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NUCLEAR CHEMISTRY COUNTING FACILITIES:
REQUIREMENTS DEFINITION

MASTER

D. W. O'Brien/J. Baker

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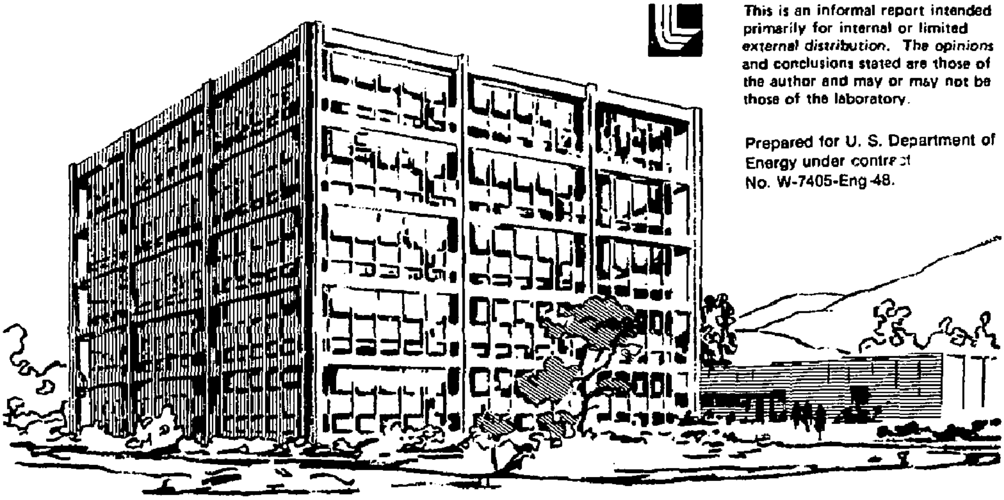

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ABSTRACT

In an effort to upgrade outdated instrumentation and to take advantage of current and imminent technologies the Nuclear Chemistry Division at Lawrence Livermore Laboratory is about to undertake a major upgrade of their low level radiation counting and analysis facilities. It is expected that such a project will make a more coordinated data acquisition and data processing system, reduce manual data handling operations and speed up data processing throughput. Before taking on a systems design it is appropriate to establish a definition of the requirements of the facilities. This report examines why such a project is necessary in the context of the current and projected operations, needs, problems, risks and costs. The authors also address a functional specification as a prelude to a system design and the design constraints implicit in the systems implementation. Technical, operational and economic assessments establish necessary boundary conditions for this discussion. This report also establishes the environment in which the requirements definition may be considered valid. The validity of these analyses is contingent on known and projected technical, scientific and political conditions.

1.0 INTRODUCTION

The Nuclear Chemistry Division houses and operates radiation counting and mass spectroscopy facilities to perform the isotopic assessment of samples for programmatic studies. While its primary responsibility is in shot analysis for the Nuclear Test Program, Nuclear Chemistry also has responsibilities in other programs such as Environmental Monitoring, Safeguards, research and support for Hazards Control and Bio-Medical groups.

At the Livermore site, Nuclear Chemistry is housed in buildings 151, 251 and 281. Production counting is carried out in the well-shielded basement of building 151. The basement is devoted to low-level alpha, beta, gamma and x-ray counting. A layout of the basement counting facility is illustrated in Figure A-1 in the appendix. Five mass spectroscopy systems and a scattering of stand-alone counting systems are also in building 151. The counting systems in buildings 251 and 281 are used primarily for research rather than production work and are more susceptible to change and reconfiguration.

Nuclear Chemistry is aware of the need for a comprehensive, well-managed plan of attack for the collection, handling and reduction of very expensive data in this unique production environment. The divergent needs, desires and goals of the scientific user groups, and a rapid succession of technological advancements in past years has caused Nuclear Chemistry to establish a formal definition of the requirements for its facilities. It is hoped that we can state where we are now, what we are doing well, what is problematic in the current system, where we expect to be tomorrow and with what capabilities to carry out our mission. This requirements definition is a first step in creating a facilities system for the better management of equipment, handling of data and the efficient use of highly skilled personnel. The requirements definition is necessary to bridge the gap from a recognized existing condition to a functional architecture for modifying the condition (Figure 1). A system design may then formalize how functions are to be implemented.

Determining the requirements of the division involved the close cooperation of the management of Nuclear Chemistry, the scientific community within the division and Electronics Engineering support which carried out the study. After announcing the intent of the study a series of seminars was scheduled in which representatives of scientific groups discussed their programmatic responsibilities and their views on how they would like to be supported by such a system. They were also asked to address specific topics involving current operations and to supply some statistics on how data is being handled now. As a follow-up to these seminars each representative was interviewed to correct and supplement notes recorded at the seminars. A questionnaire was then distributed to these same representatives to better establish statistics for analysis of the data handling needs of the facilities.

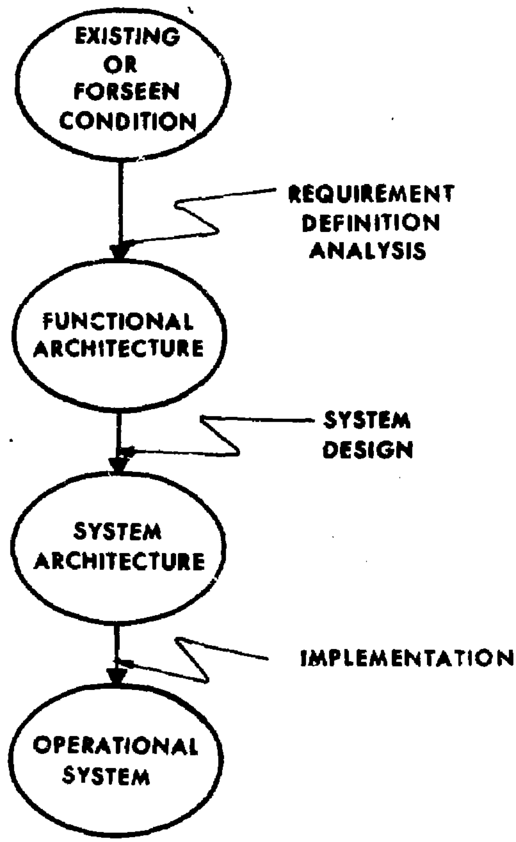


FIGURE 1
SYSTEMS DEVELOPMENT PROCEDURE

The data gathered by this means was then used to clarify the current operations, derive a problem statement, make clear design constraints and serve as a foundation for a functional specification.

2.0 BOUNDARY CONDITIONS TO BE ADDRESSED

Defining the requirements of a system cannot be accomplished without recognizing the real world bounds with which the designer must contend. The technical assessment of the requirements must demonstrate the advantages (and disadvantages) of moving from the system now in use, with its inherent limitations, to the more relaxed bounds imposed by a new system. This involves an analysis of the current operations, proposing functions to be implemented and specifying the resources available for a design implementation.

An operational assessment is intended to draw out a problem statement from the analysis of the current operations. This is of use in establishing performance parameters for the proposed system and conditions for its use.

An economic assessment explores the system now in use to uncover the risks and hidden costs of its continued operation. In proposing a functional design this assessment expresses an expected impact and states an estimate of the cost of the final design.

3.0 CONTEXT ANALYSIS

3.1 Current Operations

The operations centered in Building 151 and particularly those in the basement of that building are of primary concern. These facilities support test-shot diagnostics and other production counting and analyses. These facilities are most apt to gain from an in-depth systems analysis.

The present state of affairs within Nuclear Chemistry has evolved over a period of twenty years. The mission of the division has spawned distinct working groups, each with its own subset of responsibilities and disciplines. Each group has its own unique requirements for a consolidated (shared) system for data assimilation and reduction. These working groups operate independently of one another with separate counter systems and redundant copies of reduction codes for data analysis. For the Test Program most of the Nuclear Chemistry effort comes from these individual groups. These groups collect and analyze data which is then submitted to a concise, well defined data base referred to as the PROPHET DECK. It is from this card deck that reports are generated on the yield of nuclear explosions at the Nevada Test Site. This report is referred to as the Shot Yield report. Some statistics on counting systems, categorized by scientific user group, are listed in Table A-2 in the appendix. This table reflects current facilities usage. The reader should reference this information with the discussion of current operations. When new functions and performance perameters are discussed, only those statistics which differ from table A-2 will be cited. Figure A-3, in the appendix, illustrates the data flow from the various counters to report generation as it supports the Test Program. (Note the number of nonproductive steps which clutter the data paths.)

Some systems in operation today output data by punching cards, some punch paper tape and others write data to magnetic disk or tape. Data is converted from disks and paper tape to magnetic tape for entry into the Livermore Time Share System (LTSS) system. Punched cards are entered into an RJET and much calculation is carried out by hand. Nuclear Chemistry presently uses the 7600 computers for data reduction, analysis, report generation and archival storage. The replacement of 7600 computers with CRAY-1 mainframe computers, and the replacement of the present archival storage facility at the Computation Center presents a dilemma. Though Nuclear Chemistry has little control over events affecting the LTSS, the division will have to expend time, money and allocations for personnel to convert to alternative data processes.

At present most detectors are categorized and numbered accordingly. However, users often refer to detector systems with seemingly arbitrary names. The reader should be aware that this report refers to detector systems as they are referred to by users.

3.1.1 Heavy Elements Group

The Heavy Elements Group within Nuclear Chemistry runs Alpha and Beta detector systems in the basement of Building 151. These systems are primarily in support of the Test Program shot diagnostics and find sporadic use between shots. In Room B130, at the location indicated (Figure A-1), the Heavy Elements Group runs the following systems:

3.1.1.1 Automated Alpha Systems. Two types of detectors are used in the automated systems:

- Frisch grid-type detectors, F.G.5-8 and 9-12 (two sets of four detectors)
- Alpha solid-state detectors (HE14, four detectors)

3.1.1.1.1 Operating Characteristics. Nine characteristics are typical of the automated Alpha counting systems:

- Automated sample changers
- Each set of four is supported by an ND130 multichannel analyzer (MCA)
- 128 channel spectral resolution
- PDP-8/i monitors for count/stop criteria (no preset count or preset time)
- User enters sample type, ID, chamber, etc. via PDP-8/i terminal keyboard
- Samples are counted only once
- Maximum count rate approximately 10,000/min.
- About 36 samples/shot
- About 500 samples/year

3.1.1.2 Other Alpha Systems. Three detector systems are used in the non-automated Alpha counting systems:

- Frisch grid type detectors (four each), F.G. 13-16
- Alpha solid-state detectors, 81-84
- Four Frisch grid detectors, HE6

3.1.1.2.1 Operating Characteristics. Three characteristics are typical of the non-automated Alpha counting systems:

- Each set of four is supported by an ND130 MCA paper tape output
- No sample changers
- No automated monitoring and control

3.1.1.3 Beta System. Three of the same type of Beta counters are used in the system at locations beta 85, 86 and 88.

3.1.1.3.1 Operating Characteristics. Three operating characteristics are typical of the Beta counting system:

- Single channel integral counters (each)
- Sample changer support
- Thumbwheel ID of samples

3.1.1.4 Heavy Element Counting System Procedure. Typically samples are loaded into sample changers or directly in front of detectors by an operator. The operator then records parametric and ID data in a log. The automated systems also require some data input via the PDP-8/i terminal keyboard. The data input is then merged with the spectral or count information. Data from the automated systems is sent by wire to the PDP-8/i in the next room. An OCTOPUS readable magnetic tape is then recorded for data reduction on the 7600 computers. The less automated systems produce paper tape records. These records are also moved to OCTOPUS readable magnetic tapes via the PDP-8/i. The raw data (on mag tapes) are hand carried to the computation center for analysis using the codes BRUNHILDE (to resolve exponential beta decay curves) and FLORRIE, a reduction code used on alpha data.

3.1.1.5 Heavy Elements Counting Systems Data. Data from the low background alpha counters, HE6, is also used with data from mass spectrometers to resolve the isotope Pu236. The codes required to analyze this data are YUMYUM and YYPU36 (which makes use of mass spectroscopy information).

3.1.2 Mass Spectroscopy Group

The Mass Spectroscopy Group within Nuclear Chemistry acquires and reduces data which is intended to correlate with the isotopic data gathered by radiation counting. Mass spec (spectroscopy) information is used by a number of counting groups and with a number of data reduction codes to establish confidence in statistics. Currently the Mass Spectroscopy Group runs three mass spec instruments on the first floor of

Building 151. The group is also in the process of developing two more instruments to support gas analysis operations. The established mass spectrometers are rather well automated and may very well be the easiest of the established systems to tie into a consolidated system.

3.1.2.1 Operating Characteristics (MS-V and MS-VIII Systems). Ten characteristics are typical of the MS-V and MS-VIII systems.

- Mass spec electron multiplier
- Data scaler
- ND180 multichannel analyzer
- PDP-8/L minicomputer
- Paper tape reader/punch
- Joystick control
- CRT spectral display
- CRT console terminal
- Serial line-printer
- Removable disk drive (2.5M byte)

3.1.2.2 Operating Characteristics (MS-XL System). Ten characteristics are typical of the MS-XL system.

- Mass spec electron multiplier
- Preamp scaler, negative logic
- Computer controlled magnetic sweep
- PDP-8/f minicomputer
- Paper tape reader/punch
- Joystick control
- CRT spectral display
- CRT console terminal
- Serial line-printer
- One removable and one fixed 2.5M byte disk

3.1.2.3 Control and Data. For each of the above mass spec systems, control information is entered via the controlling minicomputer console terminal. Data is displayed on the CRT and controlled by a joystick through the minicomputer. Either raw data or reduced data may be printed or punched on paper tape. The paper tape is used as a transport media. Medium length data storage (less than one year) is maintained on the disk.

3.1.2.4 Data Processing. Data processing is accomplished on supporting PDP-8 minicomputers and entails calculating ratios of the number of counts corresponding to different elements or isotopes. A known concentration of a particular element is used to obtain absolute concentrations of other elements.

3.1.2.5 Processing Results. The result of the data processing is a table of elements or isotopes and the quantity of each in units of grams. The table also includes data indicating the amount of error in the quantity measurements. The final output is composed of only about 10 to 20 numbers. These final results are printed and punched on paper tape. The tape is used later to punch cards for use with other data in isotopic analysis on the 7600 computers.

3.1.3 Gas Sampling Group

The Gas Sampling Group within Nuclear Chemistry has a responsibility in the analysis of samples recovered from test shots. The short-lived Radon, Krypton and Xenon is of primary concern. Raw samples are brought to Building 151 from Nevada soon after shot time. Gamma spectra is obtained from samples, using automated GE(Li) detector stations NSS2, in Room B114. Radon, Krypton and Xenon are chemically separated from the samples and examined using beta detectors. Gas samples are also examined for Argon and Carbon 14 using gas proportional counters. The Gas Sampling Group operates the following detector systems in Room B132 in the basement of Building 151:

3.1.3.1 Detector Systems

Beta Detector Systems

- Four detector stations (61-64)
- Automated sample changers

Gas Proportional Counters

- Nine scaler/counters (71-79)
- Eight-position Labacas system
- Geiger (counter) bank

Liquid Scintillation Counter

- Stand-alone unit
- Automated sample changing

3.1.3.1.1 Operating Characteristics. Five characteristics are typical of the gas detector systems:

- Evaluation of noble gas content
- Evaluation of precise isotopic values
- Evaluation of gross composition
- Single card punched per integral count
- Samples changed and recorded on preset time

3.1.3.2 Beta Wheels. The beta detector systems, referred to as beta wheels, are semiautomated. Samples are changed and integral counts punched on cards automatically as a function of a preset time. The gas proportional counters support eight positions for sample data collection and also a Geiger bank for the determination of cosmic background within the Lobacas system chamber. The liquid scintillation counter in Room B132 is used only occasionally for detection of Tritium and is not used in support of the Test Program.

3.1.3.3 Calibration and Analysis: Before a test shot, samples are irradiated at the reactor in Building 281. Samples are then analyzed on the Ge(Li) detector system, NSS2, for use in calibration. Gamma decay curves are determined using the codes GAMANAL and BRUNHILDE. These codes are used along with beta information reduced by the codes BRUNHILDE and RHOZEE to configure yet another version of BRUNHILDE. This other version is used for production analysis of post-shot samples.

3.1.3.4 Production and Calibration Analyses. The production analyses and calibration analyses are referred to the PROPHET DECK. The PROPHET DECK uses this information in its determination of a shot yield. This same information is merged with mass spectroscopy data and used by the code DELPHI. The DELPHI code also reports shot yield information. All of the codes mentioned are run on the 7600 computers. Jobs are submitted via RJET as card decks, except GAMANAL reduction of Ge(Li) detector data. This data reduction is submitted on magnetic tape hand-carried to the computation center.

3.1.4 Automated Counting

The automated counting systems in the basement of Building 151 refer to either one of two groups of counters. One group of counters is hardwired to one of two PDP-8 minicomputers. The other group simply records single channel analyzer data on punched cards, in an automated fashion. Typically, these counting systems are supported by sample changers and are used for production data acquisition. These automated systems, listed below, provide for the radiometric assay of samples in support of environmental and programmatic (N.T.S.) studies.

3.1.4.1 Dectector Systems

- Fourteen NaI x-ray or gamma photon detectors (PM tubes)
- Thirteen beta counters (end window, methane flow, proportional)
- Six low background beta counters
- One Xe-CH4 x-ray proportional counter
- Seven 2-Pi Arson flow, alpha counters
- Eight MCS8 automated Ge(Li) systems

3.1.4.1.1 Operating Characteristics. Nine characteristics are typical of the radiometric automated systems.

- One to ninety minutes/sample count
- About 35 sequentially-stepped sample changers (up to 26 manually-loaded positions)
- ID information entered via thumbwheel (six to eight digits)
- Single-channel analyzer to scalers to punched card with ID, stop time, length of count and scaler counts
- Two systems with lines to PDP-8/i
- Eight Ge(Li) detector systems on the PDP-8/e (five have sample changers)
- Roll-around INO/TECH analyzer for calibration of NaI detectors
- Gamma spectra recorded on magnetic tape and reduced on 7600 computers
- Other data recorded on punched card, paper tape or printed page and reduced by hand or by codes on the 7600s

3.1.4.2 Automated Sampling. These systems are "automated" only in the sense that they automatically proceed from one sample to the next in sequence using a single set of preset parameters. They also record data without manual intervention. The systems still lack scheduling or sophisticated decision making capabilities and data must still be hand-carried and transcribed to OCTOPUS usable media.

3.1.4.3 Data. Raw data is either hand-carried to the computations center on OCTOPUS readable magnetic tape or submitted as a card deck via RJET. The data from the NaI detectors, N1 and N2, are reduced using the code NAIGAM. GAMANAL is used in analyzing gamma spectra from Ge(Li) detectors and BRUNHILDE is used in reducing beta decay curves.

3.1.5 Stand-Alone Counting Systems

In basement room B132 and on the second floor of Building 151 Nuclear Chemistry maintains and uses analyzer systems which output paper tape, usually via a console teletype. These systems are used both in data production for the Test Program and as laboratory instruments. Ge(Li) Si(Li) and NaI detectors collect gamma and x-ray spectra using multichannel analyzers. These analyzer systems are used informally by a few scientist-operators and are often referred to by room number or just the operator responsible for the system.

3.1.5.1 Counter 48 and counter 45 (Room 2107A)

3.1.5.1.1 Operating Characteristics. Six characteristics are typical of the stand-alone analyzer systems.

- 15cc Ge(Li) coax crystal (counter 48)
- NaI detector (counter 45)
- Shared ND181 MCA, 1024 channels, 4MHz ADC
- Gamma spectra to mag tape via paper tape and PDP-8/i
- Data reduction using LUCY on 7600s
- Used in shot work production

3.1.5.2 "Arnie Delucchi's" Ge(Li) system

3.1.5.2.1 Operating Characteristics. Three characteristics are typical of Arnie Delucchi's system.

- Ge(Li) detector
- NS720 MCA, 4096 channels, 100 MHz ADC
- Requires high-level of user interaction

3.1.5.3 Sodium Iodide Systems (Room 2330A)

3.1.5.3.1 Operating Characteristics. Three characteristics are typical of the Sodium Iodide Systems.

- Two NaI detectors
- ND1100 MCA, 512 channel, 4MHz ADC
- Plotter support

3.1.5.4 Ge(Li) x-ray counter 52 (Room B132)

3.1.5.4.1 Operating Characteristics. Six characteristics are typical of the X-ray Counter.

- Ge(Li) detector
- Production systems
- 200-300 samples/year throughput
- Continuously used for two and three day counts
- Manual operation
- Uses LUCY for data analysis

3.1.5.5 Silicon systems D and E (Room B132)

3.1.5.5.1 Operating Characteristics. Six characteristics are typical of the Silicon systems.

- Two x-ray Si(Li) detectors
- ND181 MCA, 1024 channels (split), 4MHz ADC
- Router, coincidence busy rejector
- Plotter support
- Used for long counts, one day typically
- Little user interaction

3.1.5.6 X-Ray System (Room 2131A)

3.1.5.6.1 Operating Characteristics. Ten characteristics are typical of the X-Ray system.

- Two counters, one Ge(Li) and one Si(Li)
- One system with computer-controlled sample changer
- NDF-812 and ND2400 analyzers
- PDP-8/e controller
- Disk, mag tape support of minicomputer
- Twenty-four bit channel resolution (1024 channels)
- Up to 35 channels, sums to paper tape
- Paper tape is processed on PDP-8/i to cards for RJET
- No archival storage necessary
- Few samples per day

3.1.5.7 Usage. These systems are loosely coupled to the Test Program. Their use changes from day to day and their only communication linkage is via paper tape. The use of these systems is more dependent on the immediate needs of the operator.

3.1.6 Environmental Monitoring Group

Environmental Counting is supported in Nuclear Chemistry as an ongoing program. The scientific group which supports program requirements maintains a number of alpha and gamma spectroscopy systems in the basement of Building 151. None of these systems are used for Test Program diagnostics. Typically environmental samples with very low level radiation are counted for one or more days at a time.

3.1.6.1 Germanium (Lithium) Detector System, 2S (Room B136)

3.1.6.1.1 Operating Characteristics. Six characteristics are typical of the 2S Ge(Li) detector system.

- 15% Ge(Li) detector (On last legs) used to acquire gamma spectra
- Two ND160 MCAs support Compton Suppression System--one ND GEN II ADC
- Datamec tape output
- Typical throughput is 1.5 samples per day (0.5-1 day per sample)
- GAMANAL data reduction on 7600s
- 100% utilization

3.1.6.2 Germanium (Lithium) Detector System, 3L (Room B136)

3.1.6.2.1 Operating Characteristics. Six characteristics are typical of the 3L Ge(Li) detector system.

- 20% Ge(Li) detector to acquire gamma spectra
- LSI-11 microcomputer system support (includes Dual floppy disk drive, Line printer, Houston Omnigraph, ADM3 CRT terminal, and Datamec tape drive).
- Canberra 80 MCA (newly acquired)
- Very-low-level radiation
- Average volume of one sample per day
- GAMANAL data reduction on 7600s

3.1.6.3 Germanium Well Detector System (Room B136)

3.1.6.3.1 Operating Characteristics. The characteristics of a Canberra 80 MCA (newly acquired) will apply.

3.1.6.4 Alpha System (Room B124)

3.1.6.4.1 Operating Characteristics. Six characteristics are typical of the Alpha system in Room B124.

- Twelve surface-barrier detectors
- Three ND130 multichannel analyzers
- Typewriter and tape punch output
- Typically one week per sample
- Average volume greater than 500 per year
- 128 channel spectral data

3.1.6.5 Alpha System (Room B130)

3.1.6.5.1 Operating Characteristics. Five characteristics are typical of the Alpha system in Room B130.

- Eight surface-barrier detectors
- ND600 multichannel analyzer
- Silent 700 terminal
- Typical count duration--week(s)
- 512 channel alpha spectra

3.1.6.6 Data. Alpha data is now being reduced by hand from the typed page output of the Nuclear Data analyzers used. These peak integration calculations are simple but tedious and prone to human errors. Raw gamma spectra are processed from magnetic tapes hand-carried to Computations center using the code GAMANAL. The code yields both reduction of the raw spectral data and isotopic analysis of reduced data.

3.1.7 Tritium Counting

The tritium counting done in the basement of Building 151 is in support of Hazards Control but is not an extensive program. Measurements are made for the environmental monitoring program and include the determination of tritium in hydrogen, methane, water, milk, wine, water vapor in air, vegetable and animal tissue. The equipment comprises:

3.1.7.1 Detector Systems

- Tri-Carb Liquid Scintillation System
- Two Gas Proportional Counters

3.1.7.1.1 Operating Characteristics. There are no specific characteristics, but typically many gross counts are taken of a sample.

3.1.7.2 Data. Data is reduced on the 7600 computers and stored on photostore. A hard copy is filed. Data transfer to the customers is through photostore and occasionally by hardcopy.

3.1.7.3 Data. Three programs are used for calculating tritium content in samples. SCNTCT does the calculation for samples counted on the liquid scintillation counter and produces a plot of standard curves, the final results and a summary of data. ROOMAIR is used for screening and air-water checks and produces only a TTY hardcopy output. GASCT calculates for gas-counted samples.

3.2 Problem Statement

In the assessment of the present system it is necessary to point out that operations, as they are carried out now, are usable and robust. Data may usually be reproduced or massaged to be made usable. The present system is, for the most part, maintainable. User groups are responsible for maintaining their own redundant copies of codes such as GAMANAL and BRUNHILDE. These codes are run on the 7600 computers at the Computation Center. The electronics are also maintainable, at present, though there is considerable doubt about future maintainability. The objections (problems) with the operation of the current system may be categorized into 1) hardware and equipment related, 2) procedure related and 3) data management related.

3.2.1 Hardware and Equipment Related Problems

As technology and user needs have evolved so too have the present counting facilities. At present there is a mix of technologies represented by assorted in-house and vendor-supplied instruments to carry out the needs of counting groups. There are some instruments of recent vintage but many, if not most, are antiquated and past their expected life-time.

Questions of reliability and maintainability are of importance in the operation of these facilities. The reliability of older instrumentation is known by operations and maintenance people. Instruments may be recalibrated more frequently than ordinarily would be necessary, or even rebuilt, when required. Future maintainability is seriously doubted for some instruments no longer supported by vendors and for which there is no "off the shelf" replacement.

Equipment usability is a concern with the present facilities. The users too often find the capabilities of the present instrumentation restrictive and difficult to use. The following are examples of hardware related problems typical of the present facilities:

3.2.1.1 Front-end pulse electronics have become maintenance problems and require frequent calibration to correct for long term drift. The stand-alone-systems, environmental systems and some automated systems are particularly sensitive to this type of problem.

3.2.1.2 Systems that count for long periods of time on a single sample, such as the stand-alone-systems and environmental systems, are subject to loss of data with power outages. These systems lack nonvolatile memories and no-break power.

3.2.1.3 The DATAMEC magnetic tape drives on some environmental systems are unreliable and future maintainability is questionable.

3.2.1.4 The PDP-8/i which handles the real-time control and data assimilation, for many systems in the basement, lacks the interrupt capability necessary to make it flexible. Systems supported by this minicomputer are restricted by its architecture and capabilities.

3.2.1.5 The ND2200 multichannel analyzers supported by the NSS2 PDP-8/e based system are expected to be difficult to maintain in the future.

3.2.1.6 The NSS2 PDP-8/e based system is fully-loaded, capacity-wise, and can not support expansion of its real-time capabilities.

3.2.1.7 The present systems lack the sophistication to do automated calibration and real-time background collection and subtraction.

3.2.1.8 Some of the automated counting systems suffer from real-time clocks with poor resolution.

3.2.1.9 The sample changers on most of the beta wheels lack any position feedback mechanism. They often skip out of synchronization during operation, losing valuable data and confidence in data.

3.2.2 Procedure Related Problems

3.2.2.1 Present System. With the present system the user-scientist finds it difficult to configure special or unique schedules or criteria for counting sample . The non-forgiving, "hard wired" philosophy of the present facilities suffices in the day-to-day changes static production environment. This type of facility does not adapt to day-to-day changes, but requires designer intervention to reconfigure for a permanent change.

3.2.2.2 Data Collection. Questions of equipment and data reliability impact on data collection procedures. To ensure proper operation of equipment and quality of data, it is necessary to diligently oversee each step of the data collection and data flow operations. This type of tight control, however, leads to redundant, non-productive steps in operating procedures.

3.2.2.3 Managing this rather complicated, rigid set of procedures and syntax is difficult. Currently, Nuclear Chemistry relies on a very few expert user scientists who keep the operating mechanisms tuned and well-lubricated. These key personnel provide the critical path in the data flow, but there is no "off the shelf" replacement for their skills and experience.

3.2.3 Data Management Related Problems

3.2.3.1 Distributed. I have tried to describe here a hand carried, very distributed data-base management system. Indeed, a system does exist for the flow of correlated and uncoupled information to the PROPHET DECK used in making decisions and generating reports based on these data.

3.2.3.2 Unsophisticated. The management of data is carried out by hand-to-hand transfer of information on card decks and word of mouth communications. This management is unsophisticated, but it survives because of the "a priori" knowledge and the interpretive and massaging capabilities at each node of the process--each user.

3.2.3.3 Manpower Efforts. This informal system is susceptible to miscommunications and misinterpretations. In the past, maintaining and using this data flow system has led to problems and the need for a large ongoing manpower effort to meet these problems.

3.3 Sensitivity Factors

3.3.1 Economics

An economic assessment, within the context of the present system, brings to light some sensitive points. Risks, inefficiencies and inflexibilities of the present facility must be considered just as the cost of upgrading the facilities.

3.3.2 Risks

Nuclear Chemistry runs the risk of unrecoverable equipment failures and loss of support for antiquated vendor-supplied instrumentation, with the continued long term use of the facilities as they are now. Unreliable instrumentation is becoming a source of compromised data and a problem that generates lack of confidence in data. Another real risk is the loss of key personnel upon whom the operation of the system relies. In addition, there is always the ongoing risk of losing data due to ineffective data flow management.

3.3.3 Personnel Use Inefficiencies

Current operations make inefficient use of highly-skilled scientific personnel. It should not be necessary for talented people to constantly oversee system operations and data flow. Tedious functions with rigid, unforgiving syntax are accomplished better and cheaper with automation. The cost of requiring knowledgeable people to implement scheduling and data handling tasks could and should be avoided.

3.3.4 Maintenance Level

A sore point with the current facilities is the constant high level of maintenance necessary to keep instrumentation, controls, electro-mechanical card punches and paper tape reader/punches operational. With increasing age, the level of maintenance is bound to increase, despite the fact of diminishing allocations for maintenance personnel. Simply replacing older problematic instrumentation and electro-mechanical production of card and paper-tape media with electronic point-to-point communication and magnetic media will reduce the maintenance work load.

3.3.5 Primary Mission

The primary mission of the Nuclear Chemistry counting facilities is the support of Test Program. The facilities are not adaptable to radical changes in its requirements and may not be able to accommodate future, as yet unforseen, needs. A Comprehensive Test Ban Treaty may have a devastating effect on facilities requirements, and Nuclear Chemistry may not be able to respond to newly defined duties with the present system.

3.3.6 Overall Requirements

Another question to be addressed is exactly what does the user desire from the facilities system. The user community is accustomed to the present system, its capabilities and limitations. They are the architects of the current facilities and tend to resist change and loss of control. But the users also see inefficiencies and difficulties with their present operations. They are, hesitantly, urging that a concise system plan be implemented. Even the most pessimistic scientist-user is anxious to be rid of punched cards and paper tape.

4.0 <u>FUNCTIONAL SPECIFICATION</u>

We wish to enumerate the functions which are to be required of a system, the performance needs and the expected impact of fulfilling those needs. However, this specification cannot be "cast in concrete". The functional description presented here is intended to fulfill the requirements as they are seen for today and the immediate future. We cannot afford to overlook the possibility that either the mission of the facilities will be changed or that scientific methods will progress in a way which will make this functional specification obsolete. In either case, a well thought out functional design and system implementation should be capable of absorbing the shock of modified specifications and accommodate new functions within reasonable bounds.

4.1 Proposed Functions

The functions required of these facilities may be categorized into three groups: A) host function - the intended uses of acquired data leading to results; B) data - source and acquisition functions; and C) Communications network and data handling functions used in bringing necessary data from source to end use. The capabilities of the Nuclear Chemistry counting facilities depends on its effectiveness in all three of these areas.

4.1.1 Host Functions

4.1.1.1 Data Environment. Host functions refers to those activities necessary in drawing results from analyzed data and reporting results and interpretations. The data environment in support of these functions involves data structures, data management, data reliability, usability and security. Data storage and archival storage are of primary consideration. An analytical and interpretive environment is necessary to derive meaning from acquired raw data. A machine or systems environment is also necessary in support of human interaction with these functions.

4.1.1.2 Computation Center. Presently the host functions are being supported at the Livermore Computation Center with 7600 computers. The data environment at the Computation Center is reliable and secure. However, a robust data base management system is needed to make the system truly usable by the general-user population. The number crunching capabilities of the Computation Center are excellent with its powerful 7600 computers and comprehensive libraries. There is a problem here also, in that the 7600 computers are being phased-out and replaced with CRAY-1 computers. This change may have the resulting effect of making applications codes and libraries, which have been optimized for the 7600s, unusable. The OCTOPUS environment does not provide real-time support to the general-user population. This fact, however, has not been a deterring factor in the way Nuclear Chemistry has processed data in the past.

4.1.1.3 Local Control Preferred. It is proposed that most of the host functions now carried out at the Computation Center be moved to a locally controlled and operated, top-of-the-line minicomputer system. This minicomputer system will be required to have data base management support, systems software support and hardware support to accommodate candidate application codes such as GAMANAL and BRUNHILDE.

4.1.1.4 Data Management Requirements. The in-house host processor must provide a usable and robust data environment capable of adapting to the changing needs of the user community. Data structures must be usable and non-restrictive. A sophisticated data base management system is required to manage both raw data and reduced data in a manner controllable by the systems manager and accessible by all legal users. The data environment must provide for a maximum security level of SRD. The environment must also effectively limit access to data on an authorization and a "need to know" basis. Archival storage of both raw data and reduced data is essential, whether accomplished locally or at the Computation Center. The in-house system must provide the capability of running large interactive and batch application algorithms on a production basis. The number-crunching capabilities of this machine must be sufficient to provide turn-around time compatible with the OCTOPUS system with no degradation in quality or reliability. Library support sufficient to generate and run the application codes is also necessary.

4.1.1.5 Systems Environment. The systems environment offered by the in-house computer system must provide for batch, time-sharing, and real-time processes. A sufficient variety and amount of peripheral support is required to permit users to access data readily. This includes supporting those data storage media which are "defacto standards" at LLL. Interactive and batch graphics support is also necessary to accommodate user needs.

4.1.2 Proposed Data Acquisition Functions

4.1.2.1 Heavy Elements Group

The following are functions required to support facilities instrumentation used by the Heavy Elements Group in Room B130, Building 151:

- A ratio of four detectors per alpha pulse height analyzer should be maintained to ensure adequate resource reliability and availability.

- A 512 channel analyzer, at 20 bits per channel, is sufficient for heavy element alpha work.
- Support is necessary to acquire and process perhaps five alpha spectra per day, at a maximum count rate of 10,000 events per minute.
- Raw data should be capable of being sent from the data base back to the analyzer for inspection and processing.
- Analyzers and counters are required to be supported by local intelligent workstations capable of doing automated background collection and stripping of spectral data from the analyzers.
- Magnetic storage (about 200,000 bytes of low performance disk capacity) and hardcopy is required at the local workstation.
- Plotting capability is required, whether at the workstation or at the host processor.
- Sample changers on the beta detectors must be controlled by, and provide feed-back to, the local workstation.
- The local workstation must be able to interrogate alpha analyzers and terminate a count on user-specified criteria.
- Beta counters/scalers must be capable of being preset, controlled and read by the local workstation.

4.1.2.2 Mass Spectroscopy Group

4.1.2.2.1 MS-V, MS-VII and MS-XL. The mass spectrometers MS-V, MS-VII and MS-XL will continue to be used the way they have been in the determination of isotopic ratios for U, Pu, Np, Pa, and Li. Local data reduction will still be required but with updated, more compatible hardware than the PDP-8s now in use. The following are some functions which must be carried out in the operation of MS-V, MS-VII, and MS-XL:

- Electronic control of the magnet current to sweep the ion beam from a vaporized and ionized sample.

- MCA acquisition of spectral data.

- Mass Spec MS-V, MS-II and MS-XL require 1024 data points per measurement at 20 bits per data point. Production support is needed for 10 measurements per sample, two and one-half samples per day average (10 samples per day maximum). Storage capacity is required to handle a data throughput of 10M bytes per day for the three instruments.

- Large screen display of data being acquired.

- Local storage of raw data and reduced data.

- Local reduction of data and analysis.

- Interactive and automated data acquisition and inspection.

- Mass Spec electron multiplier required.

- Data scaling required.

- An interactive CRT terminal required at the instrumentation.

- Alphanumeric hard-copy capability required locally.

4.1.2.2.2 New Instruments. The Mass Spectroscopy Group has recently received two new mass spec instruments and expects to develop a system similar, but not identical to, the older systems. The new instruments, NUCLIDE models 6-60-SGA and 3-60-RMS/HD, will be used in the determination of isotopic ratios for He, Ne, Ar, Kr and Xe. A Texas Instrument programmable calculator was received with the spectrometers and is intended to control the magnetic field and collect raw data. A second intelligent controller is required to provide intelligence and automation as well as off-line local data reduction. The following are functions needed by this spectrocopy system:

- New mass spectrometers supporting gas sampling need 500 data points per element, 5 elements per sample at 2 samples per day. An estimated 75,000 data points/day (150,000 maximum at 20 bits per point) are to be produced.
- Automation of gas heaters and valves for the processing of samples is needed.
- Manual operation of the smaller of the two spectrometers.
- Automated and/or off-line data reduction.
- Local interactive graphics support for statistical interpolation of data.
- Local hard-copy for both graphics and alphanumeric information.
- CRT terminal for local data processing and program development.

4.1.2.3 Gas Sampling Group

The instrumentation in Room B132 used by the Gas Sampling Group will continue to perform the same functions they have in the past. The beta wheels will need to be updated and data collection will have to be more sophisticated than punched cards or paper tape. The following are necessary requirements in supporting gas sampling instrumentation:

- Gas Sampling beta wheels are to process approximately five samples per shot. Some number of replicates are required per sample per species for approximately 40 species. Samples processed on NSS2 Ge(Li) detector systems need 4096 channel resolution at 24 bits per channel. Storage capacity is required to handle a throughput of perhaps 1200 bytes per day.

- Beta wheels will have to be automated to provide local workstation control and position feed-back information.

- The counters on the beta detectors must be upgraded to be controlled by and feed data to the local workstation.

- The counters on the eight position Lobacas system must be upgraded to be controlled by and feed data to the local workstation.

- The liquid scintillation counter requires a data path to the local workstation.

- Preset entry and sample changer scheduling is to be accomplished by the local workstation.

- The local workstation is to have some capacity for magnetic data storage.

- Local alphanumeric hard-copy is required at the workstation.

4.1.2.4 Automated Counting

The detector systems represented under the category automated systems vary in their intent and capabilities. Included are integral beta counters, alpha counters, NaI x-ray or gamma photon spectral acquisition systems and Ge(Li) gamma spectroscopy systems. The following are functions required of those detector systems presently categorized as automated:

- The total storage capacity to support what is now referred to as automated counting must handle a throughput of 1M bytes per day.

- Thumbwheel ID panels are to be replaced with a preferred alternative capable of using eight digit decimal ID numbers.
- Sample changers must be controlled by and feed position information to the local workstation.
- A high resolution real-time clock is required in support of all detector systems.
- A new decade/scaler is required for the single channel systems.
- Single channel analyzers are to log data with ID information, stop time and length of count.
- SCA amplifiers with 3 decade dynamic range are required with 3 decade pulsers for support.
- SCAs require a dead-time gate for automatic dead-time correction logic output to scaler.
- A four decade line-frequency timer is needed with automatic dead-time correction derived from either external or internal signals.
- Environmental alpha systems require 512 channels of resolution.
- Obtain and record absorber information via either "keyed slots" in the sample holder and/or keyboard.
- Both automatic and interactive control and data acquisition is required of all counting systems.
- Local workstation monitoring of detectors is required for background and calibration purposes.
- Large screen, flicker-free display is necessary for spectral data.
- Counter standards information must be maintained for local use and long term historical and maintenance purposes.

- Detector calibration is to be made on the basis of standard counting configuration and sample mounting.

- Detector response is to be empirically determined from measured count rate of sample having a known nuclear disintegration rate for a particular nuclide.

- Dedicated counters are required for radioactive nuclides of particular elements.

- Samples are counted until the statistical relationship (N**1/2)/N less than or equal to 0.005 is satisfied.

- Replicate samples should agree to within 1%.

- System response with time must be checked for reproducibility.

- Samples are to be scheduled with regard to requirements for prompt data reporting.

- Sample count schedules are to consider half-lives to resolve decay curves into various components over long periods of time.

- Samples are to be counted often enough to check for contaminant activities with differing half-lives, another check for chemical purity.

- The sample changers on the NaI systems are to be controlled by, and feed position information back to, a local workstation.

- NaI detector systems N1 and N2 each need 1024 channel resolution at 24 bits per channel. A three-state programmable op-amp is used to drive the photomultiplier. It may be desirable to upgrade this system to make it more flexible.

- PDP-8/e supported Ge(Li) systems will continue to process gamma spectral data and preset information in an automated fashion.

- NSS2 Ge(Li) systems require 4096 channel at 24 bits per channel with overflow logging. Pileup-rejection/live-time correction is a must. Live-time preset of 1-99999 seconds and infinity are required.
- The PDP-8/e requires the support of a 32K memory, both a hard-copy and a CRT terminal, a hard-copy printer, a disk for data and program storage, extended arithmetic element and a decimal day clock.
- NSS2 automated analyzer and sample changer control functions are to be initiated from the PDP-8/e via MCS-8 controllers; all spectral data is to be sent from the analyzers to the PDP-8/e via the MCS-8 controllers.
- The NSS2 multi-channel analyzers should be replaced, when possible, to provide the needed 24 bits per channel and make the systems more maintainable.
- The PDP-8/e is to be replaced with a full implementation of the network work-station when possible; until that time the PDP-8/e will have to emulate adopted standard workstation functions.

4.1.2.5 Stand-Alone Counting

Those systems which are presently referred to as stand-alone counting systems are to be supported and automated just as the other systems. The NaI, Ge(Li) and Si(Li) systems in the basement are expected to tie in with other automated counting systems and also the local workstations. The detectors on the second floor in Building 151 are to be integrated and supported by a local workstation with associated peripherals. These functions are required for the stand-alone counting systems:

- Systems on the second floor require disk support to handle a data throughput of about 10K bytes per day.
- Systems in the basement need a total disk capacity to support a throughput of 2.5K bytes per day.

- All spectroscopy systems require upgrade of front-end pulse electronics. All systems require pileup-rejector/live-time correctors.
- Memory protect and/or no-break power is necessary, particularly for Silicon detectors D and E.
- User/instrument wait time should be minimal when moving data from/to analyzers.
- A local workstation with disk and alphanumeric hard-copy support is required to support second floor systems with automation and programmed intelligence.
- Si(Li) detectors D and E require upgraded ADCs.
- Detector systems D and E require 512 channels each and an upgrading of the 4MHz ADC presently in use.
- Ge(Li) counter 48 and NaI counter 45 share an analyzer which requires 4096 channels of resolution at 24 bits per channel capacity.
- Arnie Delucchi's counter in Room 2308A requires 4096 channels at 24 bits per channel.
- The NaI system in Room 2330A requires 512 channels of resolution.
- The x-ray spectroscopy system in Room 2131A requires 1024 channels at 24 bit capacity per channel.
- Plotting capabilities are required, whether at the host processor or locally.
- Large screen displays are required at all analyzers.
- Only a small amount of man-machine interaction is required. Provision for local setup with a pulser or spectral input is sufficient.

4.1.2.6 Environmental Monitoring Group

Environmental systems established in the basement of Building 151 are to be supported by local workstations. These systems require network and host processor capabilities similar to systems supporting the Test Program. The following are functions necessary to carry out the mission of the Environmental Monitoring Group:

- Upgraded front-end pulse electronics are required.
- The present system with DATAMEC magnetic tape drives must be replaced with support from a local workstation.
- Alphanumeric hard-copy is required for the alpha system in Room B130.
- Plotting capability is required to support the alpha systems.
- The Ge(Li) systems in Room B136 require workstation support with disk storage for both program and data.
- Environmental alpha systems require 512 channels of resolution and disk capacity to support a throughput of 10K bytes per day.

4.1.2.7 Tritium Counting

The liquid scintillation system and gas proportional counters in Room B136A require minimal support from a local workstation. However, it will be necessary to move acquired data to the host processor for data reduction and report generation. The following are necessary functions in supporting Tritium counting:

- A data path is required from the liquid scintillation counter to a local workstation.
- Disk support is necessary temporary data storage to support a throughput of fewer than 5K bytes per day.
- A data path must also be provided for the gas proportional counters to a local workstation.

4.1.3 Proposed Network Functions

Network functions refer to those activities which communicate or move information from/to data sources to/from the host processor. It is necessary to replace hand-to-hand and word of mouth communication with automated intelligent controllers. The proliferation of punched cards and paper tape is difficult to manage and inefficient to use. This media will be replaced with point-to-point electronic communications, in an automated fashion. This media will have sufficient safeguards and redundancy to ensure reliable transmission of data. A loosely-coupled communication environment is required. The environment must facilitate automated processing of data from its source to an appropriate reduction code, with necessary control information, and then to final report generation. This network scheme must not restrict the changing needs of the facilities.

4.1.3.1 Workstations. Local intelligent workstations must be included in a proposed network. The already established PDP-11/34 also must be accommodated. The NSS2 PDP-8/e must also be supported as a workstation emulator until it can be replaced by a standard configuration.

4.2 Performance Parameters

The capabilities of an upgraded data acquisition and analysis production facility should meet or exceed all of the capabilities of the present system. A replacement system must take advantage of newer technologies, wherever possible, to optimize the overall performance of both production and interactive counting. In many cases, resolution or data rate improvements in data acquisition are not required and often undesirable. For these instances, it is appropriate to include capabilities beyond those presently required, leaving the implementation of the added capabilities to the discretion of the scientist-user.

4.2.1 Host Function Performance Parameters

4.2.1.1 Reduction and Throughput. It is difficult to stipulate a performance criteria for the processing of data with currently used applications codes. The run time and CPU time required to reduce data is expected to be longer with the proposed minicomputer system than is possible with the 7600s. However, production throughput should be improved because of a close coupling with the data base, a higher degree of automation and direct control of processes and their priorities. A degradation of analytical integrity is not acceptable. The reduction of raw data must be reliable and repeatable.

4.2.1.2 Coupling. A coupling must be provided also to the OCTOPUS system and the 7600s while they are still available. This may be accomplished through hand-carried OCTOPUS readable magnetic tape, but it is desirable to be hard-wired when OCTOPORT becomes accessible.

4.2.1.3 Timesharing Terminals and Peripherals. The primary operating responsibility of the host processor is the batch processing of production data in an automated fashion. A sufficient number of time-sharing terminals is necessary for program development, data base interrogation and editing, interactive graphics, other interactive processes and systems monitoring and control. Approximately 12 time-share terminals are needed to satisfy projected user demand in a cluster near the host processor and throughout Building 151. Real-time support by the host processor is necessary in support of network communications. However, the host processor should not be directly responsible for instrumentation and control functions. Peripheral support on the host processor is to include seven and nine track tape drives (800 bpi, NRZI encoded); flexible diskette drive capable of reading and writing RT-11 and FILES-11 formats; a card reader with handler capable of reading both industry standard 029 card punch and LLL standard 029 punch; and printer support for graphics and alphanumeric hardcopy.

4.2.1.4 Data Base Management and Archiving. The host processor of the centralized data assimilation and reduction system must provide a sophisticated data base management system. The data environment experienced at Nuclear Chemistry in the past would be impossible to maintain as a simple file management system. A well-thought-out schema is essential to accommodate data structures which must be supported from the present system as well as newer data structures more easily used by the proposed communications network and host processor.

Nuclear Chemistry currently produces about 200M bytes (1.6 billion bits) of raw data a year. An estimated 20M bytes of reduced data and reports must be archived. Assuming a need to access data up to six months old, on a day-to-day basis, approximately 110M bytes of on-line disc storage is required for data alone. Allowing another 200M bytes for on-line support of systems, network and applications program storage and support of perhaps 20 time-sharing users a total disk capacity of 310M bytes is required by the host processor system.

Archival storage is to be provided. By law Nuclear Chemistry is required to retain information and reports sponsored by the Department of Energy and federally funded projects in an approved archival storage facility. The law may be satisfied temporarily by maintaining redundant copies of magnetic tapes at more than one physical location. However, a permanent solution is a dilemma the Nuclear Chemistry Division as well as the Computation Center must address.

4.2.1.5 Data and System Security. A new system must provide for processing and storage of data classified as SRD. Storing even raw data from various sources in one comprehensive data base provides enough correlation to require that security be provided for restricted data. Software safeguards are required to disallow any possibility of a compromise by releasing secure data to an unauthorized node in the network or to an unauthorized individual at an authorized node. The physical layout and wiring of the time-shared host processor must meet DOE 5636 standards for protected wireline systems.

4.2.2 Data Acquisition Performance Parameters

4.2.2.1 Ge(Li) and NaI Detectors. Some hardware performance specifications have become apparent for general classes of instruments. Gamma spectroscopy with Ge(Li) detectors require 4096 channels of resolution with the possibility of using 8192 channels at a later date. A count capacity of 16,777,216 (24 bits) is required for each channel with the capability of logging and recording channel overflow. For the majority of Ge(Li) use pileup-rejection/live-time correction is required supporting 100 MHz ADCs. NaI detector systems, on the other hand, need only 1024 channels of resolution (at 24 bits per channel) and are not apt to require support for very fast ADCs.

4.2.2.2 Alpha Analyzers. Alpha systems are presently using 128 channel analyzers and need to be upgraded to 512 channels. Upgrading is necessary to make use of the greater dynamic range available with modern detectors and recently developed bias amplifiers. Future requirements for some analyzers with 1024 channel resolution may be necessary.

4.2.2.3 Detectors. The requirements of individual detectors will not be specified here. It is not within the scope of this requirements definition to specify new detectors for replacement. Existing devices have been characterized and are adequate for the task. Any new or replacement detectors will be individually specified by the user-scientist.

4.2.2.4 Workstations. Hypothetically, each detector system, or cluster of detector systems, is to be supported by a local intelligent workstation. This configuration is desirable to provide programmable automation of instrumentation and controls, instrumentation calibration history, local data processing and automated network communication. Workstations should provide consistent query and data entry procedures, though each will have unique instrument responsibilities. Each workstation providing man-machine interaction should also require as little expertise as possible in running day-to-day production. Workstations should be capable of being programmed in the higher level languages, FORTRAN for scientific applications and PASCAL for scientific and all engineering tasks.

4.2.2.5 Thumbwheels, Sample Changers, and Beta Wheels. It seems necessary to replace all the thumbwheel ID panels in the basement of Building 151 with a standard reliable product. The sample changers which service integral counters all require a position feedback mechanism to the controller. The scheduling of beta wheels is a common need of the users of the facilities. A common product is appropriate.

4.2.3 Network Performance Parameters

The function of a communications network is reliable, usable movement of information back and forth from data acquisition nodes to the central node, the host processor. A network is required to be hard-wired to provide automated control and data assimilation. Sophisticated lower level and message level protocols must be used with sufficient redundancy to guarantee data integrity. Throughput, as opposed to latency, is to be emphasized because production processing will be batch oriented. To handle extended security, wirelines must be physically secure. Sufficient safeguards must be established to satisfy DOE requirements so that a compromise of data is impossible from an unauthorized node.

4.3 Expected Impacts Of Proposed Functicns

4.3.1 Controlled Efficiency at Reduced Costs

What we hope to gain from a facilities upgrade is a more usable, efficient system; functionally simple to the user; inherently reliable; and one which can be maintained in an expeditious fashion at a reduced cost to the programs. Establishing a local host processor to carry out the assimilation and reduction of data will provide a number of these advantages. Nuclear Chemistry will have intimate control of operations and the administration of off-line data handling and analysis procedures. This local capability will give the division in-house control over growth and technology migration paths. A local host processor should provide greater overall throughput because the architecture and data base are to be optimized to the Nuclear Chemistry production environment. A locally-controlled comprehensive data base management system would make data more accessible, more useful and certainly more easily maintained. Moving a reduction code like GAMANAL to a small machine would open up the door to implement it for many more applications within LLL and throughout the industry where standard algorithms of this caliber are needed.

4.3.2 Increased Data Confidence for Less Work

Upgrading the existing data acquisition systems and automating the control and scheduling of sampled data is attractive in itself. Replacing archaic paper tape producing, hard-wired instrumentation with newer products integrated into a network system will reduce the number of hours a scientist has to contribute in controlling data flow and making decisions based on data. New instruments are inherently more usable and maintainable than those now in use. With better resolution and control of data, sampling and scheduling confidence in data can grow.

4.3.3 Automated Network

Automating the network of communications and control between data acquisition and data usage at the host processor will replace punched cards and paper tape. A scientist will be able to direct that data be arquired to his specifications and submitted to the host processor for reduction and archival storage. He can specify what he wants in a report all at one time, from a workstation local to his instrumentation. An automated network also allows automatic systems monitoring and generation of statistics on instrument calibration and history.

4.3.4 Appropriate Personnel Application and Productivity Increase

A scientist should not have to handle the mundane, manpower intensive steps necessary to communicate and monitor data flow. By automating these functions, while still maintaining local control, the productivity of the facilities will benefit.

5.0 DESIGN CONSTRAINTS

5.1 Resource Specification

The development and implementation of the upgrade project discussed is to be of finite duration. The project must contend with limited and uncertain allocations and funds. The planning, scheduling and administration of the project requires the creation of four positions: a Project Engineer responsible for data acquisition and handling systems, all hardware and hardware related software and the physical plant; a Software Applications Manager responsible for coordinating the scientific staff with the computer resources available and leading teams in writing/rewriting reduction, analysis and reporting codes for the new system; a Systems Manager responsible for the host processors software systems needs; and a Facilities Administrator responsible for operations at the host processor and the administration of the overall facility. It is appropriate for at least three people to handle these job descriptions, the systems manager and administrator may possibly be carried out by one individual.

5.1.1 Personnel

The following allocations will be necessary to implement and carry out the operations of an upgraded facilities during the course of the project:

- Four allocations for Engineering Development

- Two allocations for Applications Staff
- Four allocations for Operations Staff
- Four allocations for Maintenance (N.C. and E.E.)

This does not represent an increase in the overall allocations for Nuclear Chemistry. Most of the people required for the project already exist in support of the current facilities. Allocations should come from jobs which are to be replaced by the new facilities and other projects with decreased manpower needs. Project manpower should be scheduled to come on-line/off-line as the need requires.

5.1.2 New Hardware

Hardware components and hardware/software systems will have to be acquired. Much of the front-end pulse electronics and analyzers in the basement of Building 151 will have to be replaced during the course of the project. Approximately 60 detectors will need integral counters and scalers/timers. There are about 27 gamma spectroscopy systems which require new instrumentation and multi-channel analyzers. There are over 40 alpha detectors which must be supported by new MCAs. Approximately 20 multi-channel pulse height analyzers will have to be purchased to upgrade the facilities (typically one analyzer will service four detector systems). Resources will also be needed to replace the existing thumbwheel ID panels and upgrade sample changers. And an estimated 10 programmable workstations are required to provide local control and instrumentation automation as well as provide for some local data reduction. Workstations will need peripheral support including a disk, CRT terminal and printer.

5.1.3 Host Processor

A minicomputer is required to serve as the host processor of this centralized data base/data processing system. The minicomputer includes full peripheral support as specified in the functional specification and systems software support. The computer should include a multi-tasking time-share and event-interrupt driven operating system capable of meeting the functional and performance specifications mentioned. Multiple language compilers including FORTRAN and PASCAL are acquired. A well-supported data base management system will have to be acquired. Systems software will have to be written and/or purchased to support graphics and other utility features of the system.

5.1.4 Transition Period

Time is going to be required to phase the old system to an upgraded condition. With adequate resources it is estimated this project will go to completion in four to five years. The major engineering effort should be finished in approximately three years.

5.1.5 Facilities

Space will be needed to accommodate the host processor system and operations, as well as the workstations local to the instrumentation. The host processor system will require approximately one-half of a room in the basement of Building 151. The processor is expected to require even more space as operations become active. Sufficient airconditioning and power distribution is required to accommodate the host processor in the near term and for future growth.

5.2 Facilities Usage Conditions

The requirements definition for the Nuclear Chemistry counting facilities was stipulated by the scientific community whose responsibility it is to specify functions and performance of the facilities. The implementers, engineers and programmers, have the responsibility and authority to design and develop the facilities to meet specifications. It may be difficult or prohibitive to implement a change, once a specification has been adopted. The scientific community can not be given "carte blanche" in changing specifications or purchasing instrumentation without clearing proposed changes through appropriate engineering and programming support and consulting with the project management. One drawback of a unified counting facility is that there is a coupling, one instrument to another and one instrument to the system host, that must be considered whenever a change takes place in the facilities. By the same token engineers and programmers are not granted the right to specify scientific criteria or supercede a scientific specification during implementation or operation.

One task the Facilities Administrator will have to set up is a clearing house for scientists and engineers requests. The Facilities Administrator is to be the authorized decision-making responsibility in setting priorities and scheduling work to be accomplished by the facilities. He is to have sole responsibility for system usage, accounting and security access.

5.3 Expected Costs

The estimated gross development cost of the upgrade project is $2,370,000. This includes $106,000 prepaid and allocated capital equipment money and approximately $206,000 prepaid expense money (dominated by the purchase of a PDP-11/70 minicomputer system). Capital equipment costs scheduled over the three year engineering effort will probably approach $690,000 taking into account a 7-1/2% inflation rate per annum. This represents about $602,000 at today's prices.

Expense money will face the same inflation phenomenon and will rise to an extimated $230,000 (representing $207,000 at 1979 prices). The authors manpower cost approximation, for system development only, comes to $617,000 for engineering and $520,000 for scientific personnel on a 17-1/2 man-year effort. This approximation takes into account an estimate of the cost of diverting scientific talent from research and programmatic duties to the nonproductive rewriting of reduction codes for the proposed upgraded system.

6.0 CONTINGENCY STATEMENT

The requirements definition for an upgrade of the Nuclear Chemistry counting facilities has been established for all known and projected specifications. These requirements may become invalid by events such as a Comprehensive Test Ban, a slow down of the Test Program or a scientific or technological advancement. Either a change in mission or a change in the scope of operations may drastically alter the needs of the Nuclear Chemistry Division and its counting facilities.

Should the direction of activity change, the upgraded system specified by this requirements definition should accommodate most of the change. Instrumentation and host processes are to be loosely coupled through a general purpose communication network and data base. Either or both the host functions or the data acquisition functions may change and still be adapted by the system.

A slow down of present programs will affect the performance parameters required of the facilities, but not the functions. These specifications can be modified without drastically affecting the system design and implementation. The resultant system will then have the capacity for easy growth, when required.

Creating an environment of scarce resources is difficult for project development, but some compromises are possible to function and performance specifications. It is possible to compromise on the performance and peripheral support of the host processor and some workstations. It is unrealistic to compromise a comprehensive data base system or to "make do" with antiquated instrumentation which does not lend itself to system integration. A slow down of the upgrade schedule may be sufficient to complete the project on a tight budget. There is also a difficulty with attempting to accomplish this project with insufficient allocations for necessary personnel. A sufficient number and variety of engineers, technicians and scientific programmers is needed to carry out this project regardless of its scope.

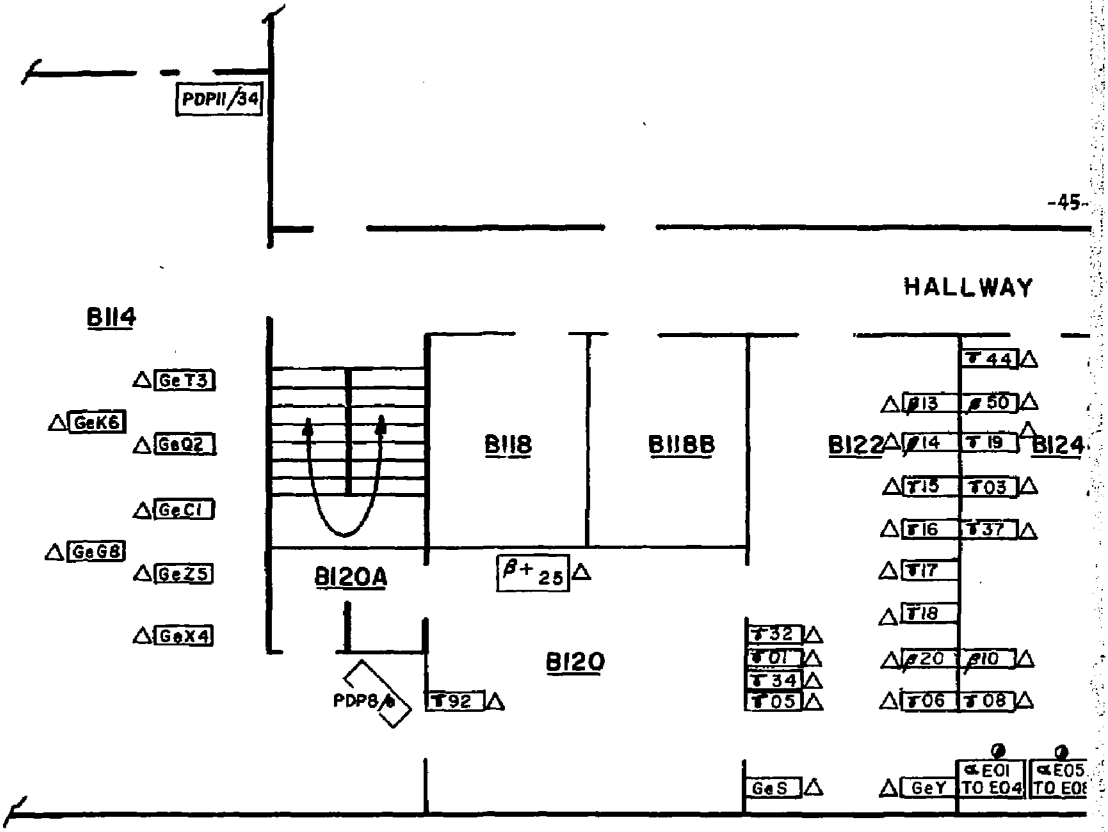
Cost projections discussed in this report are based on the requirements as they are currently viewed and reflect a need for a bulge in the capital equipment budget during the first and second year of the project. It is expected that approximately 7-1/2% increase in capital equipment cost will be incurred per annum over the course of the project to cover moderate inflation. Should the mission of the facilities change during the course of the project or should the inflation rate exceed the current level, the cost estimates for the facilities upgrade could vary by as much as 20%. If a slow down occurs in the programs supported by the facilities a cost savings of perhaps 10% could be realized at a considerable compromise in system performance but maintaining the required functionality.

7.0 CONCLUSION

This report documents the requirements definition of the Nuclear Chemistry counting facilities, as specified by the scientific user community, and also adheres to the authors' view of good engineering and management practices. The requirements of the division can be met with reasonable allocation of funds and expertise. This project can be accomplished using known technologies and techniques applied in a conservative fashion. There is no function or performance criteria which can not be accommodated with minimum development of special or unique hardware.

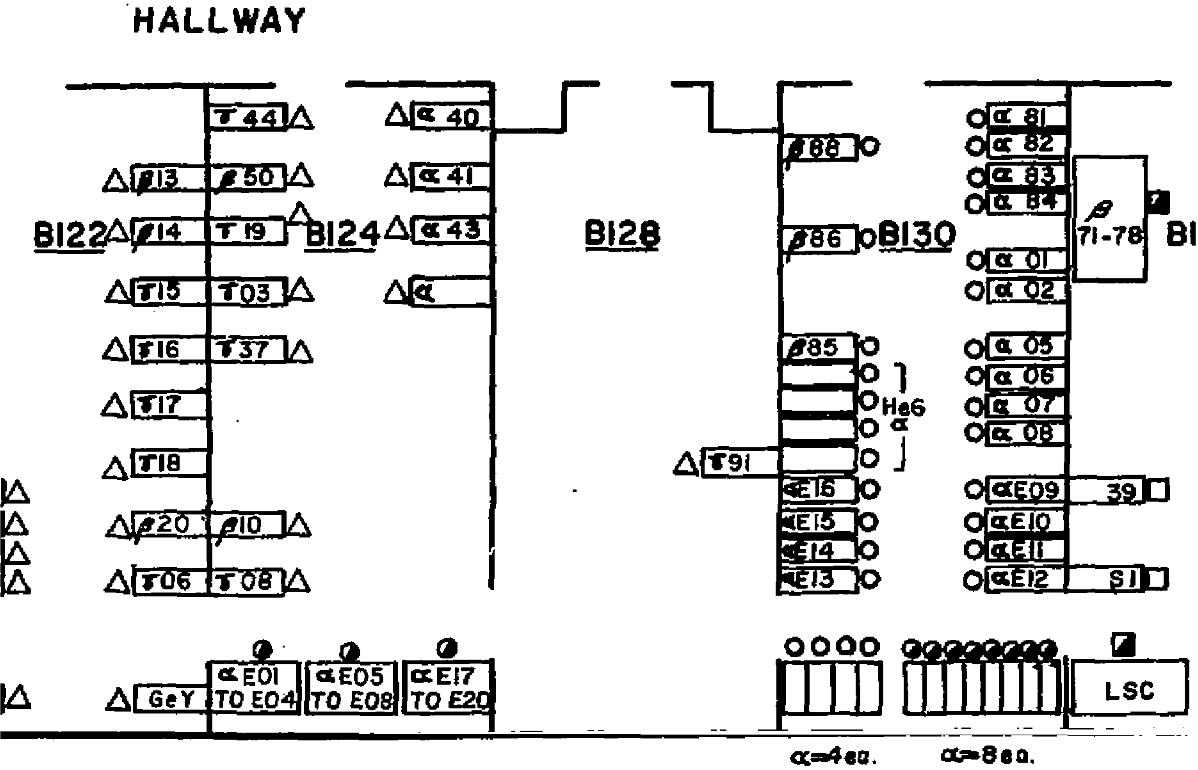
The authors express the opinion that this project is needed. It can be accomplished in a reasonable time-frame and will greatly benefit the Nuclear Chemistry Division and Lawrence Livermore Laboratory.

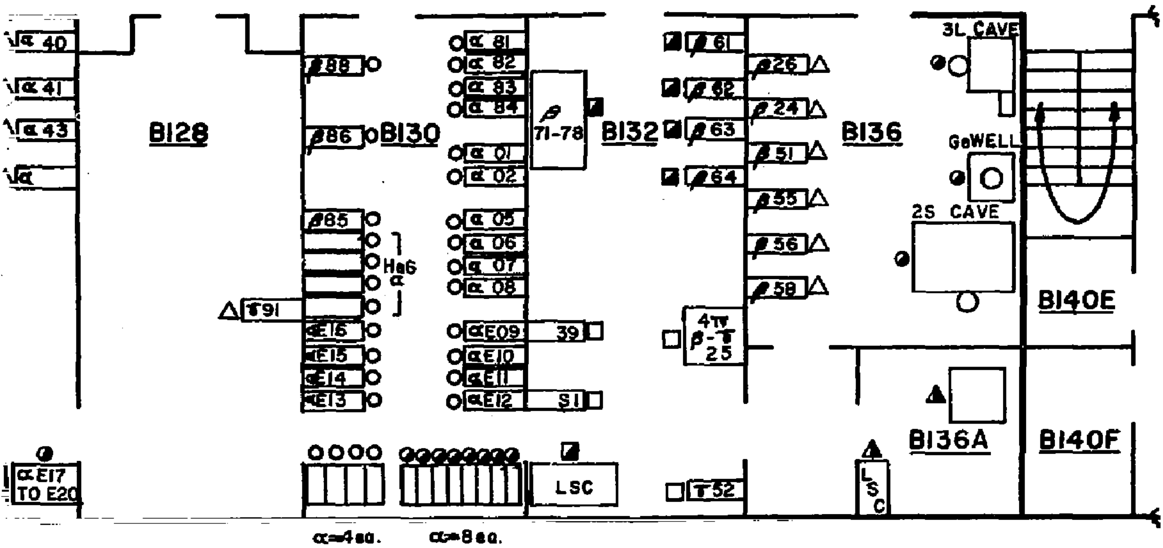
APPENDIX



○ = HEAVY ELEMENTS
△ = AUTOMATED COUNTING
□ = STAND ALONE
◐ = ENVIRONMENTAL
▲ = TRITIUM / ENVIRONMENTAL
◪ = GAS SAMPLING

A-1
NUCLEAR CHEMISTRY BASEMENT


HALLWAY
B122
B124
B128
B130
BI
γ 44
β13
β50
α 40
α 41
β14
γ 19
α 43
γ15
γ03
α
γ16
γ37
γ17
γ18
β20
β10
γ06
γ08
β88
β86
β85
He6
α
γ91
αE16
αE15
αE14
αE13
α 81
α 82
α 83
α 84
β
71-78
α 01
α 02
α 05
α 06
α 07
α 08
αE09
39
αE10
αE11
αE12
S1
GeY
αE01
TO E04
αE05
TO E08
αE17
TO E20
LSC
α=4ea.
α=8ea.



COUNTING FACILITIES LAYOUT

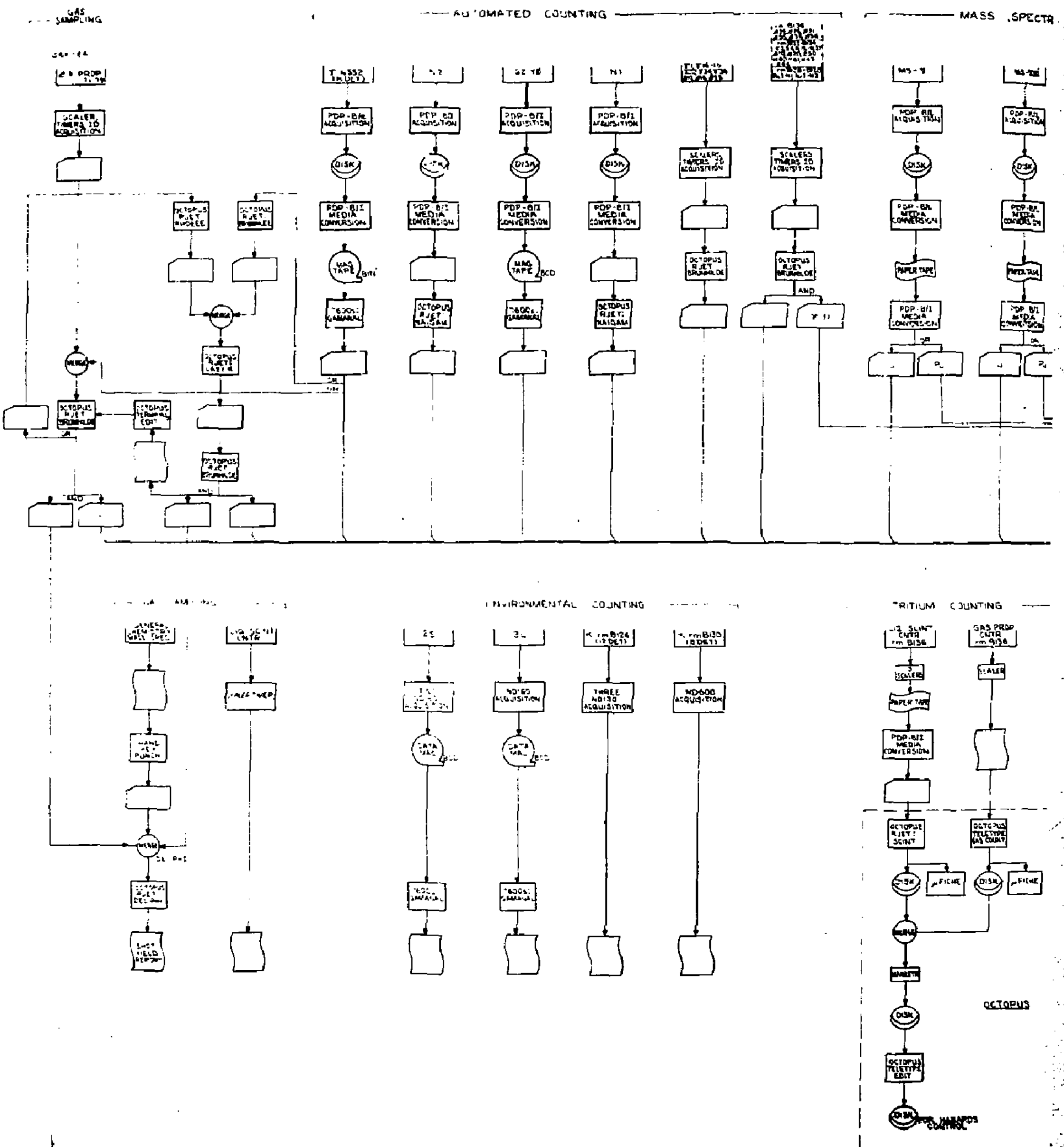
3

DATA SOURCE \ STATISTICS		THROUGHPUT: SPECTRA OR SAMPLES/DAY	THROUGHPUT: SPECTRA OR SAMPLES/SHOT OR EXPERIMENT	THROUGHPUT: SPECTRA OR SAMPLES/YEAR		DATA: RESOLUTION (Nº OF CHANNELS)	DATA: BYTES/DAY	DATA: BYTES/SHOT OR EXPERIMENT	DATA: CARDS/DAY	DATA: CARDS/SHOT OR EXPERIMENT	
GAS SAMPLING	β 60-64 & PROP 71-79	0-400	20X20	2400		1	1000	16000	100	500	30
	LIQ SCINT COUNTER	LOW	N.A.	LOW		3	LOW	LOW	LOW	LOW	LC
TRITIUM COUNTING	LIQ SCINT COUNTER	6	N.A.	1200		8	———	N.A.	40	N.A.	20
	GAS PROP COUNTER	1	N.A.	200		10	———	N.A.	0	N.A.	0
ENVIRONMENTAL COUNTING	2S Ge	AVE 4/WK	N.A.	200		2 X 4096	6.5K	N.A.	N.A.	N.A.	N.
	3L Ge	PRESENT-UNKNOWN	N.A.	UNKNOWN		4096	UNKNOWN	N.A.	N.A.	N.A.	N.
	α RM. B130	AVE 6/WK	N.A.	200		512	1K	N.A.	N.A.	N.A.	N.
	α RM. B124	AVE 20/WK	N.A.	1000		128	512	N.A.	N.A.	N.A.	N.
AUTOMATED COUNTING	NSS 2	60	60	7000		4096	720K	720K	N.A.	N.A.	N.
	N1 & N2 NaI	1.2	36	432		512	4960	150K	62	1872	22
	G2 Yϕ	2	10	240		4096	24.6K	123K	———	———	
	OTHER: γ 1,16-19,.. β 13,14,25,.. α ...	N.A.	N.A.	N.A.		2	8000	———	200	6K	7[illegible]
MASS SPEC	MS V	10	6	700		1024	1.2×10^6	7.2×10^5	30	30	30
	MS VIII	10	12	700		1024	1.2×10^6	1.4×10^6	6	6	6
	MS XI	6	18	300		1024	7.2×10^5	2.2×10^6	6	18	18
	GAS	2	10	UNKNOWN		2500	20,000	1×10^5	UNKNOWN	UNKNOWN	U
HEAVY ELEMENTS	FISH GRID 5-8, α SOLID STATE	1.2	60	600		128	———	———	———	720	7
STAND ALONE	Ge48, Ge52, NaI45	2	18	250		4096	8.4K	221K	N.A.	N.A.	N
	D & E	2	12	36		2048	0.6K	73.7K	N.A.	N.A.	N.
	$4\pi\beta-\gamma$	2-8	10	40		12	N.A.	N.A.	N.A.	N.A.	N
	NaI (3ea), RMs 2121A, 2330A	N.A.	N.A.	N.A.		N.A.	N.A.	N.A.	N.A.	N.A.	N.

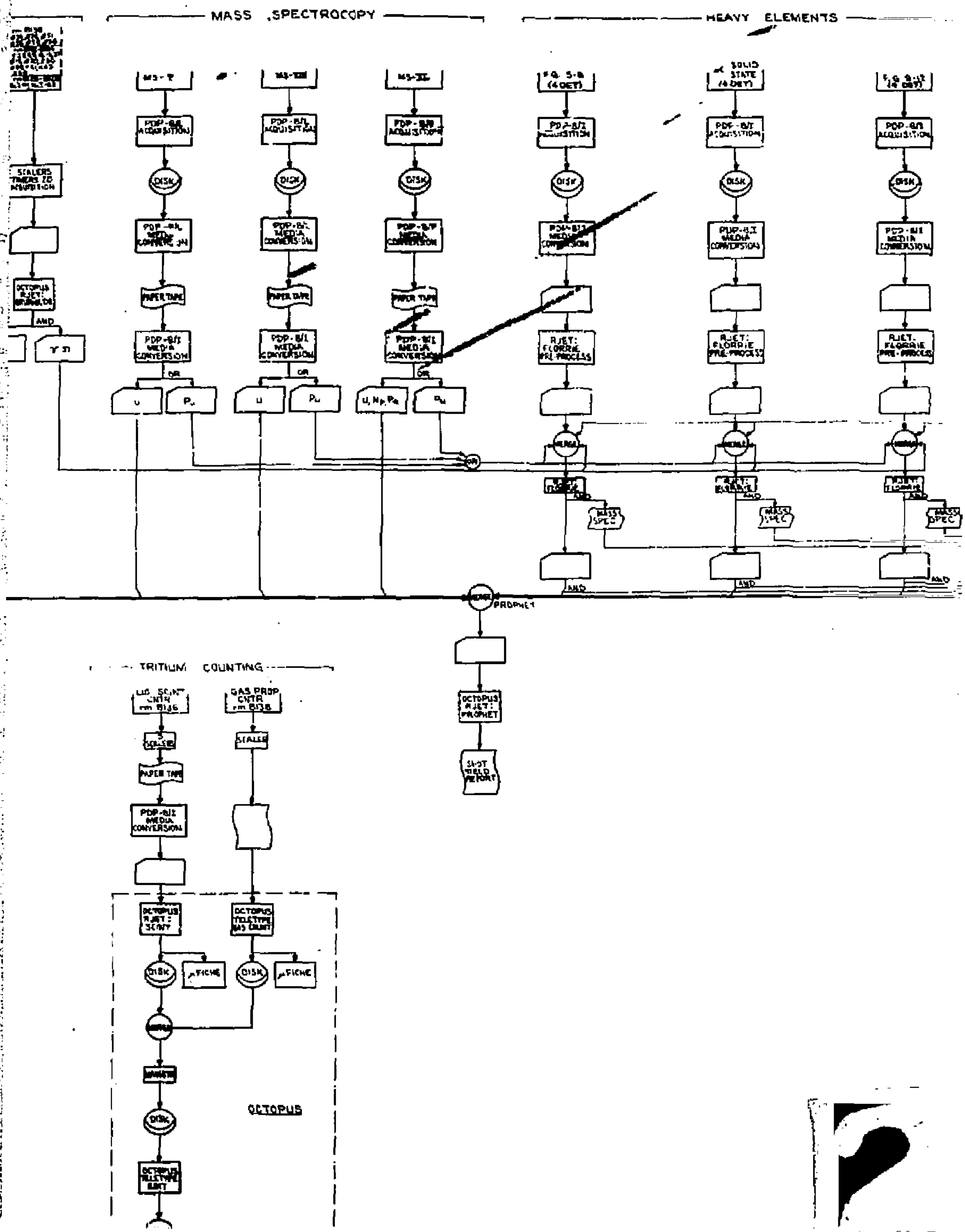
DATA: BYTES/DAY	DATA: BYTES/SHOT OR EXPERIMENT	DATA: CARDS/DAY	DATA: CARDS/SHOT OR EXPERIMENT	DATA: CARDS/YEAR		IS DATA BASE MANAGEMENT REQUIRED	IS ARCHIVAL STORAGE REQUIRED		REDUCTION CODE(S)	REDUCED DATA USED BY "PROPNET"
1000	16000	100	500	3000		YES	YES		(RHOZEE) BRUNHILDE	YES
LOW	LOW	LOW	LOW	LOW		NO	NO		NO	NO
———	N.A.	40	N.A.	2000		YES	YES		SCNTCT	NO
———	N.A.	0	N.A.	0		YES	YES		GASCT	NO
6.5K	N.A.	N.A.	N.A.	N.A.		NO	YES		GAMANAL	NO
UNKNOWN	N.A.	N.A.	N.A.	N.A.		NO	YES		GAMANAL	NO
1K	N.A.	N.A.	N.A.	N.A.		NO	YES		ND600	NO
512	N.A.	N.A.	N.A.	N.A.		NO	YES		NONE	NO
720K	720K	N.A.	N.A.	N.A.		YES	YES		GAMANAL	YES
4980	150K	62	1872	22,464		YES	YES		NAIGAM	YES
24.6K	123K	———	———	———		YES	YES		GAMANAL	YES
8000	———	200	6K	73,280		YES	YES		BRUNHILDE	YES
1.2×10^6	7.2×10^5	30	30	300		NO	YES		N.A.	YES
1.2×10^6	1.4×10^6	6	6	60		NO	YES		N.A.	YES
7.2×10^5	2.2×10^6	6	18	180		NO	YES		N.A.	YES
20,000	1×10^5	UNKNOWN	UNKNOWN	UNKNOWN		NO	YES		N.A.	YES
———	———	———	720	7200		YES	YES		FLORRIE	YES
8.4K	221K	N.A.	N.A.	N.A.		YES	YES		GAMANAL	YES
0.6K	73.7K	N.A.	N.A.	N.A.		YES	YES		XNAL	YES
N.A.	N.A.	N.A.	N.A.	N.A.		YES	YES		FUTURE	NO
N.A.	N.A.	N.A.	N.A.	N.A.		YES	YES		NAIGAM	NO
N.A.	N.A.	N.A.	N.A.	N.A.		NO	NO		GAMANAL	NO

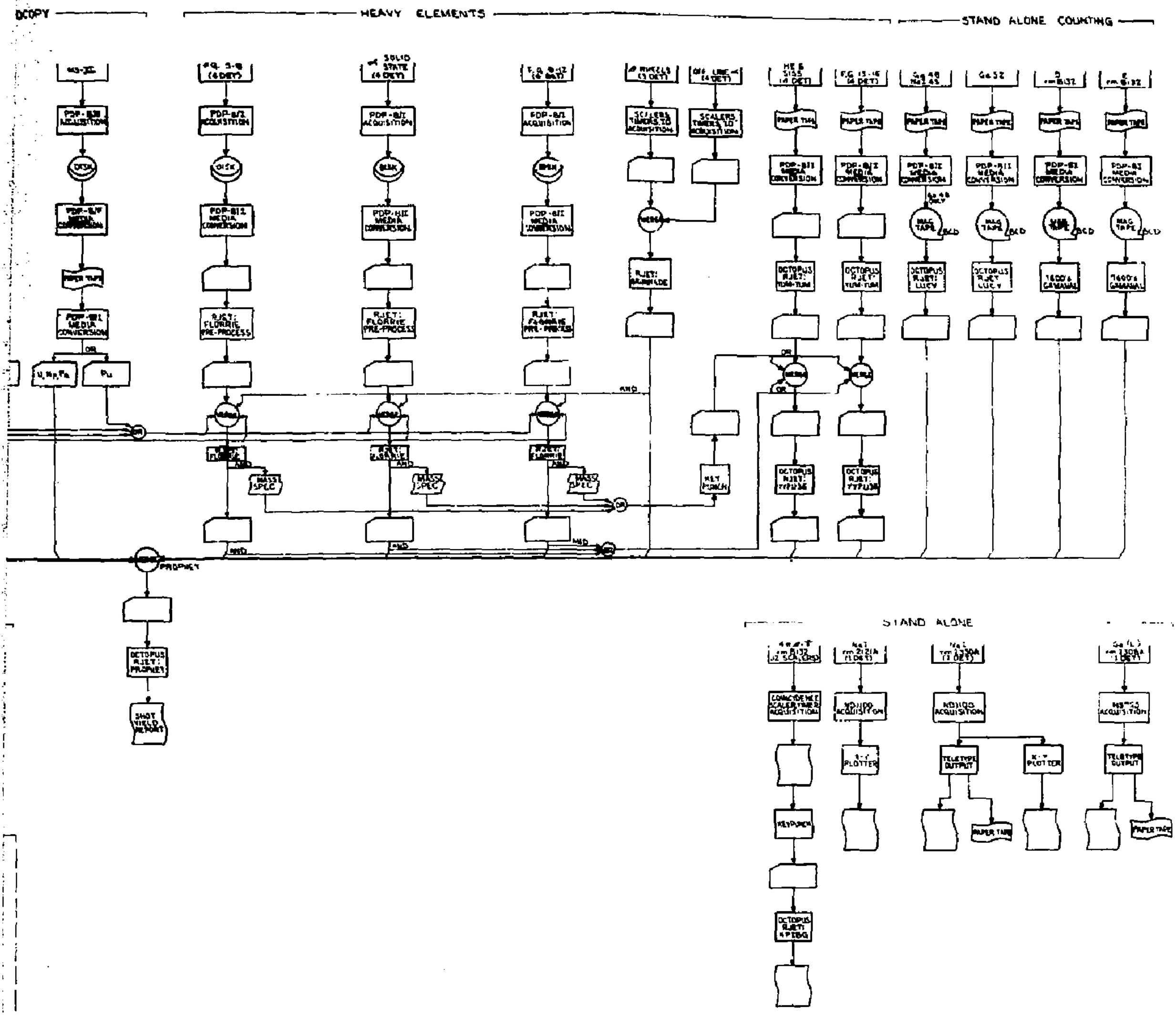
A-2
STATISTICS ON NUCLEAR CHEMISTRY COUNTING SYSTEM

	IS DATA BASE MANAGEMENT REQUIRED	IS ARCHIVAL STORAGE REQUIRED		REDUCTION CODE(S)	REDUCED DATA USED BY "PROPHET"	REDUCED DATA USED BY OTHER CODES	IS DATA PROCESSING AT LOCAL WORK STATION APPROPRIATE		IS LOCAL PERIPHERAL SUPPORT REQUIRED AT LOCAL WORK STATION	IS EXTENSIVE USER INTERACTION NECESSARY AT LOCAL WORK STATION	IS UPGRADE OF SAMPLE CHANGER OR CONTROLS REQUIRED	IS UPGRADE OF PULSE ELECTRONICS OR ANALYZER REQUIRED		HIGHEST NECESSARY SECURITY	
	YES	YES		(RHOZEE) BRUNHILDE	YES	DELPHI LAZYK	YES		NO	NO	NO	NO		PARD	
	NO	NO		NO	NO	NO	NO		NO	YES	NO	NO		PARD	
	YES	YES		SCNTCT	NO	HCSORT	NO		GRAPHICS	NO	NO	NO		NONE	
	YES	YES		GASCT	NO	HCSORT	NO		GRAPHICS	NO	NO	NO		NONE	
	NO	YES		GAMANAL	NO	NO	NO		NONE	YES	YES	NO		NONE	
	NO	YES		GAMANAL	NO	NO	NO		NONE	YES	YES	NO		NONE	
	NO	YES		ND600	NO	NO	YES		SCOPE CAMERA	YES	NO	NO		NONE	
	NO	YES		NONE	NO	NO	YES		NONE	YES	YES	NO		NONE	
	YES	YES		GAMANAL	YES	YES	YES		SPECTRAL DISPLAY	YES	NO	YES		PARD	
	YES	YES		NAIGAM	YES	NO	NO		NO	NO	NO	YES		PARD	
	YES	YES		GAMANAL	YES	NO	YES		SPECTRAL DISPLAY	NO	NO	YES		PARD	
	YES	YES		BRUNHILDE	YES	NO	SOME		PRINTER	NO	YES	YES		PARD	
	NO	YES		N.A.	YES	FLORRIE, DELPHI	YES		NONE	YES	NO	NO		NONE	
	NO	YES		N.A.	YES	FLORRIE, DELPHI	YES		NONE	YES	NO	NO		NONE	
	NO	YES		N.A.	YES	FLORRIE, DELPHI	YES		NONE	YES	NO	NO		NONE	
	NO	YES		N.A.	YES	FLORRIE, DELPHI	YES		GRAPHICS	YES	NO	NO		NONE	
	YES	YES		FLORRIE	YES	NO	YES		NO	YES	NO	YES		PARD	
	YES	YES		GAMANAL	YES	LUCY	YES		DISPLAY PRINTER	YES	N.A.	YES		PARD	
	YES	YES		XNAL	YES	NO	YES		DISPLAY PRINTER	YES	N.A.	YES		PARD	
	YES	YES		FUTURE	NO	NO	YES		DISPLAY PRINTER	YES	N.A.	YES		PARD	
	YES	YES		NAIGAM	NO	NO	NO		DISPLAY PRINTER	YES	N.A.	MCA YES		PARD	
												MCA			



DATA FLOW DIAGRAM OF NUCLE


MASS SPECTROCOPY
HEAVY ELEMENTS
PDP-8/I ACQUISITION
DISK
PDP-8/I MEDIA CONVERSION
PAPER TAPE
OR
U
Pu
U, Np, Pu
RJET: FLORRIE PRE-PROCESS
MERGE
AND
MASS SPEC
PROPHET
OCTOPUS RJET: PROPHET
SHOT YIELD REPORT
TRITIUM COUNTING
LIQ SCINT CNTR rm B136
GAS PROP CNTR rm B136
SCALER
PDP-8/I MEDIA CONVERSION
OCTOPUS RJET: SCINT
OCTOPUS TELETYPE GAS COUNT
μFICHE
OCTOPUS



A-3

.R CHEMISTRY SUPPORT OF TEST PROGRAM