11. In response to these increased demands, budgetary plans are in place to procure additional counting equipment and to apply automated methods of information management.

The scope of this HPAL upgrade project includes not only the procurement of additional equipment and a Laboratory Information Management System (LIMS), but also implementation of the associated programmatic elements necessary to achieve compliance with auxiliary DOE orders, American National Standards Institute (ANSI) standards, and industry good practices.

This document will define the objectives of the HPAL upgrade project, describe the constraints upon the project, evaluate the possible alternatives, and describe the recommended approach. Other recommendations for general quality and efficiency improvements will be included as well. A project schedule for the HPAL upgrade is

also included. This schedule should be considered preliminary since major uncertainties about project funding exist at this time.

Identification of the number of new counting instruments required to meet the expected increase in work load has been provided by HPAL personnel. Procurement and implementation of new equipment has been considered in the development of the project schedule.

Data necessary to prepare this report was gathered during trips by Science Applications International Corporation (SAIC) and NUS staff to LANL and by joint trips of LANL and SAIC/NUS staff to Brooks Air Force Base (San Antonio, TX) and to Consort Technologies (Marietta, GA), where similar LIMS were in operation or under development.

"Lessons learned" from development and implementation of LIMS at other equivalent sites will be incorporated in the project schedule.

Appendices A and B summarize the Brooks Air Force Base and Westinghouse Savannah River Company systems, respectively. Four commercially available LIMS products have also been given an initial evaluation for suitability to the tasks at hand. These products from Beckman, Radian, Laboratory MicroSystems, and Perkin-Elmer are summarized in Appendix C. Brief bibliographic information on the authors is contained in Appendix D. Appendix E contains the project schedule's task list, network diagram, and Gantt chart.

1.2 Current HPAL Operations

The HPAL program is one of the largest of its kind in the world. Over 500,000 samples are currently processed each year; this sample load is expected to grow by 50% - 100% over the next several years. Most of the samples counted are air samples from continuous air monitors (CAMs), stack samplers, fixed-head air samplers, or portable air sampling equipment used for assessment and control of radiological work. However, several other sample media are handled as well, including water and oil samples.

Many of these samples are personnel-safety related and therefore take priority over routine samples. Operational considerations dictate quick turnaround on many samples. These factors make it difficult to manage HPAL operations effectively. The

most frequently requested analyses are gross α/β counting, liquid scintillation analysis, and gamma spectroscopy.

The LANL HPAL operates seven counting facilities in several technical areas (TAs): TA-53, TA-55, TA-50, SM-43, TA-33, TA-16, and TA-54. In addition, it is desired that additional satellite counting facilities be set up in areas operated by HSE-10 and HSE-11. The types of analyses presently performed, number of samples presently analyzed, types of counting equipment presently contained at these facilities, and current counting times is summarized in Table 1. Also included in the table is the counting equipment projected to meet the expected sample and analysis load to meet regulatory requirements.

Most of the counting equipment presently used at these facilities incorporates a personal computer as the instrument controller. This is true for the Tennelec LB-5100 gas proportional α/β counters, the Packard 2250 liquid scintillation counters and the gamma spectroscopy systems which are running Ortec ADCAM System software. The 128 zinc sulfide detector alpha counting system, known locally as the IMPULSE system, is controlled by a dedicated DEC computer. This computer has recently been upgraded and is now running on a PDP 11/73 under the RSX operating system. The other instruments, which include the Nuclear Measurements Corporation PC-5s and PC-55s an Eberline SAC-4 counters are not computer controlled and may not be readily upgraded to computer control. Therefore, manual data entry for these counters will likely be necessary. All new equipment will likely be controlled by a personal computer.

Table 1. Current and Projected HPAL Counting Requirements and Capabilities

Area	Types of Samples	Present # of Samples per year	Present Equipment	Needed Equipment	Required Count Time	Background
TA-53 (LAMPF)	Activation Products H-3 Swipes Alpha/Beta Surveys Smears/Water/Oil	100,000 Total	1 Packard 1600 LSC	NaI Array(8-16) 2 Gamma-X Spec (40%) 1 Multi-Alpha/Beta	1-10 min (LSC) 500 sec (gamma)	18 cpm (H-3) 27 cpm (gross)
TA-55 (Pu Facility)	Air/Stack Nose Swipes Contamination Swipes Water/Oil H-3/C-14	75,000 LSC 126,000 LB-5100 1,100 PC-5 137,000 IMPULSE 339,100 Total	2 Packard 2250 LSC 4 Tennelec LB-5100 PC-5s, SAC-4s IMPULSE 128 Alpha	1 LSC (2550) 3 Multi-Alpha/Beta 1 Gamma-X Spec (40%)	1-10 min (LSC) 1 min (alpha/beta) 10 min (IMPULSE) 1000 sec (gamma)	.2 cpm (alpha)
TA-50 (Waste)	Contamination Swipes Air Test Nose Swipes Misc. H-3 Water/Oil	11,000 LSC 58,000 LB-5100 69,000 Total	1 Packard 2250 LSC 1 Packard 1500 LSC 2 Tennelec LB-5100	1 2550 LSC (upgrade) 3 Multi-Alpha/Beta 1 Gamma-X Spec (40%)	1-10 min (LSC) 1 min (alpha/beta) 1000 sec (gamma)	
SM-43 (Admin.)	Content Water Paper & Char Air Filters (stack) Soil/Water Smears Wound Analysis	12,000 e,b,g Spec 4,050 PC-55 13,800 TLD 80 Wound 30,000 Total	2 Gamma Spec beta spec alpha spec PC-55s, PC-5s TLDs Wound Scint.	2 Gamma-X Spec (40%) 1 Packard 2550 LSC 1 Multi-Alpha/Beta	1000 sec (gamma) 1 min (alpha/beta)	
TA-33, 16, 41	H-3 Swipes Water/Oil	12,000 TA-33 10,000 TA-16 Low TA-41	2 Packard 2250 LSC 1 Packard 1500 LSC	_____	1 min	
TA-54 (TRUPAC)	Contamination Swipes alpha/beta	25,000	1 Tennelec LB-5100 (Series III)	? Multi-Alpha/Beta	1 min	
CMR Bldg. (Satellite)	Contamination Swipes	_____	_____	8 Multi-Alpha/Beta (5,000 each machine)	1 min	
HSE-1 (Satellite)	Contamination Swipes	_____	_____	14 Multi-Alpha/Beta (5,000 each machine)	1 min	

2 HPAL Requirements

2.1 Upgrade Objectives

A successful project requires clearly defined goals. The objectives of the HPAL upgrade program are to:

- meet customer's regulatory and operational requirements;
- ensure the quality and integrity of data produced;
- maximize cost-effectiveness of equipment and personnel;
- meet ancillary regulatory requirements, such as those for performance-based training and records management; and
- minimize the impact of system failures.

New or impending regulatory guidance, such as the new DOE Order 5480.19[1] and the draft NCRP report on radiation protection records[2] should be considered as well.

The HPAL program processes more than 500,000 counting analyses each year for monitoring workplace contamination and release of radioactivity from the workplace in support of operational health physics programs. These analysis results are also used to demonstrate compliance with radiological health protection regulations. All counting equipment in the HPAL is currently operated in stand-alone mode, and all data processing is performed by hand entry and transcription. The purpose of the LIMS is to automate the collection of analytical results from the counting instrumentation and facilitate their transfer to and storage in a database for easy retrieval by personnel responsible for the monitoring and compliance activities.

The functional objectives of the LIMS system are to:

- facilitate increased productivity and fast turnaround of operational health physics sample results;

- improve the chain-of-custody accountability of samples and defensibility of analytical data;

- facilitate data verification by laboratory technicians and validation by laboratory supervisors and enhance the QA and statistical QC aspects of the laboratory;

- provide rapid access to stored data so that information could be easily consolidated and incorporated into reports;
- provide a user-friendly, non-intimidating interface so that it will be easy to use and easy to learn; and
- adapt easily to changes brought about by the addition of equipment or evolution of operations.
- provide complete integration of all counting equipment into a local area network to allow automatic transfer of counting data from the counting equipment to the database;
- allow independent manual entry of results into the database;
- interface to the Oracle-based HPIMS (HSE VAX) system in order to help keep radiation exposures as low as reasonably achievable (ALARA) and to facilitate environmental tracking and reporting;
- facilitate the rapid log-in of sample identification/information;
- provide for unique identification of samples;
- automate the production of laboratory management reports;
- promote interchangeable hardware and reusability of software modules; and
- provide for uniform data backup, archival, and retrieval.

In addition, independent operation and generation of final results by each counting system may be desirable and this design option will be considered for incorporation into the system. In order to meet HPAL programmatic obligations, the method chosen for implementation of the LIMS must:

- effectively utilize resources and take an approach that has a reasonable implementation schedule;

- utilize existing equipment and be extensible to planned equipment purchases as well as anticipate future expansion;
- incorporate requirements from the QA program, training, and monitoring program technical basis into the design;
- be designed and implemented using LANL QA requirements, industry standards, and good practices; and
- be implemented in accordance with DOE and LANL data/system security policies.

The HPAL upgrade is driven by the regulations. Several of these regulations are newly announced or impending. The scope of this project also includes the associated programmatic elements necessary to achieve compliance with these DOE Orders, ANSI standards, and industry good practices in the areas of quality assurance, training, and records management.

2.2 HSE Information Systems

The HPAL program provides radiological sample analysis services and operational support to a variety of customers, including Operational Health Physics staff in HSE-1, HSE-10, and HSE-11. Stack-sampling data generated by the HPAL is utilized by HSE-8 in generating effluent reports for various regulatory agencies. HPAL also generates personnel-related data, such as nasal smears and wound counts, as well as data used to certify items as being suitable for shipment and for removal from a radiologically controlled area.

An independent project has already initiated the development of an overall health physics information management system (HPIMS) for the HSE Division. The HPIMS development effort does not address the laboratory automation needs of HPAL. However, the records produced by HPAL are a significant part of the overall health physics data management effort. Therefore, interface of the HPAL LIMS to the HPIMS is required.

HPAL provides both personnel- and workplace-related data to the HPIMS. Nasal smear and wound count results from HPAL are linked to the HPIMS personnel exposure database, while results from continuous, fixed-head, and portable air

samplers support the HPIMS work area monitoring. The HPAL LIMS to HPIMS interconnection paths are represented in Figure 1.

The HPAL LIMS will be separate from, subordinate to, and linked with the HPIMS. A consolidated, complete solution to management of all health physics data will require close cooperation between all involved parties.

This report deals with various issues of information management and connectivity requirements in an attempt to develop a scenario to potential program alternatives that increases the throughput and efficiency of HSE-1 operations. It is acknowledged that budgetary factors are unpredictable and aspects of the entire system may be purchased and implemented in a piece-meal fashion. Therefore, every opportunity should be taken to partition system elements in a logical way and to minimize expenditures on temporary solutions.

2.3 Calculations and Data Validation

Calculation software is supplied by the vendors of the instruments which are controlled by a personal computer. However, the vendor-supplied software often does not perform the calculation of results in a satisfactory manner to meet the laboratory need. Further calculation of uncertainties or inclusion of correction factors is often required. Furthermore, reports generated by the vendor-supplied software must be validated and often abridged before the data can be accepted into a database. Therefore, for most instruments it is required that interface software be developed to provide the final calculations and data validation and acceptance.

2.4 Assumptions/Constraints

Data transfer to the HSE VAX where the HSE Occupational and Environmental Health Information System resides under the Oracle Relational Database Management System is required. This system will allow the collection and storage of all current and historical counting results and allow the trending, tracking, and QA oversight necessary by personnel responsible for the monitoring and compliance activities. It would be desirable to have summary-level data accessible to HPAL customers on the HSE VAX, but this report has assumed that the customers will not have direct access to the laboratory workstation databases.

The HPAL LIMS will be required to provide a common user interface for logging samples into the system, tracking them through the analysis process, and reporting the

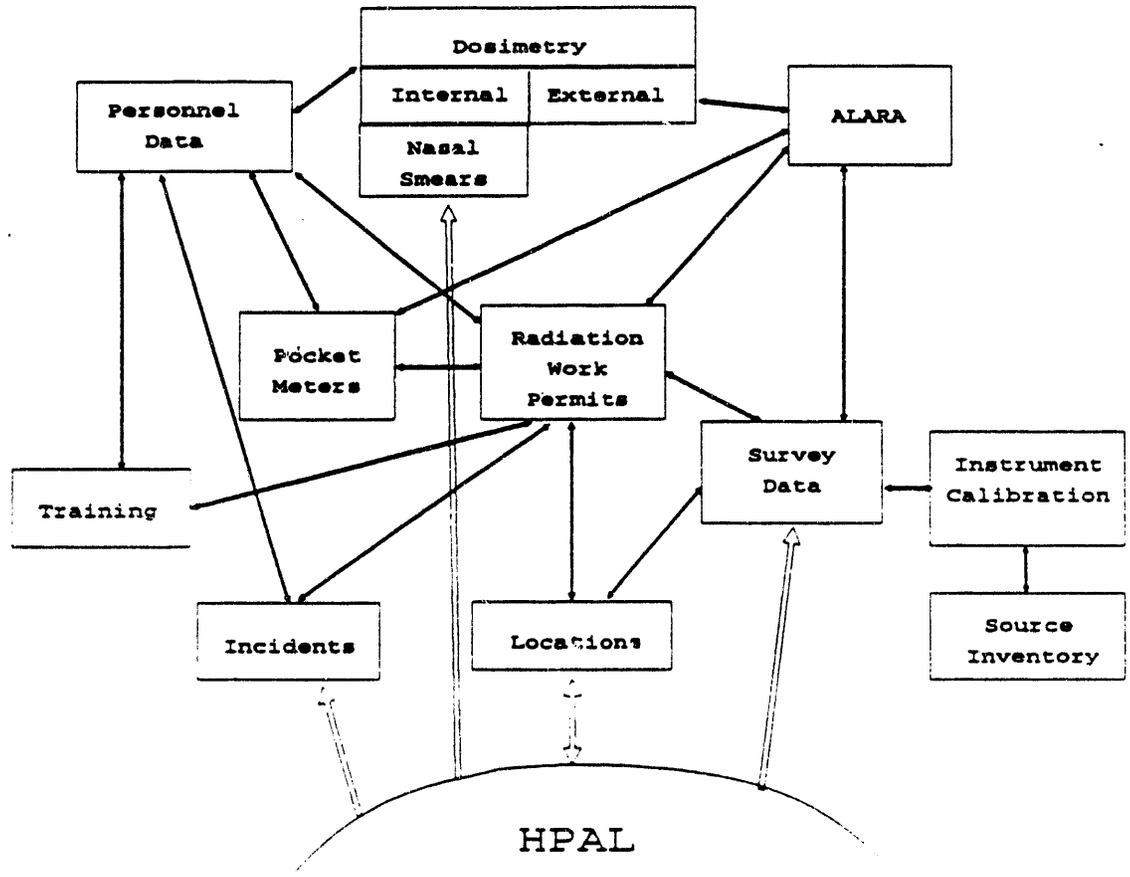

Figure 1. The HPAL system interfaces with, and is subordinate to, the overall HPIMS.

results to provide comprehensive chain-of-custody. It is assumed that the HPAL LIMS will also need to utilize an Oracle Relational Database Management System to facilitate communication between the two databases and to minimize support costs.

It was originally envisioned that all counting equipment could be directly connected to the HSE VAX via an Ethernet Network. However, discussions with Network and Hardware System Management personnel have revealed that the HSE VAX resides on an administrative partition of a "confidential sensitive" network. A continual direct link from the various laboratory locations to the HSE VAX will, therefore, be impossible through an Ethernet Network.

Normal DECNET communications between any workstation(s) in the laboratories and the HSE VAX is also ruled out. This will also preclude the option of controlling all instruments from a central location outside of each local laboratory. Data transfer, however, may be made in batch mode via a secure (lock boxes) T-1 Link utilizing a modem.

The data transfer constraints resulting from the security concerns require that the sample logging and tracking database be located locally in each laboratory on a computer other than the HSE VAX. A local area network (LAN) can be provided to connect all counting instrumentation within a lab to the local workstation where the database resides.

Software requirements specifications are assumed to contain the information detailed in ANSI/IEEE Standard 830, *IEEE Guide to Software Requirements Specifications*[3]. Additional requirements are contained in ANSI N13.6[4]. Software documentation is assumed to consist of both technical and user manuals, as required by ANSI N413[5]. The technical manuals include system functional descriptions, system structure charts, data flow diagrams, and data dictionaries.

It is further assumed that no cost accounting will be incorporated into the HPAL LIMS. Only the typical management reports, such as number of samples processed each period, breakdown of workload by analysis type and sample turnaround time will be available. However, any further cost analysis or cost chargeback system desired in the future can be integrated later.

Major funding uncertainties for fiscal year 1991 (FY 91) exist at this time. These budget factors are unpredictable and may necessitate an implementation plan that is slower than desired. Multi-year development efforts are at risk since funding in future fiscal years is even more uncertain.

2.5 Programmatic Elements

2.5.1 Quality Assurance

DOE Order 5700.6B[6] requires "*...plans and actions to assure quality achievement in departmental programs shall be established, implemented, and maintained with primary emphasis on achieving a high degree of operational success and with due consideration to health and safety, environmental protection, performance, reliability, and other concerns.*"

In order to achieve this requirement, a well-defined QA program will need to be developed and implemented to assure that all development and operational activities of the HPAL and HPAL upgrade project are adequately controlled to ensure that quality objectives are obtained. DOE Order 5700.6B specifies the preferred standard for implementing QA to be ANSI/ASME NQA-1, *Quality Assurance Program Requirements for Nuclear Facilities*[7].

ANSI/ASME NQA-1 will form the foundation of the overall QA program. In addition, other activities will need to be developed to control specific elements of the LIMS. These items are addressed below.

2.5.2 Procurement

Government procurement regulations require that competitive procurements occur except when prior experience, unique capabilities, excessive costs/programmatic delays, or other similar considerations justify a sole source procurement. Although LANL staff are extremely knowledgeable and up-to-date on commercially available instruments, purchasing agents usually are more comfortable with competitive bidding against a set of documented, precisely stated specifications.

2.5.3 Procedures/Training

Procedures will need to be developed or modified whenever operations are changed; training on those revised procedures must also be provided and documented.

In many cases, stepwise refinement of procedures will occur. Therefore, procedure development and training will be required throughout the entire HPAL upgrade project.

New DOE regulations have affected HPAL training programs. DOE Order 5480.18[8] requires an accredited performance-based training program. Draft DOE 5480.XX[9] specifies the required education and work experience for various health protection-related personnel.

2.5.4 Records Management

Both QA records and vital records will be created by HPAL. QA records must either be stored in a vault rated for a four-hour fire, or else dual-storage of the same record in two separate locations must occur. Vital records are those which would be needed to restart HPAL operations after a disaster such as fire or flood; they require similar protection.

DOE Order 1324.2A[10] provides only generic guidance for document retention. Records created for specific purposes, such as demonstrating compliance with environmental release limits, may have additional, more stringent retention requirements.

3 Recommendations

3.1 Project Phasing

The HPAL upgrade project will span several years and will cost several million dollars to implement. Therefore, it is important to have effective project management systems in place with meaningful milestones and planned phases of development activities.

This report recommends that the central laboratories be implemented first, starting with TA-55. The initial effort should be directed at the existing single-chamber α/β counters, liquid scintillation counters, the IMPULSE system, and any new multi-chamber α/β counters purchased as part of this project. Over 90% of the projected sample workload is processed on these instruments.

Phase I of this project should encompass the implementation of these four instrument types at the four central labs. Phase II will be a refinement period for the LIMS and will develop the summary-level application on the HSE VAX. Phase III will incorporate α- and γ-spectroscopy and will integrate the satellite labs into the HPAL LIMS program. Phases II and III may be run in parallel if sufficient resources are available.

The modular development proposed here offers substantial flexibility in accelerating or slowing the scope or rate of development due to changing priorities or funding. For example, all software for the PCs is readily duplicated within a lab and among different labs once it is developed for a single instrument. Similarly, laboratory-level databases are easily duplicated in additional labs.

Instruments omitted from the initial effort can be integrated with manual data entry until such time as automated instrument interfaces can be developed in later phases. Therefore, a well documented manual system for all instruments in all labs should be running smoothly on paper before any computerized LIMS can succeed.

3.2 Programmatic Upgrades

It is strongly recommended that programmatic documentation and upgrades occur *before* trying to automate HPAL operation with a LIMS. While previous LIMS projects have used the new computer system to force programmatic changes, the approach proposed here is to first implement the program upgrades manually. Only then would the revised program be automated (Figure 2). Other software development projects have shown that trying to computerize an incompletely-documented program is difficult, inefficient, and very expensive. A summary of recommended programmatic upgrades is shown in Figure 3.

While some programmatic documentation exists for HPAL, translating that program into computer instructions requires that all possible errors and unusual situations, and how to handle them, be thoroughly documented before any software development can proceed.

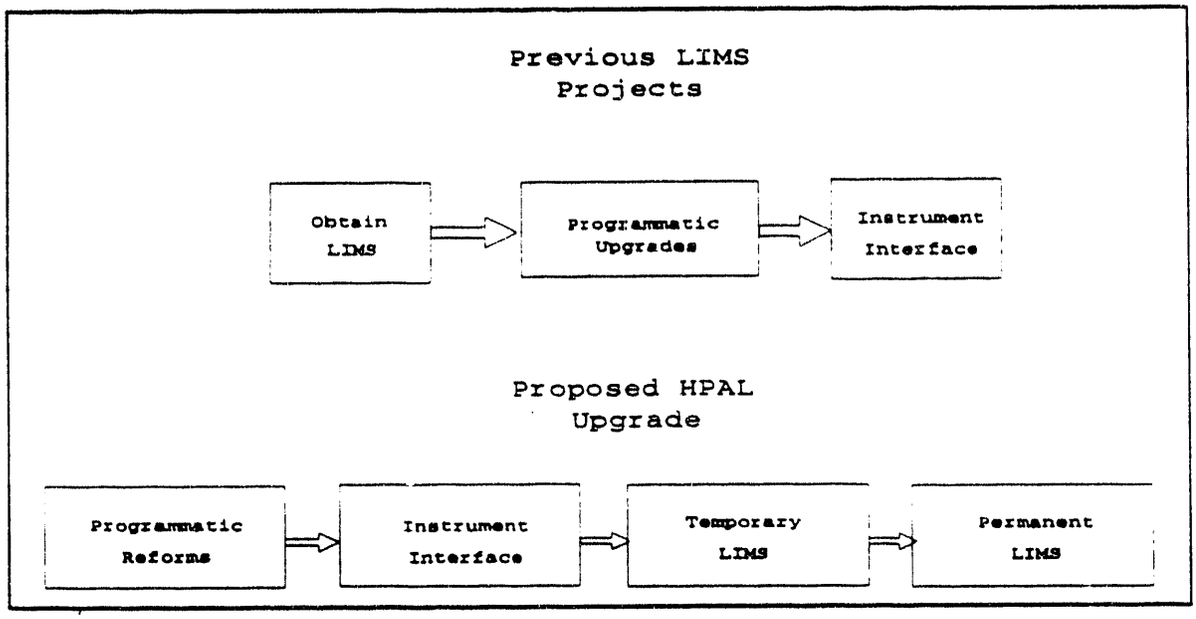

Figure 2. Programmatic changes should occur before using a LIMS.

3.2.1 Quality Assurance

The first step in the project should be the development of a comprehensive QA plan that meets the 18 basic criteria of ANSI/ASME NQA-1. Supplemental elements of NQA-1, such as software validation and verification (V&V), may be optionally applied. Documented acceptance criteria should be developed for all software developed or procured. Both factory and site acceptance tests should be used whenever possible.

Recommended Programmatic Upgrades

1. Standardize forms/reports
2. Implement sample accountability (sample tracking, chain-of-custody, etc.)
3. Implement process quality controls (spikes, blanks, and duplicate samples; quality control charts)
4. Begin QA surveillance (blind QA program)
5. Document data reduction algorithms (quench corrections, error propagation, etc.)
6. Provide QA training for HPAL staff

Figure 3. Most of the recommended programmatic upgrades are QA-related.

The QA plan should document the organizational structure and reporting lines and should also formally establish a point of interface to each of the customer organizations. LANL should designate a HPAL project QA officer, independent of cost and schedule obligations, to oversee the quality-related aspects of the entire HPAL upgrade project. The following quality elements deserve special mention:

Control of procured items and services - Procurement QA should be formalized with detailed technical specifications and acceptance test plans. In addition to the initial acceptance testing, periodic continuing performance tests should be performed to monitor long-term stability of each instrument. These acceptance/performance test records should be correlated to maintenance records for each instrument. For example, replacing major system components in an instrument may cause a large change in its calibration factors, which would need to be clearly explained on that instrument's permanent records/control charts.

Quality assurance records - QA records should be identified and protected through dual storage. ANSI/ASME NQA-1 allows for protection of QA records by storage in a fireproof vault with a four-hour burn through rating, but these are not commercially available. Therefore, the dual storage option allowed by NQA-1 is recommended.

Design control - Software QA and configuration control will be important elements of this project. The LIMS and instrument interface programs will require a substantial amount of software to be written and documented. While NQA-1 is a good standard for implementing hardware QA, it does not contain enough specific requirements to control the software development and operational life-cycles. In summary, a software QA program needs to be developed and it needs to be subordinate to the overall LIMS QA program.

A minimum standard that may be used for implementing software QA is ANSI/IEEE Standard 730, *Software Quality Assurance Plans*[11]. This standard provides the minimum elements needed to establish an effective software QA program. In addition to addressing software QA, IEEE 730 also provides the necessary framework to implement a software test program and software V&V program, if desired.

The LIMS will require a substantial amount of documentation to be developed and maintained over the life of the program. These documents will undergo substantial change during the initial phases of LIMS development. To ensure that a positive system of control is established to assure that LIMS is reflective of the current requirements and designs, it is strongly recommended that a configuration management program be implemented at the project level.

Currently, DOE Order 4700.1[12] provides guidance on the development of configuration management programs. While this order provides general guidance, it does not specify that the order is a mandatory requirement for implementing configuration management plans. Any standard that is consistent with the guidance of the order may be used in its place. It is recommended that other configuration management standards be reviewed to determine if another standard would be more suitable to control LIMS development.

Process control is discussed separately below.

HPAL staff, especially HPAL upgrade project team members, should receive training in the fundamentals of quality assurance as soon as possible.

3.2.2 Forms Standardization

Various organizations currently submit samples using a wide variety of sample submission forms (i.e., TA-55 Airborne Results, Swipe Data Sheet, Swipe Data Results, Airborne Contamination Test, Nose Swipe Contamination Test Sheet, Special Air Test Results, Special Air Test/CAM Alarm).

HSE-1 should take steps to initiate a forms control program whereby all sample analysis requests must accompanied by a sample analysis request form. Standardizing these request forms will help to ensure that all required analytical and identification information accompanies the samples. Samples without forms could be rejected.

A three-part, peel-and-stick, barcoded form is recommended. The first part would be placed in the sample logbook by the customer taking the sample. The second part would be placed on the standardized sample request form. The third would be placed on the sample itself.

Electronic sample request forms may be reasonable. PC program diskettes could be distributed to customers, who could then enter the ancillary sample data (location, flow rates, on/off times) directly. These PC diskettes, along with the electronically-prepared sample request form, would be submitted to the analysis lab with the samples. This approach has some advantages, but the quality of the incoming data files would need to be carefully screened.

Standardizing the formats of the HPAL sample analysis results reports would also be very beneficial. Different customers request different sample results reports, causing additional workload and potential for errors in transcription.

3.2.3 Sample Accountability

Administrative control measures applied in the central counting facilities could improve the efficiency of operations, address chain-of-custody requirements, and enhance QA. Counting labs should adopt as much similarity as possible in these physical arrangements. Counting labs should have designated areas with clearly posted sample staging positions. The posted areas could be cabinets, bench tops, or shelves designated to segregate and delineate the following steps:

Sample Receiving - Sample receiving should be a highly controlled process. Chain-of-custody should be initiated by requiring designated lab personnel to review sample submission forms for appropriateness and accuracy of information, inspect the condition of samples, verify number of samples in the batch and ensure discrete identity of each, prior to acceptance of the samples. Acceptance may be granted by signing a sample receipt and placing the samples in the "controller" sample staging area.

Sample Staging - The sample staging area should be a locked cabinet or simply a designated area in a lab where access is controlled. Sample log-in does not need to take place immediately as long as the staging area is properly controlled. This provides an opportunity to balance priorities by grouping samples requiring the shortest turnaround requirement. It also provides the opportunity to arrange batches of samples to make best use of an automatic counters' maximum loading capacity.

Sample Log-in - At this point in the sample handling process, the sample identification needs to be finalized for initialization of the sample accountability records. The identification needs to be retained through the analysis process, regardless of the counting system or analysis method. Therefore, the identification syntax must be the same throughout the analysis process (such as pre-assigned serial numbers).

The log-in process needs to be highly efficient, yet serve as the point where virtually all known information regarding the analysis request is loaded into the HPAL LIMS and verified by the lab technician. Locations, sample types, sample methods, handling information, dates, times, and so forth should be entered into the system once. The entry process should be carefully protected against errors as much as practical.

Log-in can be made more efficient through the use of a customer base description table. Log-in is also the point in which all applicable information regarding the analytical request needs to be loaded into the sample analysis record data table.

In-Process Samples - Proper chain-of-custody also depends on sequencing individual samples within a batch and recording the corresponding position number of the automatic system. It is usually not possible to identify individual filters, swipes, or liquid scintillation vials with any more detail than a simple sequence number. In-process samples normally should not require a designated in-process posting area unless manual counting systems are being used with a high volume of samples.

Sample Holding Area - It is reasonable to expect that a designated sample holding area is necessary while counting results are being verified. The results verification step is a critical phase in the decision process since it is important to avoid the premature destruction or disposal of a sample prior to obtaining a dependable result. The hardcopy printout from the analysis system should accompany the batch (or individual sample). It is important to designate samples at this stage within two categories: (1) awaiting verification; and (2) verification complete and sample is classified (i.e., recount, dispose, archive).

3.2.4 Process Controls/Blind QA Program

Process control of laboratory instruments should be monitored and documented through the use of quality control (QC) samples (spiked samples, blanks, duplicates, or split samples). A criteria should be established for the frequency of these QC samples; in many labs, at least 5-10% of the samples processed are calibration, QC, or blind QA samples. Oak Ridge National Laboratory has recently begun running three QC/QA samples for every nine normal samples (25% QC)[13].

Adoption of a meaningful process control program will therefore increase the current workload substantially. However, it is stressed that the highest priority objectives in the HPAL upgrade project are to meet the customer's regulatory requirements and to have sufficient QC/QA documentation to ensure the integrity and quality of the data produced. Therefore, quality must take priority over efficiency.

The implementation of industry-standard QA practices, such as sample chain-of-custody documentation, process controls (spikes, blanks, and duplicates), and data validation steps will lower the current throughput approximately 5%.

A blind QA program, with externally-supplied standards, is highly recommended. Unknown samples will be submitted along with other samples by customer organizations or by appropriate QA personnel. Control charts of accuracy and precision should be maintained, as well as documented corrective actions when equipment or personnel fail to operate within the control limits. A documented system for handling contested data should also be established.

3.2.5 Data Reduction Algorithms

Calculation of sample results (activity per sample ± uncertainty) is required at the PC level. Programmatic decisions on how to calculate efficiencies, backgrounds, quench correction factors, and propagated errors must be made quickly and completely documented before any software development can begin.

Calculation of final sample results (activity concentration) should occur on the LIMS to reduce data entry requirements, simplify operations, and reduce the cost of software development for the instrument interface. Information such as sample location, flow rate, and filter on/off times should be captured at sample log-in time. Sample results from the instruments can be related to this log-in data and the final report printed from the LIMS. Backup systems, with procedures and calculational forms, will be required for during periods when the LIMS is unavailable. These calculations may be performed by hand or by a stand-alone PC program.

3.2.6 Required Counting Times

Minimum counting times for each type of analysis are based on the sensitivity required by DOE 5480.11 (or other applicable regulation). The sensitivity required can be inferred from maximum release limits.

Analysis of blank samples should not be confused with these limits when the uncertainty in the analysis is considered. This criteria is met when the minimum detectable activity (MDA) is less than the release limit. However, "industry good practice" dictates that a further margin of safety be obtained by requiring

MDAs to be a factor of 10 less than the maximum release limits. Minimum counting times should be set accordingly.

3.3 Instrumentation

3.3.1 Instrument Upgrades

Since software interfaces will need to be developed for each type, brand, and model of counting instrument, it is recommended that uniformity of brand and model for each type of instrument be sought. Most existing equipment for each type of instrument is from the same manufacturer. However, the upgrade of some existing instrumentation to newer model numbers will be necessary to realize this objective. The instrument upgrade will likely be less expensive than developing separate software for the instrument interface. Procedural development and training costs will be reduced, as well.

For this same reason, it is recommended that all new equipment purchased for each instrument type be purchased from the same manufacturer as the existing equipment where possible. One exception to this recommendation would be the purchase of new, multichamber α/β counters.

First, it is recommended that all new instrumentation for gross alpha or α/β counting be purchased with specification for personal computer control. While it should be possible to interface the IMPULSE system to the LIMS, it is recommended that the need that this instrument fills be supplied in other labs by the use of commercial instruments under the control of a personal computer.

Secondly, it is recommended that multichamber gas proportional α/β counters be purchased in place of automatic single chamber α/β counters in order to provide decreased turnaround time for α/β analyses. However, since the typical counting times range between 1 and 10 minutes, it is highly recommended that automatic sample changer multichamber counters, such as that offered by Gamma Products, be considered for use.

Even though this type of system only has four chambers per instrument while other multichamber counters have as many as 16 chambers, it is likely that, for one minute count times, the two types will provide comparable turnaround times due to the sample change time required. The Gamma Products system is built

on proven technology and offers some advantages with respect to calculation control and LIMS interface.

The number of disparate hardware platforms and associated operating systems that are supported should be minimized to the extent possible. In any case, at least two operating systems will be involved since the instrument-control PCs are running IBM PC-DOS (or Microsoft MS-DOS) and the HSE VAX is running VAX/VMS. Consideration should be given in future upgrades of the IMPULSE system to migrating to a more VMS-compatible platform. Minimizing the number of disparate systems to be maintained will reduce development, maintenance, training, and documentation costs.

3.3.2 Uninterruptible Power Supply (UPS)

An uninterruptible power supply (UPS) should be installed in every laboratory to prevent loss of data due to power outages and to prevent power anomalies from affecting sensitive laboratory instruments. Standby power systems or power conditioning units, such as constant-voltage transformers, are not recommended.

If possible, the UPS should be installed in a new lab before the instruments and computers it will service are moved in. A power distribution system can easily be mounted around the perimeter of each lab to power all the instruments, computers, networking equipment, and ancillary units. Network cabling, such as thinwire Ethernet, can be installed at the same time.

Consideration should be given to ground loops within the laboratory as well. electromagnetic radio-frequency interference can affect proper instrument performance, so all cables should be shielded and securely bonded at both ends. Cable lengths should be kept to a minimum, with no excess coils lying around. Radio transmitters, including walkie-talkies, should not be allowed in the labs.

3.4 Records Management

A Certified Records Manager should be retained to develop the record taxonomy, to research their life cycle and retention/disposition requirements, to segregate substantive records from facilitative records, and to ensure that the requirements for admissibility of records as evidence in a court of law are being met. QA and vital

records require special protection and must be identified and handled accordingly. The records management program should be distributed, but tightly integrated.

A substantial investment has been made in the generation of technically correct data, so it is important that this data be documented, retrievable, and legible several decades from now. Upper managers often mistakenly confuse records management with "filing"; this tendency should be avoided.

Investing in good records management practices *now* will repay that investment many times over in improved staff efficiency.

3.5 Prototype LIMS

3.5.1 Motivation

There is sufficient motivation to use a temporary, off-the-shelf LIMS before implementing a custom, permanent LIMS. Foremost is that a custom, permanent LIMS will take years to specify, procure, and implement.

Finding uncertainties in future fiscal years may leave LANL with only a fraction of a custom LIMS. If funding is cut in the middle of the multi-year development of a custom LIMS, little functionality or productivity improvement will be realized. A temporary, prototype LIMS can be implemented quickly and cheaply and is therefore less subject to risks due to funding cutbacks in future years.

A prototype LIMS may provide as much as 80% of the desired functionality for as little as 20% of the cost of a permanent, custom LIMS. This will quickly improve productivity and sample accountability for a modest cost.

It would be difficult to completely specify the permanent LIMS functional requirements because HPAL staff have not used a LIMS before. Using a prototype LIMS allows HPAL staff to learn the rudiments LIMS operations and write better specifications before committing major capital expenditures to a permanent LIMS.

No specific package (commercial or one available through the DOE/DOD community) is recommended here. Appendix C details the capabilities, advantages, and disadvantages of the four commercially-available packages reviewed for this report.

3.5.2 Philosophy

Experience has shown that version 2 of any computer program is the first one that really works. Therefore, it is recommended that the first LIMS be considered *disposable*. It should therefore be as inexpensive as possible, consistent with functional and quality requirements.

The programmers and systems analysts involved with this project should endeavor to understand the process they are trying to computerize. If possible, it would be best to take a computer specialist and have them work in the labs for a while. Likewise, computer-literate and adept health physicists are recommended for key project team positions. The most successful software projects have been those that have personnel from both disciplines that are cross-trained so that they can effectively communicate.

The prototype LIMS should be evaluated after startup and a reasonable use period. If it is not acceptable, then development of a custom LIMS should be initiated. However, judicious selection of the prototype LIMS may be serendipitous; it may be adequate for long-term use as is.

3.6 Custom LIMS

Any software used to automate a laboratory must operate the same way the lab does. Commercial packages, although extensively configurable, may not be able to be refined to this degree.

One advantage of a custom LIMS is that there are no per-user, per-instrument, per-server, or per-lab licensing costs. However, a permanent commitment must be made to maintain and refine the software system (including documentation and test cases). A custom, Oracle-based LIMS would also be able to be more tightly integrated to the HPIMS on the HSE VAX. For example, common location tables and other redundant information could be maintained once instead of having separate tables on separate systems. In addition, a custom LIMS will afford the use of custom functions and applications, such as customer description tables and custom-printed barcode labels.

3.6.1 Customer Descriptions

Maintaining a customer base provides a capability to rapidly process analysis requests. Database customer description tables could be maintained through the use of an interactive editor application that allows easy updates or appends. The description editor should also allow the report generation process to make use of customer. The information to be maintained in this data table is summarized below:

- credible analysis requests
- standard analysis requests
- credible sample types
- credible sample methods
- approved requestors
- address information for report generation
- report format preferences
- credible and standard locations
- unique evaluation requirements (DACs, release limits)
- link to incident records (identify incidents)
- unique trigger limits for immediate notification
- default data entry parameters (stack flow rate, aliquot size)

The default information, identified in the customer description table, may be prompted during log-in or other steps in the sample analysis process for more rapid and accurate transaction processing capability. The information may also be useful for error checking capability to ensure that proper combinations of parameters are matched (i.e., locations within a facility, collection methods that match sample types). For example, the user is only presented with choices of

credible responses to aid the decision process and ease training requirements. Other examples of this level of error checking/user-guided inputs will be discussed in sample log-in functions.

3.6.2 Barcode Technology

The burden of processing high volumes of analysis requests may be augmented through the use of serial tracking numbers to identify individual samples or batches. Labels may be preprinted and distributed to customers, with specific serial number ranges or additional fields in the sample identification number to identify individual customers, areas, or batches. Customers may retain tracking numbers for future reference. Serial identifications facilitate the administration of blind QA samples analysis results. Each customer base may be assigned a numerical range that can quickly direct appropriate customer identification at log-in.

Use of barcode label printing and scanning technology may enhance the central counting labs ability to process high volumes of samples. Printing of barcode labels should be avoided unless it is necessary to print high-density barcodes with unique information on-demand. Administrating a scheduled routine sample collection program may be a possible application.

It is recommended that preprinted labels be purchased in volume to satisfy the barcode application requirement. Sophisticated multiple label peel-off forms can be extremely useful and inexpensive. Unfortunately, many samples cannot be properly labeled due to size and geometry consideration. However, most situations can be satisfied if envelopes or tags are used to accommodate an appropriate label.

It is recommended that high quality laser diode barcode scanning devices be used in lieu of pencil-type or infrared scanners. Fixed-mounted, high throughput scanners may be applicable in some situations. The expenditure to ensure highest read rates will guard against situations where a technician would rather type a tracking number than struggle with the barcode reader, thereby introducing transcription errors into a "finicky" system.

All inputs to the database should be carefully protected and kept to a minimum. The advice of a Certified Data Manager may also be useful in assessing ways to minimize keystrokes and to ensure data accuracy and integrity.

3.7 System Architecture

HPAL information management requirements are partitioned to allow a step-wise implementation path and to promote efficient, long-term pathways. Figure 4 shows the proposed LIMS architecture.

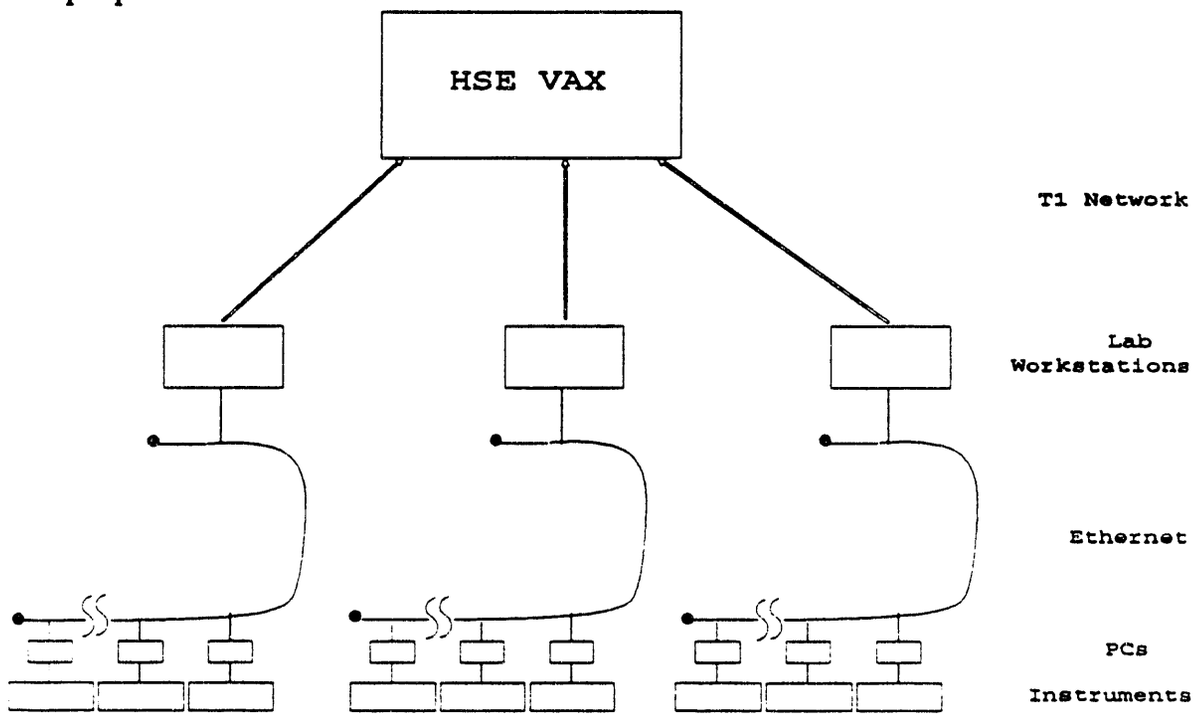

Figure 4. Proposed HPAL LIMS architecture.

The HSE Division is participating in the development of a comprehensive Occupational and Environmental Health Information System based on the Oracle relational database product to maintain software portability and to affiliate with software support capabilities. Within this framework, the HPIMS is integrated into the overall program. In addition, the HPAL LIMS will facilitate the integration of sample accountability, automated data analysis and evaluation, counting instrument data interfacing, and lab QA management in each respective central counting lab.

This HPAL LIMS hierarchy facilitates duplication at the HPAL LIMS level. A single HP central counting lab constitutes a unique arrangement of counting equipment implemented in a way to best serve the analysis requirements of the identified "customer base." The generic HP LIMS software, duplicated at each central counting lab, is configured to process analysis requests, manage sample accountability information, accept counting instrument data, and generate reports to meet the unique analysis objectives of the counting facility. A central counting lab's HP LIMS will also be configured to track and manage QA-related information. In addition to managing counting laboratory activity results and raw analytical information, the HPAL LIMS will provide the means to upload final results and summary data to HPIMS on an intermittent basis.

Each HP central counting laboratory (or satellite lab) may be configured with a single lab network. This lab network will be the pathway in which counting instrument activity results are transferred to the lab host Workstation. A straightforward means to accomplish the capability is to interface each respective counting instrument or group of instruments to a dedicated processor such as a PC through a serial or proprietary link. The lab network should take the form of a LAN topology to serve adjacent offices and labs within the local complex. An Ethernet network is recommended since it will support both PC-to-PC and PC-to-VAX communications. It will also work with many of the commercial LIMS products available.

An online network connecting the various analysis laboratories is highly desirable, but will be difficult to implement because of computer security requirements and the high cost of laying cable or fiber. It offers substantial advantages, such as distributed databases on remote approval/validation of sample results. However, this report has not assumed the availability of such a network.

The HP LIMS implementation within each central counting lab will support one lab database host and any required number of lab workstations. It is intended that a lab workstation may also serve as the lab database host if necessary. Lab host processors will retain all local (counting lab specifications) database information, facilitate backup and archival operations, provide for remote access to the HSE Division VAX for uploading of results to HPIMS, and perform report formatting and queuing for electronic transmittance or hardcopy printing.

Lab workstations provide the primary interface to all HP LIMS functions. These functions include all lab configuration and QA utilities, customer base description table editing, sample accountability information management, results evaluation and

approval, database query, and reporting operations. It is recommended that the lab workstations be capable of operating an X-Window graphical interface (GUI) such as OSF/Motif in addition to supporting Oracle and Ethernet protocol such as TCP/IP or DECnet.

Lab counting instruments interfaced to the HPAL LIMS will be attached to the lab network. It is recommended that the dedicated PCs be configured as *end nodes* on the lab network. Lab counting instruments should be interfaced to a dedicated PC.

Some manual counting instruments with a low volume of routine sample processing requirements may depend on manual database entry methods for reasons of practicality and cost savings. Manual TLD readers or PC-55 gas-flow proportional counters may fit this description.

3.7.1 Instrument Interface

It is desirable to reduce or eliminate manual transportation of analytical information. Counting instrument interface to data reduction and reporting processes can be accomplished by numerous methods. Some instrument manufacturer's market off-the-shelf products that may satisfy the transfer requirement but fall short of satisfying data reduction and reporting requirements. Other instruments may simply provide a serial port with primitive output capability.

It is anticipated that each instrument group with automatic sample processing capability, or in the case of gamma spectroscopy where a PC performs the multichannel analyzer function, will be capable of data acquisition, data reduction for calculation of activity per sample results with the development of applicable software, and transfer of those results to a database host across a LAN.

A recommended design approach would involve establishing a standard format "template" for activity results to be transferred to the database host. These common-format files are termed *metafiles* because they are independent of the instrument that created them. This simplifies the software sophistication on the lab host and allows flexibility for attaching any combination of interfaced counting systems to the lab network. Since each group of counting instruments will require development of a unique software application, these applications can

be developed to meet this exact same design requirement for generic file transfer capability.

This file standardization also implies that final results will be generated at the lab database host level. This is an efficient way to handle this requirement since the database host will retain dates, times, air volumes, and results flagging and screening criteria. Figure 5 summarizes the hierarchy.

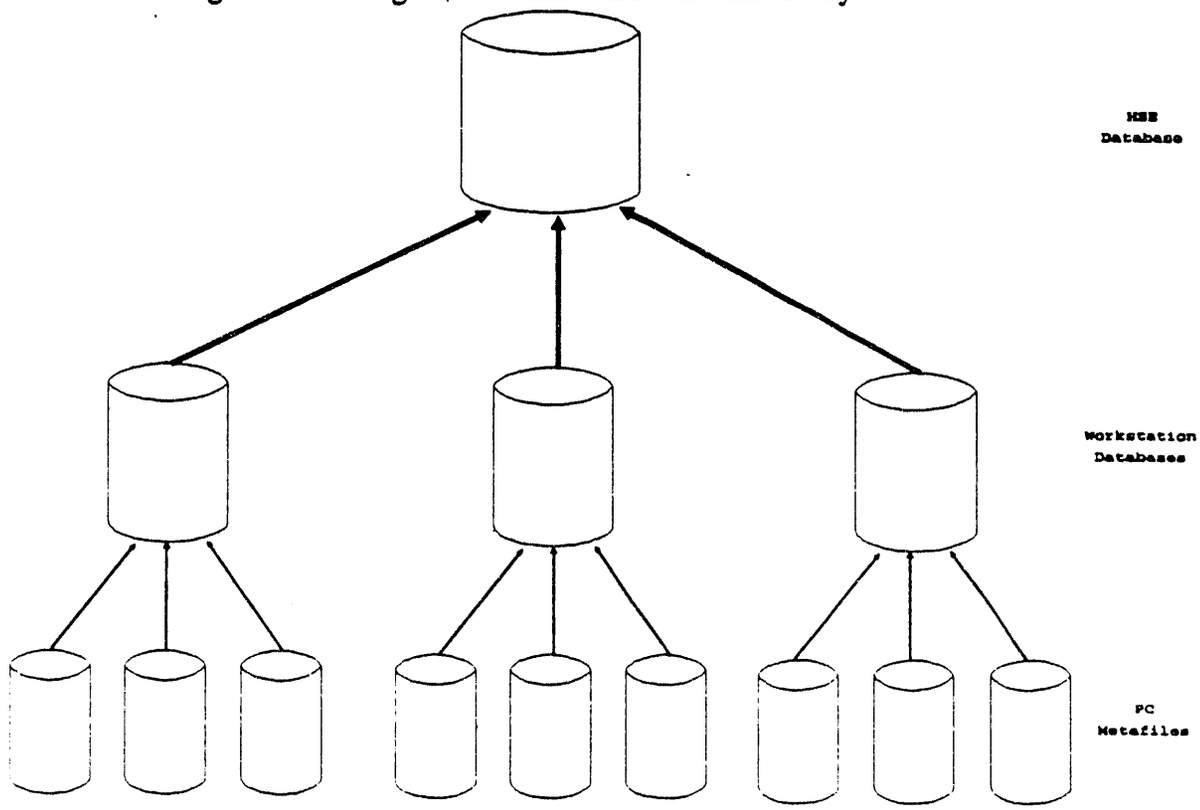

Figure 5. The lab workstation databases cushion the HSE VAX database from the lab traffic.

In order to effectively develop and test instrument interface programs, at least one of each kind of instrument will need to be readily available or even

dedicated to development. This same consideration applies when testing the instrument/LIMS interface.

3.7.2 Reporting of Results

Administrative review of results before release to the customer is strongly recommended; implementation of this QA step must be formally documented on paper before any custom software can be developed.

A lab workstation with GUI capability should be used to evaluate results against screening criteria and to perform statistical analyses of data populations. Evaluations against established trigger values may be performed by selecting the desired "test" from a list. The list could represent an evaluation criteria description table. Default evaluation criteria may be set during log-in or by referencing credible evaluation criteria from the customer description table. Multiple evaluations could be performed and compared throughout the use of multiple windows.

Examples of evaluation criteria may include establishing percent of a DAC in room air samples, flagging unacceptably high nasal smear activity levels, and comparing against contamination control limits, transportation, and release decisions.

3.8 Procurement

Most procurement on this project can be competitive. This approach has the benefit of requiring that the functional requirements be fully researched and clearly documented, which is an integral step to procurement QA. A natural extension of these specifications is a set of acceptance criteria for each instrument, which should be documented in a procedure. Sole source procurements can be complex, but may be justified in some cases. The time required to develop a sole source justification will likely offset any time saved in not having to "bid it out." The value of some procurements will be high, making sole sourcing even more difficult.

Approximately two months will be required for each non-complex competitive procurement, plus approximately three months for vendor delivery schedules.

3.9 Procedure Development

Approximately 100 procedures will need to be developed in the following areas:

I. Quality Assurance
   - A. Basic QA elements (18 procedures)
   - B. Preparation of QC Samples
   - C. Interspersing & Interpreting QC Samples
   - D. Blind-Audit Program
   - E. Corrective Actions

II. Instrument Procedures (for each instrument)
   - A. Setup and Acceptance Testing
   - B. Calibration
   - C. Operation
   - D. Maintenance
   - E. Emergency Activities/Backup Plan

III. Operations
   - A. Sample Log-in
   - B. Sample Preparation
   - C. Contamination Control
   - D. Data Validation/Release of Results
   - E. Notification Levels

IV. Computer Operations
   - A. System Startup/Shutdown
   - B. Data Transfer from PC to Lab Workstation
   - C. Data Transfer from Workstation to HSE VAX
   - D. Computer System Backup

V. Records Management
   - A. QA Records Protection
   - B. Vital Records Protection
   - C. HPAL Records Creation & Distribution
   - D. HPAL Records Storage, Retrieval, & Disposition

VI. Training
- A. Staff Certification for HPAL Tasks
- B. Staff Qualification for HPAL Instruments

4 Project Schedule

A preliminary project schedule has been prepared according to the assumptions, design constraints, project phasing, operational considerations, and funding uncertainties described earlier. Development of a project schedule started with a list of tasks and their estimated durations followed by identification of task interdependencies. PC-based project management software (Scitor Project Scheduler 4, Version 2.2) was then used to prepare the resulting Gantt chart. Figure 6 shows the overall project management process.

The project evaluation and review technique (PERT) was used to estimate the times for each of the tasks. This method uses optimistic, most likely, and pessimistic time estimates. These durations are multiplied by probability weights to determine the expected value of the time it will take to complete that task. This report has used standard PERT weights of 1, 4, and 1 for optimistic, most likely, and pessimistic estimates, respectively. These values approximate a normal distribution. The expected duration is therefore 1/6 times the optimistic duration plus 4/6 times the most likely duration plus 1/6 times the pessimistic duration.

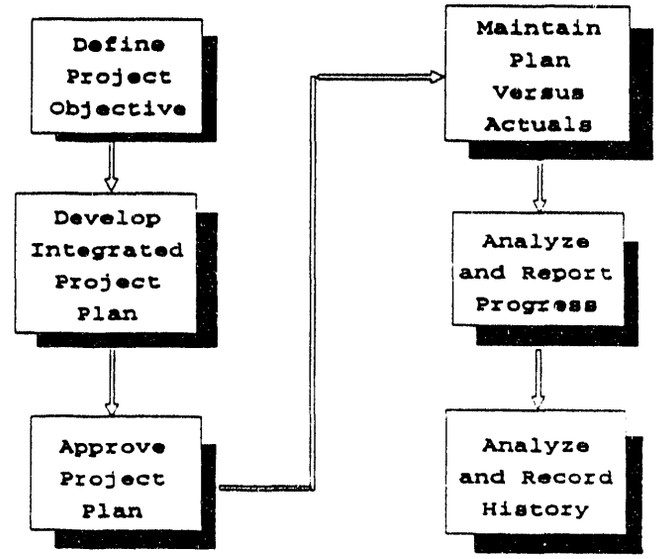

Figure 6. This needs analysis document encompasses the first two phases of project management.

Pragmatic time estimates were used, based on the authors' prior experience with large programmatic upgrades and software development projects. The estimates are in person-weeks and are based only on calendar time. Care has been taken not to use "mythical man-month" thinking[14] in the development of this schedule. Further refinement of this schedule should occur once funding uncertainties are removed and after input from HPAL customers and management has been received.

It is important to understand the difference between a "computer program" and a "computer system" in order to effectively schedule development of quality software. Most programmers tend to think of only how long it would take to write the actual computer code. The pitfall of this is that they have omitted the time necessary to write documentation (both technical and end-user) and to develop and document a suite of test cases to facilitate initial and continuing software testing. The schedule developed here is for a *computer system*, including time to write the code, document it, and thoroughly test it.

Whenever new ways of doing business, new instruments, or new computer systems are introduced, QA considerations dictate procedure development or revision and staff training. Since an iterative approach has been proposed here, several occurrences of these tasks are therefore present in the project schedule.

Figure 7 shows how the project schedule was developed. Appendix E shows the task list, network diagram, and Gantt chart for the HPAL upgrade project.

The approach outlined here would have a prototype LIMS running in TA-55 (interfaced with the four principal instruments noted previously) in approximately one year. Procedure revisions, training, and replication to the other

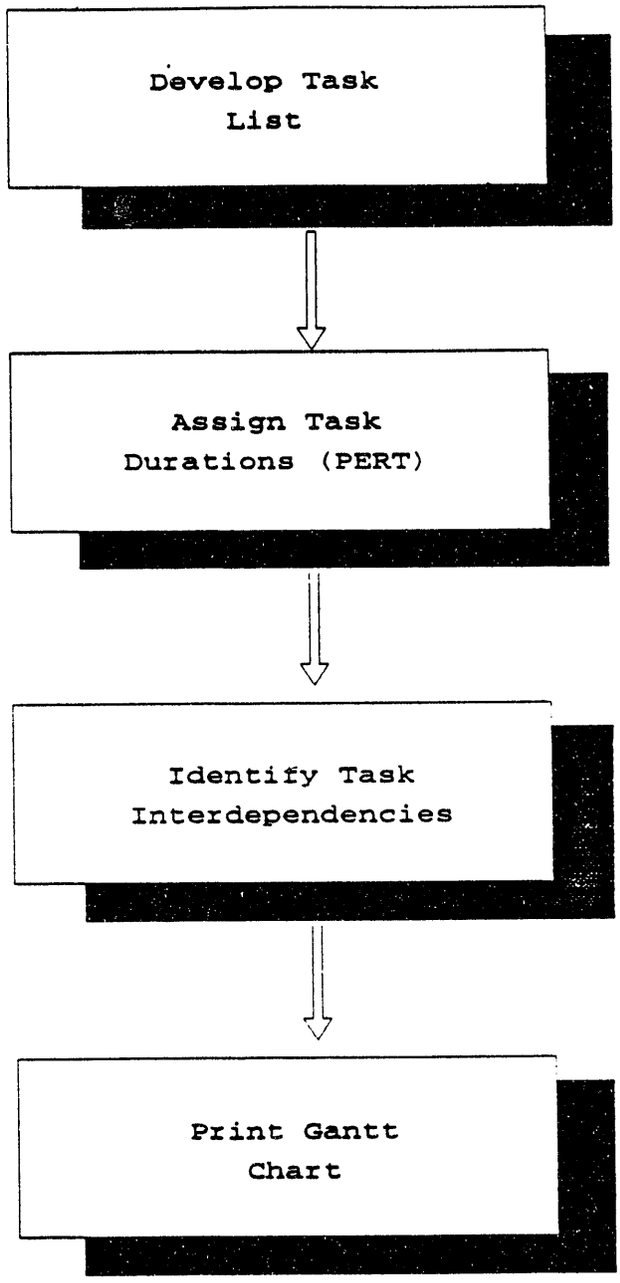

Figure 7. The PERT analysis method was used to estimate the task durations.

central labs will be complete by March 1993. All central labs can be operating on the final, custom LIMS by mid-1994.

Less detail has been provided for later phases of the project since it is expected that these schedules would be substantially revised after incorporation of lessons learned from Phase I.

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Appendix A The Brooks Air Force Base LIMS

The Occupational and Environmental Health Laboratory (OEHL) of the United States Air Force is located at Brooks Air Force Base (AFB), San Antonio, TX. The OEHL performs radiological analyses on the following types of samples: environmental, bioassay/human, contamination swipes, and in-house QC. The OEHL performs various radiological analyses on between 10,000 and 15,000 samples per year. Most analyses are performed by chemical separation followed by gross counting or spectroscopy. Instruments used include two Gamma Products G5000 α/β counters, one Berthold α/β counter, one Micrad α/β system, one Packard 2250 liquid scintillation counter, one 16-channel alpha spectroscopy system, one Canberra series 90 gamma spectrometer (with three automatic sample changers and one manual sample changer), a NaI(Tl) detector array, and a Canberra whole-body counter.

Brooks AFB has implemented a LIMS system in their radiological laboratory. The system uses an ORACLE relational database kernel running on a VAXCluster. The LIMS provides for sample log-in and status tracking, results entry, review and approval, and storage and retrieval of final results. A parallel paper system is also maintained until all analyses are complete on each sample. Unique sample identification is provided through the use of serial sample numbers. Data entry is facilitated using menu screens and screen forms which require most data to be manually typed in. Limited use of pick menus for field entry is provided. Data review is conducted in five steps: counting room technician review, first review for QA by a radiochemist, final review by a health physicist, ready to report review by the chemist and health physicist, and a general report review by the branch officer in charge.

All results are currently entered into the LIMS through manual data entry. However, OEHL plans to provide instrument interface to all of their counting instruments. Plans are to use DEPCA (Digital Equipment Corp.) LAN cards and Oracle Data Loader (or SQL*Loader) software utility to make the connection between ASCII files on instruments controlled by personal computers and the ORACLE database on the VAXCluster. The OEHL has experienced difficulty in designing an interface to the Packard liquid scintillation counter since the system architecture does not allow simultaneous operation of the counter by the controlling personal computer and connection to a network through the DEPCA card. It is anticipated that the α/β counters, which are controlled by a personal computer, and the gamma spectrometers, which are controlled by a MicroVAX II, can be interfaced to the VAXCluster through a network without much difficulty.

Appendix B The Westinghouse/Savannah River LIMS

The Westinghouse Savannah River Company (WSRC), located near Aiken, SC, is a 300-square-mile DOE facility. Their Environmental Protection Department's Environmental Monitoring Section is implementing a comprehensive computer automated system to manage the collection, analysis, data evaluation, and reporting of environmental radioactivity data. The design goal of the system was to meet the demands of a rapidly growing environmental monitoring program while enhancing the quality and defensibility of reported results. Chain-of-custody and data handling/archiving aspects of the system will be compliant to new DOE Orders.

The system was designed using the Ingres relational database and DECWindows Graphical User Interface (GUI) on DEC VAXStation 3100s in a networked laboratory complex. The software was developed in VAX C with "embedded" SQL commands. Workstations communicate to the database host (MicroVAX 3800) for access to up-to-date description, scheduling, chain-of-custody and analytical information. The processing load on the database host is minimized by use of intelligent workstations.

Consort Technologies, Inc., Atlanta, GA has been contracted to provide consulting and software development services to WSRC. The project software development contract, initiated November 1987, will exceed $2,000,000 when complete in 1990. Hardware networking, and application software costs are estimated to be in excess of $300,000. The high cost of the development effort is attributed to the environmental monitoring program's lack of accurate procedures and QA program when the project was initiated. These deficiencies made it difficult to establish a firm project scope and resulted in wasted effort and the loss of calendar time until these programmatic deficiencies were addressed. New DOE orders issued during the project also impacted the project's scope. Specific compliance elements such as reporting and statistical treatment of data were added to the project scope.

However, the work has resulted in an impressive collection of flexible and sophisticated functions integrated into a comprehensive application. Many objectives of the project have been exceeded, with the exception of counting instrument interfacing to the LIMS database. Consort will provide the system components to integrate liquid scintillation counting instruments. All other analytical results will require manual data entry into the database until the other instruments are fully interfaced.

Other DOE sites have indicated an interest in obtaining a version of the Savannah River system for configuration into their programs. However, Consort Technologies has

obtained copyright protection on the software system. The software system is available to the DOE community for the cost of a support arrangement with Consort Technologies. The copyright excludes companies other than Consort from modifying the software.

Appendix C Commercial LIMS Products Evaluated

SAM LABORATORY INFORMATION MANAGEMENT SYSTEM (LIMS)

"SAM" is Radian Corporation's version of a LIMS capable of being implemented on Digital Equipment Corporation's VAX systems or on computer systems utilizing the PC-DOS operating systems. The Sam LIMS is compatible with several local area networks including DECNET, Novell Advanced Network, HP ThinLAN, IBM Token-Ring Network, and IBM PCLan. It has been in the marketplace for over 5 years and is used in all of Radian's analytical chemistry laboratories including their radioanalytical laboratory. It is also used in several other radioanalytical laboratories.

SAM is designed for controlling and handling information from a number of types of analytical chemistry laboratories and generating required reports including sample analyses and laboratory status reports. Also provided is the capability to formulate user-defined tests, calculations, video displays, and printed forms. The system supports sample log-in, test assignment, customizing of test descriptions, and sample label printing. The system flags sample analyses which are overdue and accepts analysis results manually entered or through automatic data transfer from laboratory data systems. It also provides support for known and unknown QA samples, trending and statistical analysis for QC, status and cross-reference reporting with any of the information items, and historical reporting of any recorded data over a user-selected time frame.

Information Access

- Can access information from an MS-DOS computer or directly access the RS-232 interface from an instrument.

- Can access the information from an IEEE-488 or GPIB instrument interface if the access is indirect through an MS-DOS controller computer.

Information Transfer to VAX

- If the LIMS is running on a VAX, all needed information is easily transferred from the MS-DOS instrument controller computers to the VAX via Digital Equipment Corporation's DECNET network.

- If the main file server computer is an MS-DOS computer using a PC network such as the Novell network to communicate with the instrument controller PCs, the PC network may have to be disabled, typically for a few minutes to an hour, for the appropriate files to be transferred to the VAX via a mode of communication such as the DECNET network.

Statistical Uncertainty Calculations

- All uncertainty calculational results may be both calculated and stored in the database. The Sam LIMS has a complete library of higher mathematical functions including the square root, logarithmic, and exponential functions.

Reports

- Reports may have both text and graphical output in several forms, including user-defined forms. Statistical calculations may be performed, and the resulting reports may be saved to a file.

File Import/Export

- Can access instrument data files transferred to the file server computer from PCs computers in the network.

- Files may be exported to external graphics packages or other analysis or database packages such as Lotus 1-2-3 and dBase.

- Ability to reformat selected data for transfer to other computer systems.

Cost

- The cost of the LIMS software for a networked system (either VAX or MS-DOS computer based), not including technical support or training, is approximately $18,500 plus $500 for each additional networked node having direct access to the LIMS. For a networked system of 10 or more nodes, a site license is available for an additional $5,000. Custom programming by Radian Corporation is available.

Advantages

- This LIMS has many capabilities and can satisfy most of the data handling requirements of a radioanalytical laboratory.
- A VAX computer may be used as the file server for large laboratories.
- It is relatively inexpensive when compared to some other systems.
- The source code for the LIMS is available for $5,000 and may be modified locally if needed.
- The system is only partially menu driven and offers faster overall operation for manual data input than systems totally driven by menus. It achieves this through the frequent use of function keys to perform certain operations that would be indicated by menu selections in menu driven systems.

Disadvantages

- SAM appears to be targeted to the support of commercial analytical chemistry laboratories in that it also handles a certain amount of financial bookkeeping and invoice generation. The fields relating to finances can be disabled, however.
- Even though the system is partially menu driven, it is not as user friendly as a totally menu driven system, but instead affords faster overall operation through frequent use of the function keys with the assistance of a help screen.
- A number of the video displays are "busy" and therefore would be more confusing to the inexperienced user than in some other systems.
- SAM is written in the System J programming language (similar to C with a highly developed user interface library). This is a disadvantage since this programming language is relatively unknown and nonstandard.

LABVANTAGE LIMS SERIES

Laboratory MicroSystems, Inc., are the developers of the "LabVantage" LIMS. The system operates within the PC-DOS/MS-DOS environment and was developed using the Informix SQL database engine and various other tools for other functions. Each video screen in the system, except some of the fundamental menus, is either largely or entirely user-definable and is very configurable to the specific needs of a laboratory. The system can support as many results per sample as the hard disk storage capacity will allow.

A network of PCs running this LIMS can be configured in such a way that if the file server computer goes down, the system and network can be running again within the time it takes to install one of the "mirrored" hard disks from the file server computer in a substitute PC. To act as an "electronic traffic controller" within the network, Laboratory MicroSystems, Inc. uses an inexpensive MS-DOS computer, which may not even possess a hard disk. This gives the file server computer the ability to adequately handle inputs from a number of computers (up to 30 or 40), depending on the number of instruments connected to each instrument controller computer and the overall data transfer rate required within the network. The system can also interface directly with many types of instrumentation, if this is needed.

LabVantage can also function on a single MS-DOS computer, but within a network system. In this configuration, data files may be transferred at appropriate times from any one or all of the other instrument controller computers in the network to the MS-DOS computer on which LabVantage is installed. After file transfer, LabVantage can process the files appropriately.

Laboratory MicroSystems also has an "instrument driver" program, which is actually a source code program generator. It will output a BASIC language source code file, which can be used to interpret the raw data files generated from instrument data input. Using this program generator, the local programmers facility may generate custom file translator programs. These translate the raw data files from any of the RS-232 interfaced laboratory equipment into a form compatible with the LabVantage system.

Information Access

- Can access either a file from an MS-DOS computer or the RS-232 instrument interface directly.

- Laboratory MicroSystems does not presently support the IEEE-488 or GPIB communication format. However, some of their customers have successfully made the interface.

Information Transfer to VAX

- Laboratory Micro-Systems does not support an interface between a VAX and MS-DOS computer. However, they will formulate one for an extra fee. Another method of data transfer would involve disabling the PC network, typically for a few minutes to an hour, for the appropriate files to be transferred to the VAX via a mode of communication such as the DECNET network (or other appropriate communication method) designed for communication between a VAX computer and one or more PCs.

Statistical Uncertainty Calculations

- The uncertainty calculational results may be stored, but this LIMS only has the ability to add, subtract, multiply, and divide. However, statistical calculations may be produced with the report generator program.

Reports

- Reports may have both text and graphical output in a number of forms. Statistical calculations may be performed, and the resulting reports may be saved to a file.

File Import/Export

- LabVantage can import data from instrument data stations and from existing databases.

- Files may be exported to external graphics packages or other analysis packages such as Lotus 1-2-3.

Cost

- The cost of a single-user system (a single PC running LabVantage II) with sample tracking, report writer, and graphics design programs is about $14,000. For a four-user system the cost is about $20,000; an eight-user system is approximately $25,000. These costs do not include the cost of any network software, technical support, or training.

Advantages

- LabVantage has an exceptionally user-friendly menu system.

- It is capable of satisfying most of the data handling requirements of a radiological laboratory since it is able to be configured to the needs of a specific laboratory quite flexibly, generally without the need for any source code modification.

Disadvantages:

- Laboratory MicroSystems, Inc. customarily charge their customers by the "node" in networked systems plus an additional charge in some cases for the number of laboratory instruments accessed within the network. If the capability of the network is expanded by adding nodes or instruments to the system, an additional license fee must be paid.

- If more than a single database is required, the vendor will charges additional fees.

- The source code is not available. However, Laboratory MicroSystems, Inc. will make the necessary modifications for a fee.

CALS LABMANAGER SYSTEM

The "CALS LabManager System" LIMS is produced by Beckman Instruments, Inc. and is implemented on Digital Equipment Corporation's VAX computer systems. This LIMS host computer can be a Hewlett Packard computer, or 80286-class (or higher) MS-DOS computer. The host can be networked with other computers and instrument controller computers, and/or directly communicate with laboratory instruments. When the host computer is a VAX, the CALS LabManager System can access all the built in capabilities in that VAX host, such as the VMS Mail Utility. Instrument data collected can be stored, retrieved and formatted for additional analysis by other popular VAX software. The CALS LabManager System supports multiple user-defined database configurations, as needed.

Examples of features of CALS LabManager System which can be configured and reconfigured, as necessary, by the laboratory include the organization of commands into user-defined menus, menu "pick lists" for data entry, sample log-in and data entry screen formats, user-defined help text activated, organization and contents of the supplied dictionaries and user-defined dictionaries, prompting messages, displayed messages, report formats and contents, links between sample type and user-specified testing sequences, and multilevel system and data security.

Archiving and either continuous or batch mode updating is also supported. The system will automatically keep two separate images of the active database on either one or two separate hard disks, if desired. Standard report-writing tools are available.

Information Access

- Can access either data from an instrument controller computer or the RS-232 interface directly. Access may also be made through one of Beckman's Digimetry Instrument Couplers.

- Can access data from an IEEE-488 or GPIB output indirectly through an instrument controller computer or through one of Beckman's Digimetry Instrument Couplers.

Information Transfer to VAX

- If the LIMS is running on a VAX, all needed information is easily transferred from the instrument controller computers to the VAX via the network interface.

- The system can also be configured to automatically and continuously send data to an Oracle database. The data may also be sent in batch mode.

- If the host computer is an MS-DOS computer utilizing DEC's PCSA network, the information may be transferred to a VAX computer and to an Oracle database in batch mode.

Statistical Uncertainty Calculations

- All uncertainty calculational results may be both calculated and stored in the database. The CALS LabManager System has both built-in functions and a mathematical function dictionary, enabling it to perform higher mathematical functions including the square root, logarithmic, and exponential functions. The laboratory may also define its own function dictionaries.

Reports

- Reports may have both text and graphical output in user-defined formats. Graphical output may be in user-specified colors. Trend plots and plotting results against time may be performed. Statistical calculations may be performed, and the resulting reports may be saved to a file.

File Import/Export

- CALS LabManager System can import data files from instrument data stations and from existing data bases.

- Data may be exported to nearly any external analysis packages because the format of the exported data may be user-defined. The analysis packages include nearly all such software on any type computer within the network and any computer in which appropriate communications have been established.

- Data files may easily be transferred to an Oracle database. The VAX and HP versions of CALS LabManager are written in the FORTRAN language. The MS-DOS computer version is written in the C language. A proprietary balanced B tree design was developed to achieve a gain in performance over that level of performance which would be obtained through the use of one of the standard database languages. However, tools were built-in to efficiently transfer the LIMS data to databases based on database languages such as Oracle.

Cost

- The cost of a VAX or Hewlett Packard host based system is about $110,000. The cost of an MS-DOS computer host based system is about $25,000 for four active users. Licenses for additional labs are available at a 25% discount. These costs do not include the cost of any technical support or training.

Advantages

- The user interface is almost completely determined by the laboratory and may be changed at any time.

- This LIMS appears to be much more flexible than any other LIMS evaluated here and has the ability to be configured to the needs of a specific laboratory. For extremely unusual needs which cannot be met through a user-defined function dictionary or criteria dictionary, the laboratory may write its own custom programs and link them to the CALS LabManager system through programming "hooks."

- Multiple databases may be defined. In addition, one or more of them may be used for training or software testing, if desired.

- In many respects, this system is the most capable of all the LIMS evaluated in this report. In general, it is capable of satisfying the data handling requirements of most radiological laboratories.

Disadvantages:

- This LIMS has a higher cost than some of the other LIMS reviewed here.
- The LIMS which operates on the MS-DOS computer hosts has most of the basic capabilities of the VAX or Hewlett Packard counterpart except the extreme flexibility of user-defined video displays, menus, and reports.
- An effect associated with the great flexibility of CALS LabManager is that it is more complicated to setup initially and to make significant changes in its operation than in some other systems which offer fewer choices and less flexibility.

SQL*LIMS SYSTEM

The Perkin-Elmer Corporation produces SQL*LIMS, which uses the ORACLE relational database management system. SQL*LIMS will be discussed only briefly here since Los Alamos National Laboratory already has one such system at HSE-9.

The system operates on the DEC VAX series of computers under the VMS operating system. It possesses full networking capabilities, allowing the user to link all computers in the network, whether they are micros, minis, or mainframes via Ethernet and DECNET.

The SQL*LIMS has similar capabilities as the CALS LabManager LIMS, except that in a number of important ways it lacks the user-interface flexibility achieved by the CALS LabManager LIMS. SQL*LIMS is less flexible than CALS LabManager in the following areas:

- Control over menu structure and the exact text in each line of the menus.
- Control over the text appearing on the video displays and the positioning of text and data input blanks or other requestors on those displays.
- The wording and content of help messages when the user requests help from the system.
- The format of printed reports and the text appearing in them.

Cost

- A system capable of supporting 5 simultaneous users is $35,000 for the software only. A system such as this may have many computers and instruments linked in a network.

Advantages:

- The cost of this system is not as great as some of the other LIMS systems evaluated.
- The system has most of the basic capabilities of the CALS LabManager system.

Disadvantages:

- The user-interface is not as developed on this system as it is on some other LIMS.

Appendix D About the Authors

Tony A. Rhea, CHP

Mr. Rhea is a Certified Health Physicist (CHP) with over 8 years of experience in health physics, project management, and health physics information management at both DOE and NRC facilities. He holds a Bachelor's degree in chemistry and a Master's degree in health physics. He is the Software Editor for *Health Physics* and currently serves on ANSI standard committees in the areas of occupational radiation exposure records and radiation protection surveys. He is currently the Health Physics Manager for SAIC's Oak Ridge, TN office.

Thomas L. Rucker, Ph.D.*

Dr. Rucker has more than 13 years of experience in radioanalysis and radiological monitoring, including laboratory and counting room management, QA/QC program management, project management, laboratory automation development, environmental and effluent radiological monitoring program development, and personnel dosimetry program development. Dr. Rucker holds a Bachelor's degree in Chemistry, a Master's degree in Environmental Chemistry, and a Ph.D. in Analytical Chemistry with a minor in Health Physics. Dr. Rucker is currently a Senior Radiochemist at SAIC's Oak Ridge, TN office.

Michael W. Stafford*

Mr. Stafford is an Environmental Health Physicist with over 9 years of experience in a combination of field survey and project management assignments. He holds a Bachelor's degree in Environmental Engineering and a Master's degree in Health Physics. Mr. Stafford has been project manager on several environmental monitoring projects and has also managed many multi-disciplinary health physics laboratory automation projects. Most recently, he was project manager for the development and implementation of the Westinghouse/Savannah River Company's environmental health physics laboratory information management system. Mr. Stafford is currently a Principal Investigator in NUS's Aiken, SC office.

*Currently awaiting notification of the ABHP CHP exam results.

Appendix E Project Schedule

The project schedule follows this page. A task list with estimated task durations, a network diagram, and a Gantt chart are included.

This schedule has assumed the availability of sufficient resources to implement phases II and III in parallel. If this proves not to be the case and these phases are therefore sequential, the implementation time for the entire project will be extended significantly.

TASK LIST
PROJECT: LANL HPAL Upgrade

CURRENT DATE: 09/28/90
AS OF DATE: 10/01/90

JOB#	WBS CODE	JOB NAME	PERT VALUES	DURATION	STATUS	SCHEDULED START	SCHEDULED FINISH
100	01.	BEGIN PHASE I	0/0/0w	0w	Milestone	10/01/90	10/01/90
200	02.	ORGANIZATION/QA	0/0/0w	0w	Milestone	10/01/90	10/01/90
210	02.1	Identify customer contacts	2/4/8w	4w	Critical	10/01/90	10/29/90
220	02.2	Develop QA plan	3/4/6w	4w	Noncritical	10/29/90	11/26/90
230	02.3	Approve project schedule	3/4/8w	5w	Critical	10/29/90	12/03/90
299	02.99	Organization/QA complete	0/0/0w	0w	Milestone	12/03/90	12/03/90
300	03.	PROGRAMMATIC UPGRADES	0/0/0w	0w	Milestone	12/03/90	12/03/90
310	03.1	Forms control	0/0/0w	0w	Milestone	12/03/90	12/03/90
311	03.11	Standardize forms/reports	6/8/12w	8w	Noncritical	12/03/90	01/28/91
312	03.12	Implement new forms/rpts	6/8/12w	8w	Noncritical	01/28/91	03/25/91
320	03.2	Sample accountability	0/0/0w	0w	Milestone	12/03/90	12/03/90
321	03.21	Define program	8/12/18w	12w	Noncritical	12/03/90	02/25/91
322	03.22	Implement program	8/12/18w	12w	Noncritical	02/25/91	05/20/91
330	03.3	Process controls	0/0/0w	0w	Milestone	12/03/90	12/03/90
331	03.31	Define spike/blank QC pgm	10/12/18w	13w	Noncritical	12/03/90	03/04/91
332	03.32	Implement control charts	12/18/26w	18w	Noncritical	03/04/91	07/08/91
340	03.4	Blind QA Program	0/0/0w	0w	Milestone	12/03/90	12/03/90
341	03.41	Define program	3/4/6w	4w	Noncritical	12/03/90	12/31/90
342	03.42	Implement blind QA program	3/4/6w	4w	Noncritical	12/31/90	01/28/91
350	03.5	Data reduction algorithms	0/0/0w	0w	Milestone	12/03/90	12/03/90
351	03.51	Document algorithms	12/18/26w	18w	Noncritical	12/03/90	04/08/91
352	03.52	Implement algorithms	12/18/26w	18w	Noncritical	04/08/91	08/12/91
360	03.6	Deliver QA training	1/2/3w	2w	Noncritical	12/03/90	12/17/90
398	03.98	Program upgrades approved	0/0/0w	0w	Milestone	04/08/91	04/08/91
399	03.99	Program upgrades complete	0/0/0w	0w	Milestone	08/12/91	08/12/91
400	04.	INSTRUMENT UPGRADE	0/0/0w	0w	Milestone	12/03/90	12/03/90
410	04.1	Specify instruments	18/12/18w	14w	Noncritical	12/03/90	03/11/91
420	04.2	Procure instruments	10/12/30w	15w	Noncritical	03/11/91	06/24/91
430	04.3	Setup/calibrate instruments	6/8/18w	9w	Noncritical	06/24/91	08/26/91
440	04.4	Acceptance test instruments	4/6/8w	6w	Noncritical	08/26/91	10/07/91
450	04.5	Develop procedures	16/18/26w	19w	Noncritical	08/26/91	01/06/92
499	04.99	Instrument upgrade complete	0/0/0w	0w	Milestone	01/06/92	01/06/92
500	05.	RECORDS MANAGEMENT	0/0/0w	0w	Milestone	12/03/90	12/03/90
510	05.1	Perform records survey	1/2/3w	2w	Noncritical	12/03/90	12/17/90
520	05.2	Research retention req.	2/3/4w	3w	Noncritical	12/17/90	01/07/91
530	05.3	Investigate LANL standards	1/1/2w	1w	Noncritical	12/17/90	12/24/90
540	05.4	Recommend file stations	2/3/4w	3w	Noncritical	01/07/91	01/28/91
550	05.5	Procure filing equipment	6/8/12w	8w	Noncritical	01/28/91	03/25/91
560	05.6	Records mgmt. training	1/2/4w	2w	Noncritical	03/25/91	04/08/91
570	05.7	Records mgmt. procedures	6/8/16w	9w	Noncritical	03/16/92	05/18/92
599	05.99	Records management complete	0/0/0w	0w	Milestone	05/18/92	05/18/92
600	06.	COMPUTER SECURITY PLANS	0/0/0w	0w	Milestone	12/03/90	12/03/90
610	06.1	Risk assessment	1/2/3w	2w	Noncritical	12/03/90	12/17/90
620	06.2	Security plan	2/4/6w	4w	Noncritical	12/17/90	01/14/91
630	06.3	Network plan	2/3/4w	3w	Noncritical	12/17/90	01/07/91
699	06.99	Computer security complete	0/0/0w	0w	Milestone	01/14/91	01/14/91
700	07.	INSTRUMENT INTERFACE	0/0/0w	0w	Milestone	12/03/90	12/03/90

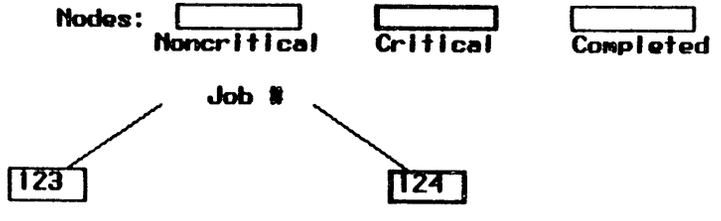
JOB#	WBS CODE	JOB NAME	PERT VALUES	DURATION	STATUS	SCHEDULED START	SCHEDULED FINISH
710	07.1	Design architecture	2/4/6w	4w	Critical	12/03/90	12/31/90
720	07.2	Interface Tennellecs	12/16/24w	17w	Critical	12/31/90	04/29/91
730	07.3	Interface liquid scintill.	0/0/0w	0w	Milestone	04/29/91	04/29/91
731	07.31	Upgrade to Packard 2550s	12/16/18w	16w	Critical	04/29/91	08/19/91
732	07.32	Develop LSC interface	8/12/18w	12w	Noncritical	04/29/91	07/22/91
740	07.4	Interface IMPULSE	12/16/24w	17w	Critical	08/19/91	12/16/91
750	07.5	Interface multichamber units	6/8/16w	9w	Critical	12/16/91	02/17/92
760	07.6	Implementation	0/0/0w	0w	Milestone	02/17/92	02/17/92
761	07.61	Revise procedures	10/12/24w	14w	Critical	02/17/92	05/25/92
762	07.62	Implement/startup	1/2/6w	3w	Noncritical	05/25/92	06/15/92
763	07.63	Train HPAL staff	4/8/12w	8w	Critical	05/25/92	07/20/92
770	07.7	Develop file transfer prog.	2/4/6w	4w	Noncritical	12/03/90	12/31/90
799	07.99	Inst. interface complete	0/0/0w	0w	Milestone	07/20/92	07/20/92
800	08.	NETWORKING	0/0/0w	0w	Milestone	12/03/90	12/03/90
810	08.1	Specify/procure hdwe/soft.	8/12/16w	12w	Noncritical	12/03/90	02/25/91
820	08.2	Purchase/install UPS	18/24/36w	25w	Noncritical	12/03/90	05/27/91
830	08.3	Pull Ethernet thinwire cable	3/4/6w	4w	Noncritical	02/25/91	03/25/91
840	08.4	Test network performance	1/2/4w	2w	Noncritical	03/25/91	04/08/91
899	08.99	Networking complete	0/0/0w	0w	Milestone	05/27/91	05/27/91
900	09.	PROTOTYPE LIMS	0/0/0w	0w	Milestone	04/08/91	04/08/91
910	09.1	Specify requirements	6/8/12w	8w	Noncritical	04/08/91	06/03/91
920	09.2	Obtain off-the-shelf LIMS	8/12/15w	12w	Noncritical	06/03/91	08/26/91
930	09.3	Install/configure (TA-55)	6/8/16w	9w	Noncritical	08/26/91	10/28/91
940	09.4	Implementation	0/0/0w	0w	Milestone	10/28/91	10/28/91
941	09.41	Develop procedures	10/12/16w	12w	Noncritical	10/28/91	01/20/92
942	09.42	Train personnel	6/8/12w	8w	Noncritical	01/20/92	03/16/92
950	09.5	Evaluate prototype	4/12/24w	13w	Critical	07/20/92	10/19/92
960	09.6	Replicate in TA-53	3/4/10w	5w	Noncritical	10/19/92	11/23/92
970	09.7	Replicate in TA-50	4/6/12w	7w	Noncritical	11/23/92	01/11/93
980	09.8	Replicate in TA-43	4/6/12w	7w	Noncritical	01/11/93	03/01/93
998	09.98	TA-55 running on LIMS	0/0/0w	0w	Milestone	07/20/92	07/20/92
999	09.99	All central labs on LIMS	0/0/0w	0w	Milestone	03/01/93	03/01/93
1000	10.	FINAL LIMS	0/0/0w	0w	Milestone	10/19/92	10/19/92
1010	10.1	Finalize needs/requirements	3/4/6w	4w	Critical	10/19/92	11/16/92
1020	10.2	Specify software RFP	6/8/12w	8w	Critical	11/16/92	01/11/93
1030	10.3	Procure final LIMS	20/26/40w	27w	Critical	01/11/93	07/19/93
1040	10.4	Buy required hardware	10/12/18w	13w	Noncritical	01/11/93	04/12/93
1050	10.5	Install/configure (TA-55)	3/4/6w	4w	Critical	07/19/93	08/16/93
1060	10.6	Acceptance test LIMS	3/6/9w	6w	Critical	08/16/93	09/27/93
1070	10.7	Implementation	0/0/0w	0w	Milestone	09/27/93	09/27/93
1071	10.71	Onsite LIMS assistance	8/12/24w	13w	Critical	12/20/93	03/21/94
1072	10.72	Modify procedures	10/12/16w	12w	Critical	09/27/93	12/20/93
1073	10.73	Train personnel	6/8/12w	8w	Noncritical	12/20/93	02/14/94
1080	10.8	Replicate in other labs	0/0/0w	0w	Milestone	03/21/94	03/21/94
1081	10.81	TA-53 LIMS	2/4/8w	4w	Critical	03/21/94	04/18/94
1082	10.82	TA-50 LIMS	3/6/10w	6w	Critical	04/18/94	05/30/94
1083	10.83	TA-33 LIMS	2/4/8w	4w	Critical	05/30/94	06/27/94
1098	10.98	TA-55 running on final LIMS	0/0/0w	0w	Milestone	03/21/94	03/21/94
1099	10.99	Cent. labs on final LIMS	0/0/0w	0w	Milestone	06/27/94	06/27/94
1999	19.	END PHASE I	0/0/0w	0w	Milestone	06/27/94	06/27/94
2000	20.	BEGIN PHASE II	0/0/0w	0w	Milestone	06/27/94	06/27/94

JOB#	WBS CODE	JOB NAME	PERT VALUES	DURATION	STATUS	SCHEDULED START	SCHEDULED FINISH
2003	20.31	Job task analysis	12/16/24w	17w	Critical	12/12/94	04/10/95
2010	20.1	Stabilize final LIMS	8/12/16w	12w	Critical	06/27/94	09/19/94
2020	20.2	Refine procedures	8/12/16w	12w	Critical	09/19/94	12/12/94
2030	20.3	Establish 5480.18 training	0/0/0w	0w	Milestone	12/12/94	12/12/94
2032	20.32	Design/develop program	18/26/52w	29w	Critical	04/10/95	10/30/95
2033	20.33	Implement training program	12/16/24w	17w	Critical	10/30/95	02/26/96
2034	20.34	Evaluation program	8/12/16w	12w	Critical	02/26/96	05/20/96
2040	20.4	Develop HSE VAX Application	18/26/40w	27w	Noncritical	12/12/94	06/19/95
2999	29.	END PHASE II	0/0/0w	0w	Milestone	05/20/96	05/20/96
3000	30.	BEGIN PHASE III	0/0/0w	0w	Milestone	06/27/94	06/27/94
3010	30.1	Implement satellite labs	0/0/0w	0w	Milestone	06/27/94	06/27/94
3011	30.11	Resolve programmatic issue	8/12/18w	12w	Noncritical	06/27/94	09/19/94
3012	30.12	Install network	12/16/20w	16w	Noncritical	09/19/94	01/09/95
3013	30.13	Procure hardware	10/12/16w	12w	Noncritical	09/19/94	12/12/94
3014	30.14	Modify procedures	6/8/12w	8w	Noncritical	09/19/94	11/14/94
3015	30.15	Train personnel	6/8/12w	8w	Noncritical	01/09/95	03/06/95
3020	30.2	Integrate spectroscopy	0/0/0w	0w	Milestone	06/27/94	06/27/94
3021	30.21	Gamma spec instr interface	12/18/24w	18w	Noncritical	06/27/94	10/31/94
3022	30.22	Alpha spec instr interface	8/12/18w	12w	Noncritical	10/31/94	01/23/95
3023	30.23	Modify procedures	12/16/24w	17w	Noncritical	01/23/95	05/22/95
3024	30.24	Implement spectroscopy	4/6/8w	6w	Noncritical	05/22/95	07/03/95
3025	30.25	Train personnel	6/8/12w	8w	Noncritical	07/03/95	08/28/95
3099	39.	END PHASE III	0/0/0w	0w	Milestone	08/28/95	08/28/95
4099	49.	END PROJECT	0/0/0w	0w	Milestone	05/20/96	05/20/96

NETWORK DIAGRAM REPORT
PROJECT: LANL HPAL Upgrade
Network Diagram Legend:

CURRENT DATE: 09/28/90
AS OF DATE: 10/01/90

Noncritical Links: ————————
Critical Links: ————————

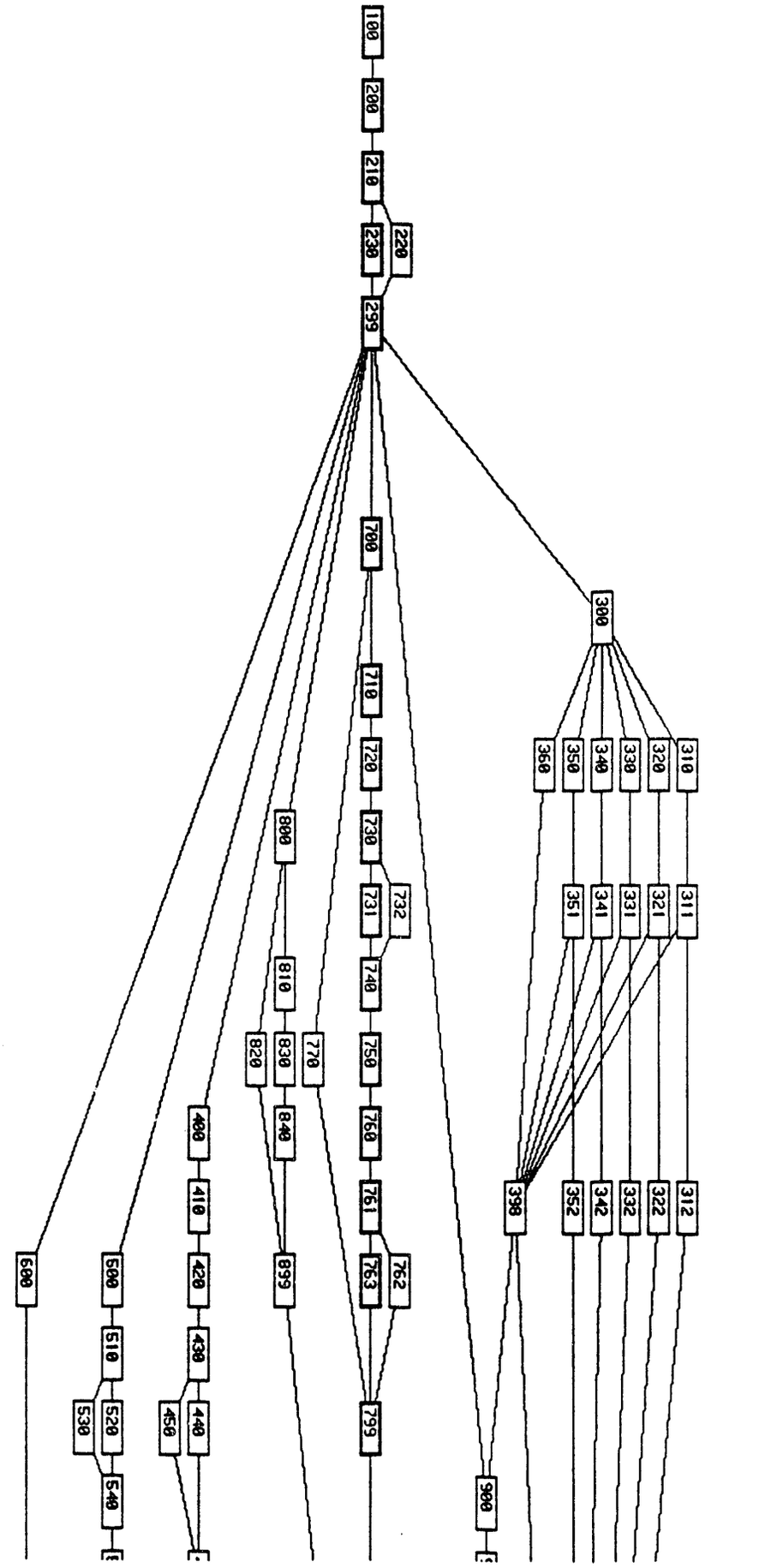


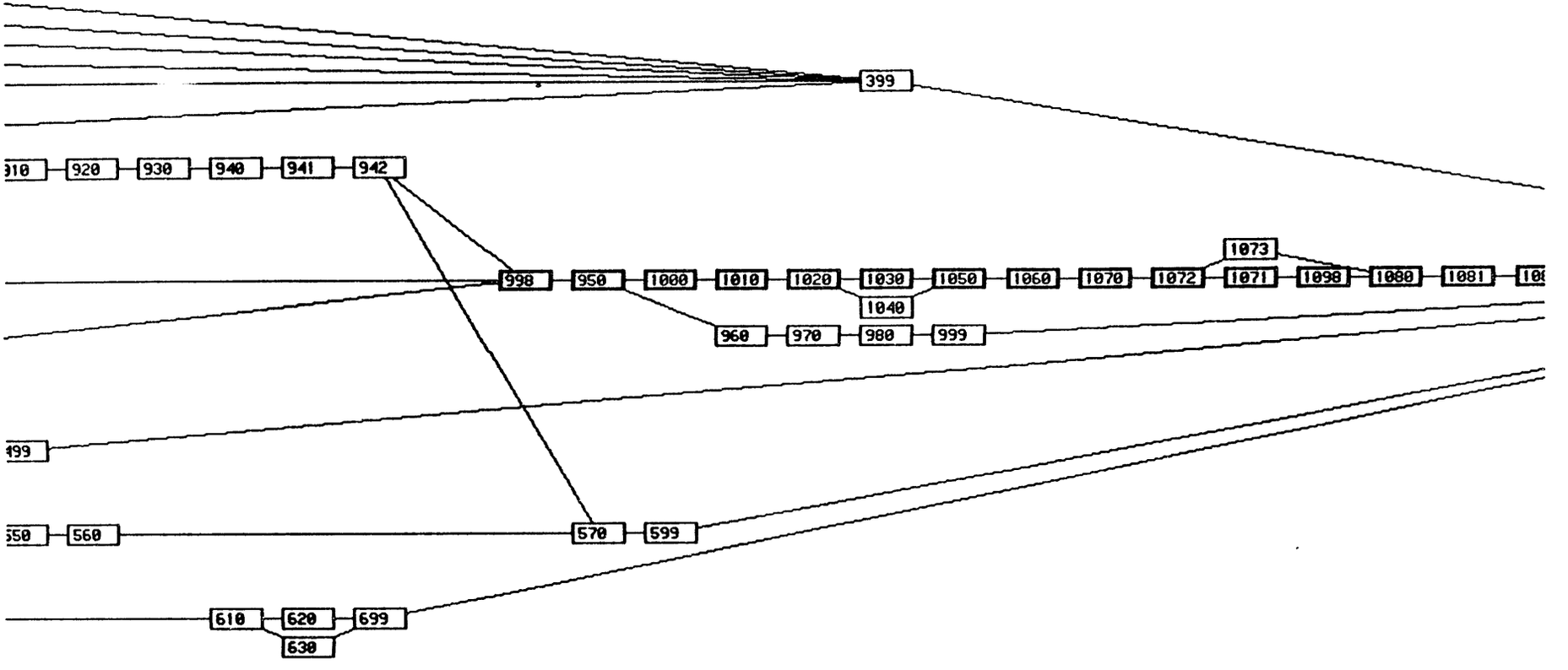
Noncritical Job Node

Critical Job Node

NE_WORK DIAGRAM REPORT
PROJECT: LANL HPAL Upgrade

CURRENT DATE: 09/28/90
AS OF DATE: 10/01/90

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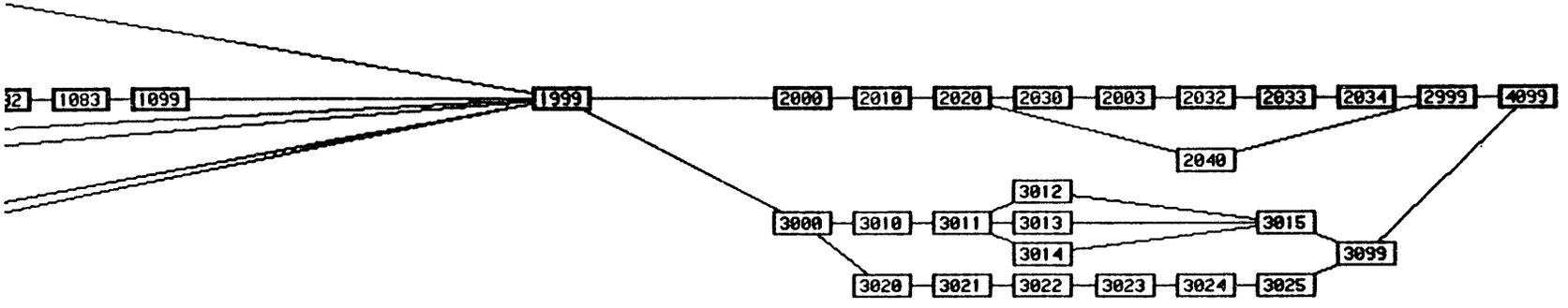
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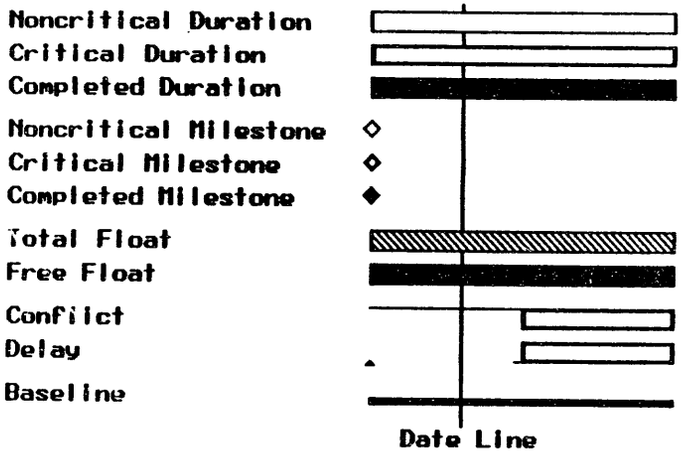
GANTT CHART REPORT
PROJECT: LANL HPAL Upgrade

CURRENT DATE: 09/28/90
AS OF DATE: 10/01/90



PROJECT: LANL HPAL Upgrade
GANTT CHART REPORT
CURRENT DATE: 09/28/90
AS OF DATE: 10/01/90
WBS
Name
1990 1991 1992 1993 1994 1995 1996
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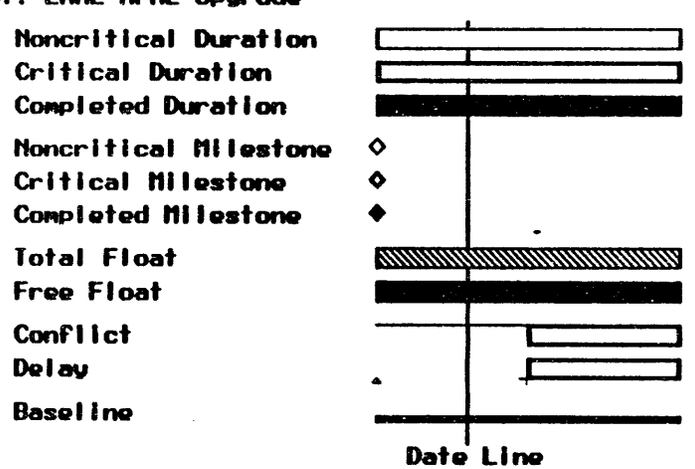
01. BEGIN PHASE I
02. ORGANIZATION/QA
03. PROGRAMMATIC UPGRADES
04. INSTRUMENT UPGRADE
05. RECORDS MANAGEMENT
06. COMPUTER SECURITY PLANS
07. INSTRUMENT INTERFACE
08. NETWORKING
09. PROTOTYPE LIMS
10. FINAL LIMS
19. END PHASE I
20. BEGIN PHASE II
29. END PHASE II
30. BEGIN PHASE III
33. END PHASE III
49. END PROJECT

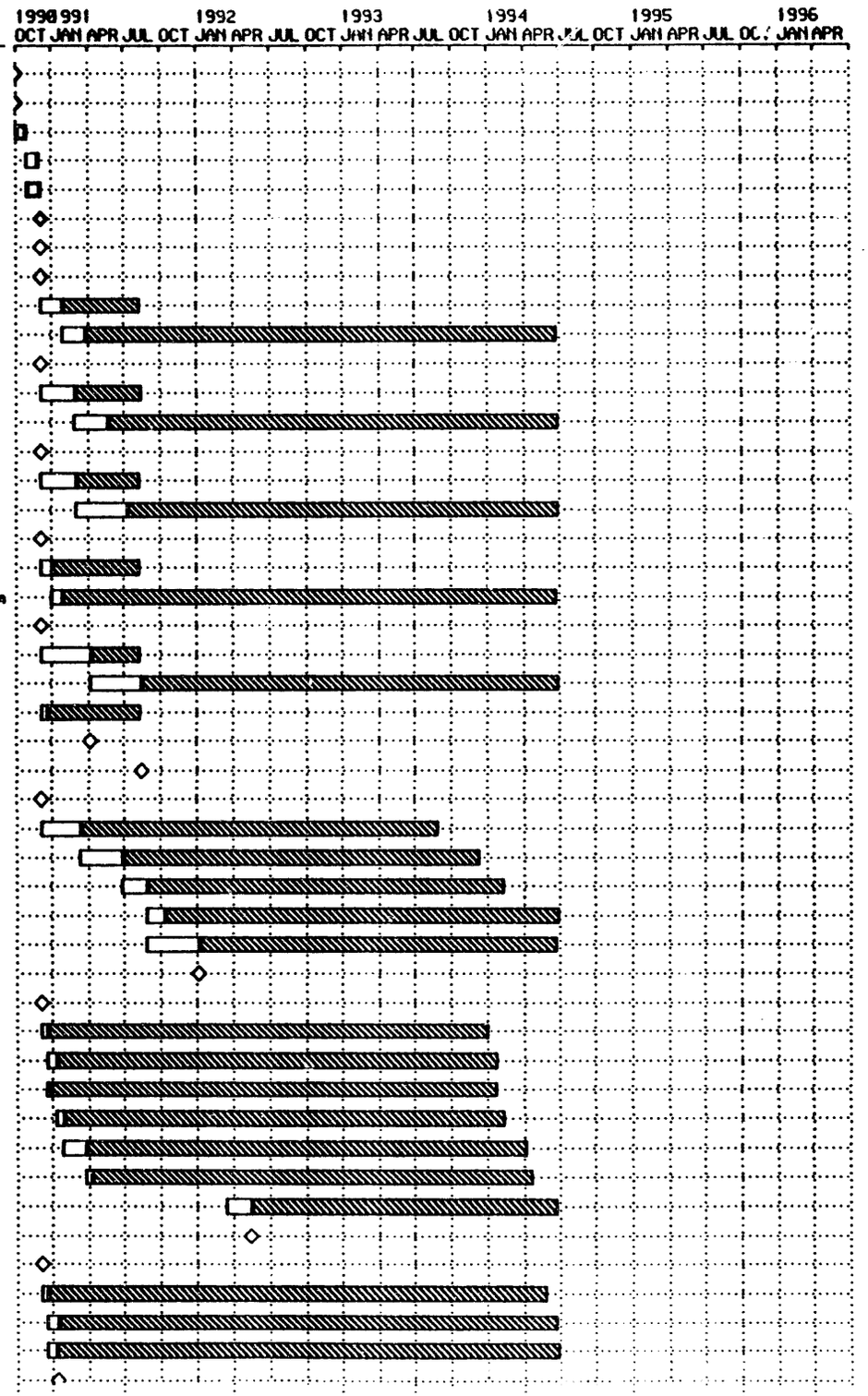
GANTT CHART REPORT
PROJECT: LANL HPAL Upgrade

CURRENT DATE: 09/28/90
AS OF DATE: 10/01/90

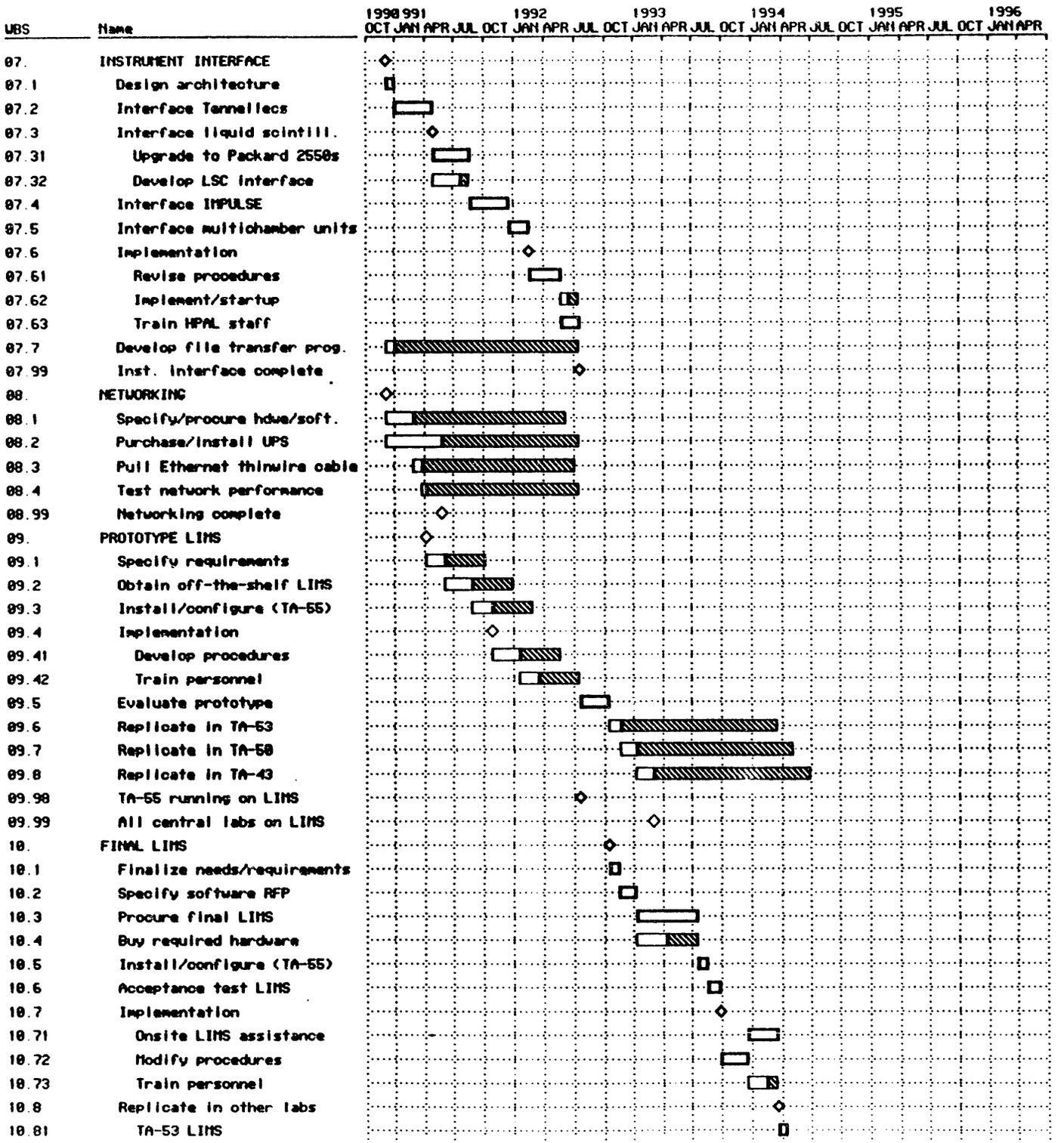


CURRENT DATE: 09/28/90
AS OF DATE: 10/01/90

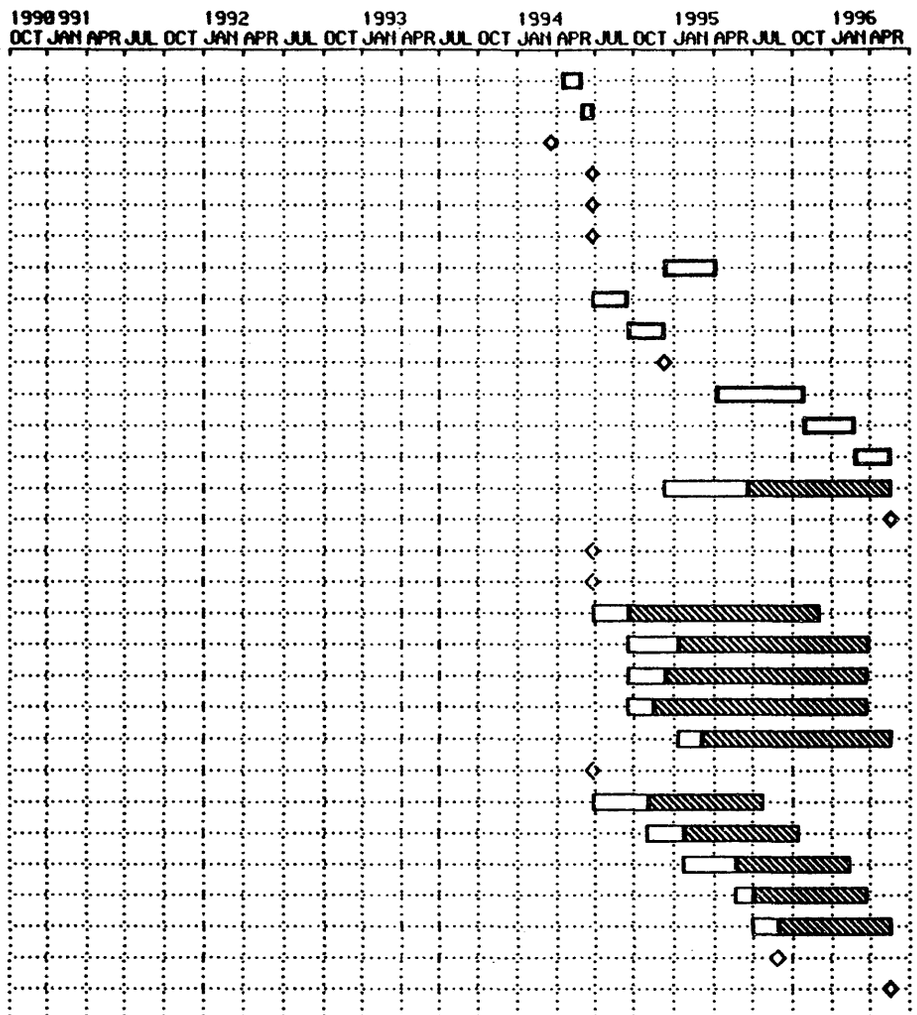
;A.TT CHART REPORT
ROJECT: LANL HPAL Upgrade



WBS	Name
01.	BEGIN PHASE I
02.	ORGANIZATION/QA
02.1	Identify customer contacts
02.2	Develop QA plan
02.3	Approve project schedule
02.99	Organization/QA complete
03.	PROGRAMMATIC UPGRADES
03.1	Forms control
03.11	Standardize forms/reports
03.12	Implement new forms/rpts
03.2	Sample accountability
03.21	Define program
03.22	Implement program
03.3	Process controls
03.31	Define spike/blank QC pgm
03.32	Implement control charts
03.4	Blind QA Program
03.41	Define program
03.42	Implement blind QA program
03.5	Data reduction algorithms
03.51	Document algorithms
03.52	Implement algorithms
03.6	Deliver QA training
03.98	Program upgrades approved
03.99	Program upgrades complete
04.	INSTRUMENT UPGRADE
04.1	Specify instruments
04.2	Procure instruments
04.3	Setup/calibrate instruments
04.4	Acceptance test instruments
04.5	Develop procedures
04.99	Instrument upgrade complete
05.	RECORDS MANAGEMENT
05.1	Perform records survey
05.2	Research retention req.
05.3	Investigate LANL standards
05.4	Recommend file stations
05.5	Procure filing equipment
05.6	Records mgmt. training
05.7	Records mgmt. procedures
05.99	Records management complete
06.	COMPUTER SECURITY PLANS
06.1	Risk assessment
06.2	Security plan
06.3	Network plan
06.99	Computer security complete


UBS
Name
1990 1991 1992 1993 1994 1995 1996
OCT JAN APR JUL OCT JAN APR JUL OCT JAN APR JUL OCT JAN APR JUL OCT JAN APR JUL OCT JAN APR
07. INSTRUMENT INTERFACE
07.1 Design architecture
07.2 Interface Tennelecs
07.3 Interface liquid scintill.
07.31 Upgrade to Packard 2550s
07.32 Develop LSC interface
07.4 Interface IMPULSE
07.5 Interface multichamber units
07.6 Implementation
07.61 Revise procedures
07.62 Implement/startup
07.63 Train HPAL staff
07.7 Develop file transfer prog.
07.99 Inst. interface complete
08. NETWORKING
08.1 Specify/procure hdwe/soft.
08.2 Purchase/install UPS
08.3 Pull Ethernet thinwire cable
08.4 Test network performance
08.99 Networking complete
09. PROTOTYPE LIMS
09.1 Specify requirements
09.2 Obtain off-the-shelf LIMS
09.3 Install/configure (TA-55)
09.4 Implementation
09.41 Develop procedures
09.42 Train personnel
09.5 Evaluate prototype
09.6 Replicate in TA-53
09.7 Replicate in TA-50
09.8 Replicate in TA-43
09.98 TA-55 running on LIMS
09.99 All central labs on LIMS
10. FINAL LIMS
10.1 Finalize needs/requirements
10.2 Specify software RFP
10.3 Procure final LIMS
10.4 Buy required hardware
10.5 Install/configure (TA-55)
10.6 Acceptance test LIMS
10.7 Implementation
10.71 Onsite LIMS assistance
10.72 Modify procedures
10.73 Train personnel
10.8 Replicate in other labs
10.81 TA-53 LIMS

WBS	Name
10.82	TA-50 LIMS
10.83	TA-33 LIMS
10.98	TA-55 running on final LIMS
10.99	Cent. labs on final LIMS
19.	END PHASE I
20.	BEGIN PHASE II
20.31	Job task analysis
20.1	Stabilize final LIMS
20.2	Refine procedures
20.3	Establish 5480.18 training
20.32	Design/develop program
20.33	Implement training program
20.34	Evaluation program
20.4	Develop HSE VAX Application
29.	END PHASE II
30.	BEGIN PHASE III
30.1	Implement satellite labs
30.11	Resolve programmatic issue
30.12	Install network
30.13	Procure hardware
30.14	Modify procedures
30.15	Train personnel
30.2	Integrate spectroscopy
30.21	Gamma spec instr interface
30.22	Alpha spec instr interface
30.23	Modify procedures
30.24	Implement spectroscopy
30.25	Train personnel
39.	END PHASE III
49.	END PROJECT



END

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