REVIEW OF ELCAP DATA COLLECTION PROCESS

Report for ELCAP Staff

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1. Executive Summary

The ELCAP system has successfully progressed from development to its current operational stage. Now effort is being directed at minimizing operational costs, while continuing to provide effective data acquisition and analysis.

The data acquisition process is basically one of capturing field measurements and transferring them to the analysis system. As such, a variety of components contribute to the overall process. The data acquisition process consists of four parts: the field signal, data logging in the field, data collection, and data validation. Figure 1 conceptualizes the major components of the ELCAP data acquisition process, and identifies the functions of the HP data collection system as the focus of this report.

Costs directly associated with HP system operation are on the order of $144,000 per year. Over $100,000 of this total is due to the current 1.1 FTE required for operator staff time. These costs can be reduced by upgrading certain capabilities of the current data collection system. With an investment in software development and selected equipment, operator staff time can be reduced well below 0.50 FTE.

This review was initiated in order to define the best upgrade path for the current system. Three options were evaluated: 1) HP upgrade, 2) IBM/AT upgrade, and 3) a microVAX upgrade. For the HP option, enhancement of existing software on the current system was investigated. For the IBM/AT option, adaption of the existing PCDAS system as a replacement for the HP system was considered. The microVAX option examined the replacement of the HP system with development of equivalent capability directly on an ELCAP microVAX.

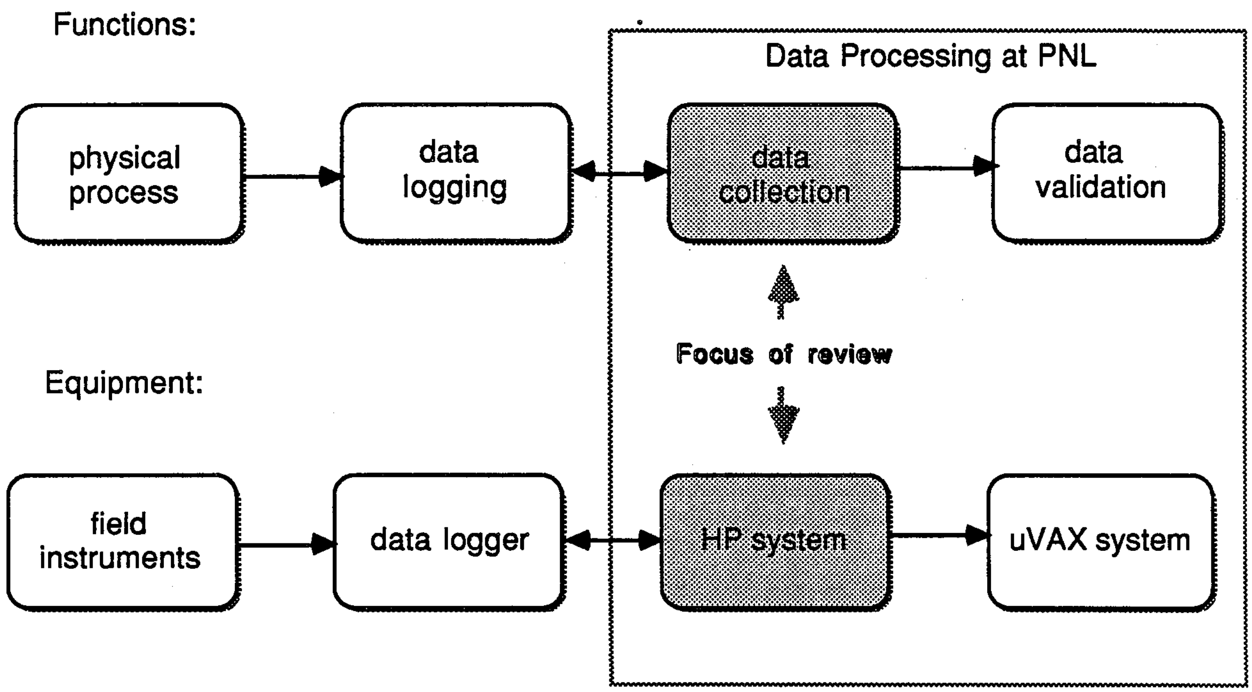
The IBM/AT upgrade option is recommended as the best overall alternative. There are two primary reasons for this recommendation: the direct payback and the indirect benefits. First, the IBM/AT option has the best direct payback, which will be a minimum of $70,000 over two (2) years. Direct payback is the difference between reduced operating costs and the investments needed to achieve those reductions.

The second reason supporting this recommendation, indirect benefits, may be as important as the direct payback. All other PNL metering projects have adopted the IBM-based PCDAS system for data collection. ELCAP can gain from new developments in these projects if ELCAP uses the same technology. Improvements in field support or data processing may be possible at little cost to ELCAP, and both consume substantial resources at present. By embracing IBM-based technology, ELCAP stands the best chance of further increasing savings in system operation. Thus, the IBM upgrade path may make it feasible to extend ELCAP's operating life.

The current HP system has a good design - networked workstations with a large, shared disk. However, IBM systems have developed superior capability for ELCAP-type applications. The IBM/AT system with PCDAS, if implemented, will be similar to the current HP system - only the IBM workstations will be networked directly to the ELCAP microVAX (the HP system is not).

The HP system broke important ground with ELCAP, and from that experience and others, PCDAS arose. Since the early 1980's, IBM/PC hardware and software support has improved dramatically. Indeed, a future growth path for IBMs has already appeared in the PS/2 systems. In terms of system support from both suppliers and PNL, the IBM upgrade path clearly has the advantage.

FIGURE 1. MAJOR COMPONENTS OF ELCAP DATA ACQUISITION PROCESS.



2. Purpose and Scope

The primary purpose of this report is to summarize my review of the ELCAP data acquisition process. The review focuses on the HP data collection system and its interaction with data loggers and the microVAX. The report makes appropriate recommendations for upgrading that system.

The ELCAP Program has progressed to a fully operational stage. Operating costs are significant and must be minimized while maintaining or improving the current high levels of data quality and data capture.

ELCAP staff have identified possible actions for reducing operating costs on the HP system. *The goal of an upgraded system is to be able to acquire data from 200 loggers per day with 0.5 FTE operator time.* Currently, operator time is about 1.1 FTE. The purpose of this review is to identify the best upgrade path. The upgrade path must pay for itself over a projected 2-year period. At least three options were to be investigated: HP system upgrade, IBM/AT upgrade, and microVAX upgrade. Other options could also be recommended as appropriate.

In evaluating the cost-effectiveness of each option, payback estimates were calculated based on *ELCAP operating costs for data collection only.* Costs associated with data validation, management of the data processing system, and field maintenance activities are not specifically evaluated. These activities appear to be effective at present, and improvements in the data collection system should indirectly benefit these other activities. Any estimates in this report attempt to be conservative, by purposefully understating the payback estimates. There is uncertainty associated with any estimate. Areas of major uncertainty are identified in the report.

3. Approach

The first step was to review the existing data acquisition system's documentation and discuss the system with ELCAP staff. ELCAP staff were a primary resource, and they had many good suggestions for system upgrade.

The ELCAP system as a whole is large and complicated. The development of a simplified model for important data acquisition processes was needed to define upgrade requirements. That model is described in the Simplified Model section of this report.

An important part of minimizing costs is knowing what they are. Current costs for system operation are outlined in the section titled Major Costs of Operation. Based on these costs and a review of the data collection system, upgrade needs are identified in a separate section titled Identification of Needs for Potential Upgrade.

Each of the three options for upgrade were evaluated in separate sections. Common points for comparison exist among the three options, but there are significant points which defy easy definition for direct comparison. Significant points are discussed, whether comparable or not.

Finally, conclusions and recommendations were described in the last section of this report. Appendices were included where supporting information is needed.

4. Simplified Model of Data Acquisition Process

This section defines a simplified model for the data acquisition processes. In a sense, the model summarizes my understanding of the current data acquisition process. The simplified model outlines important assumptions about current ELCAP data acquisition, such as current data flow volumes and rates.

Figure 1 illustrates the major components of the data acquisition process. Focus is on the HP system and its interactions with the microVAX and data loggers. The HP system performs ELCAP's data collection functions. The following paragraphs examine three important aspects of the simplified model: 1) data flow paths, 2) data communication rates, and 3) data volumes and flow rates. Calculations are intentionally on the conservative side.

4.1. Data Flow Path

Each of the major components shown in Figure 1 have subcomponents. A good description of data flow subcomponents is given in PNL-6317, entitled **PCDAS Version 2.2, Remote Network Control and Data Acquisition** by M. J. Fishbaugher. Figures 2, 3, and 4 are adapted from Fishbaugher for reference here. The overall system and its subcomponents are expanded somewhat in Figure 2. Figure 3 further expands the description of the data logger or field data acquisition system (FDAS). Figure 4 describes the data collection function in greater detail. Taken together, these three figures should define the current data flow paths involved, up to the microVAX interface. By definition, some final data acquisition tasks are completed on the microVAX, such as data validation and TCB (transposed compressed binary) file preparation.

FIGURE 2. DATA COLLECTION NETWORK (adapted from Fishbaugher)

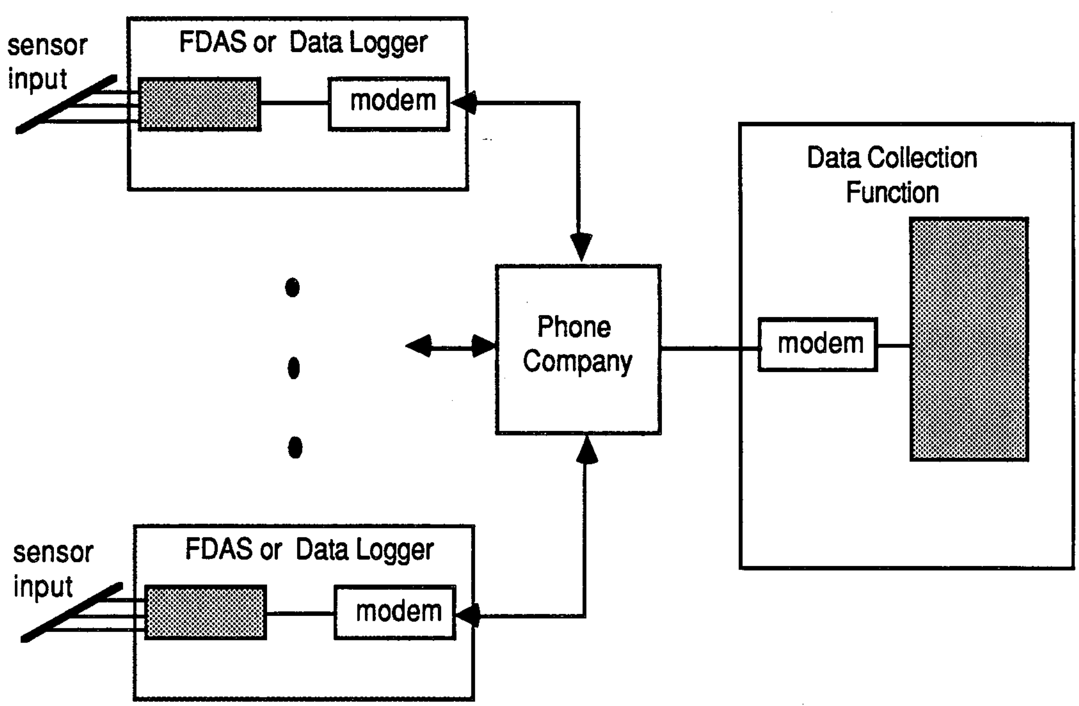


FIGURE 3. DATA LOGGER OR FIELD DATA ACQUISITION SYSTEM (adapted from Fishbaugher)

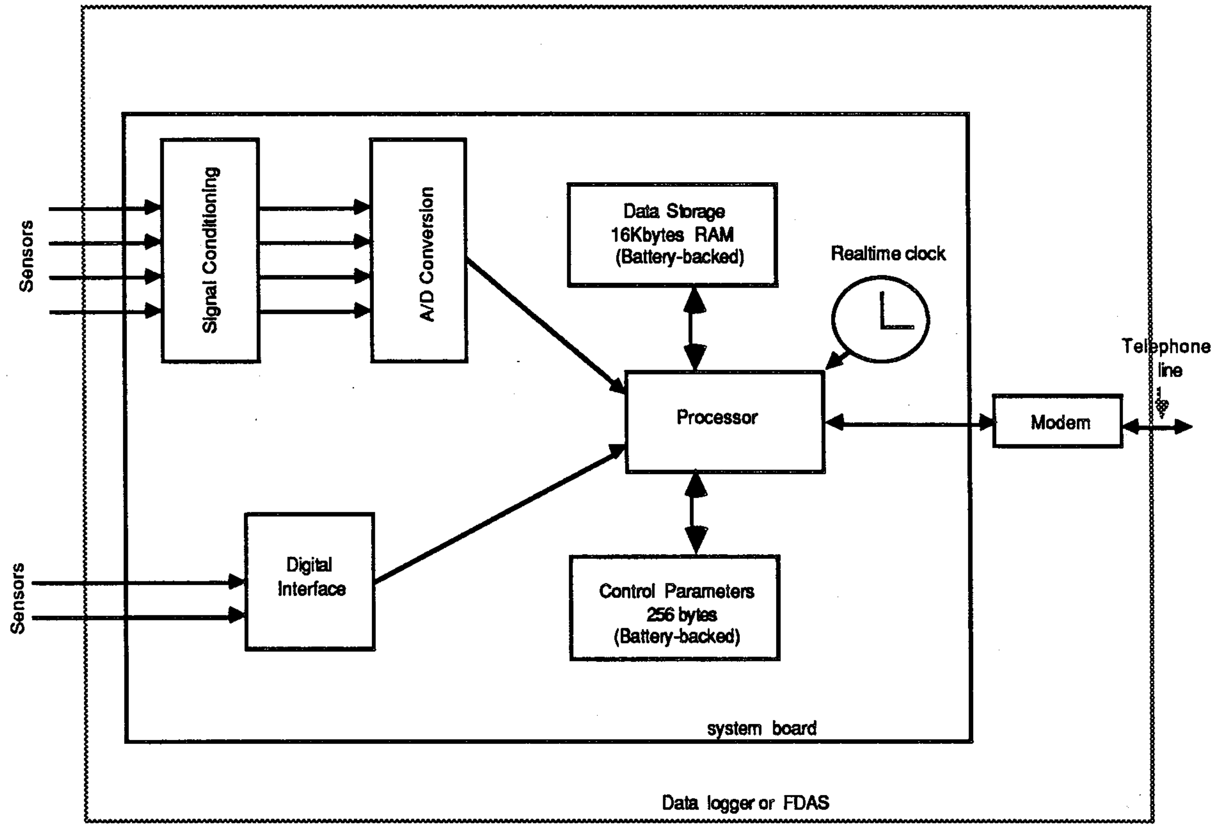
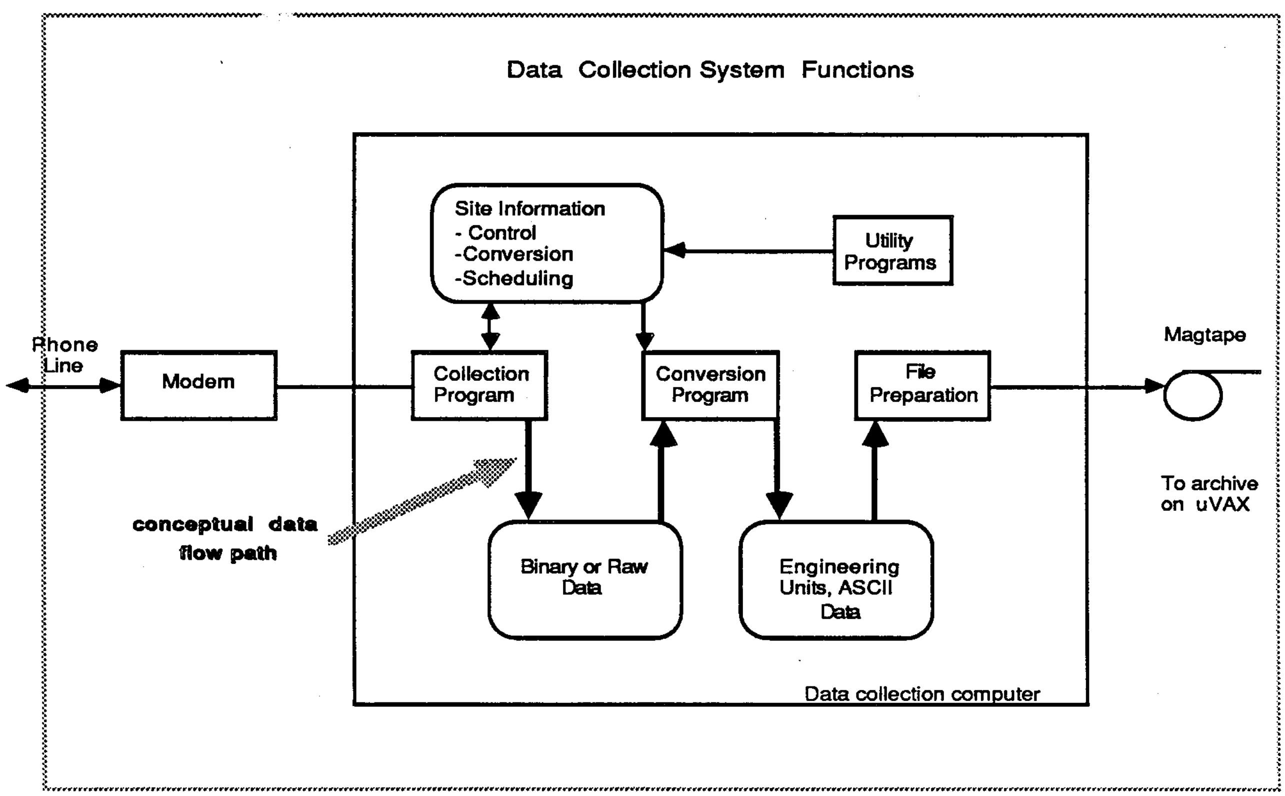


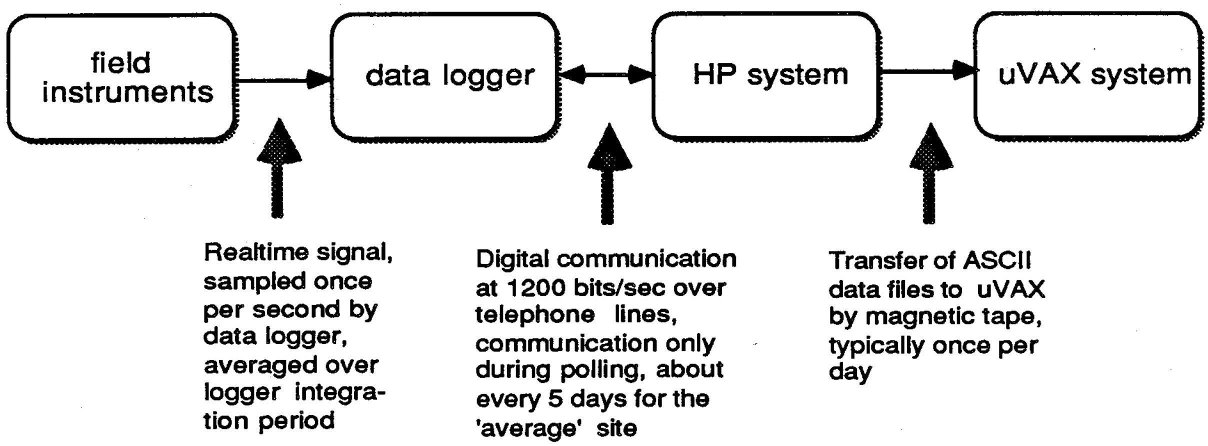
FIGURE 4. CURRENT FUNCTIONS OF DATA COLLECTION SYSTEM (adapted from Fishbaugher)



4.2. Data Communication Rates

The data communication rates between major components are obviously important in determining overall system speed. Figure 5 describes the speed of communication among these components.

FIGURE 5. ELCAP COMMUNICATION SPEEDS BETWEEN COMPONENTS



4.3. Data Volume and Flow Rates

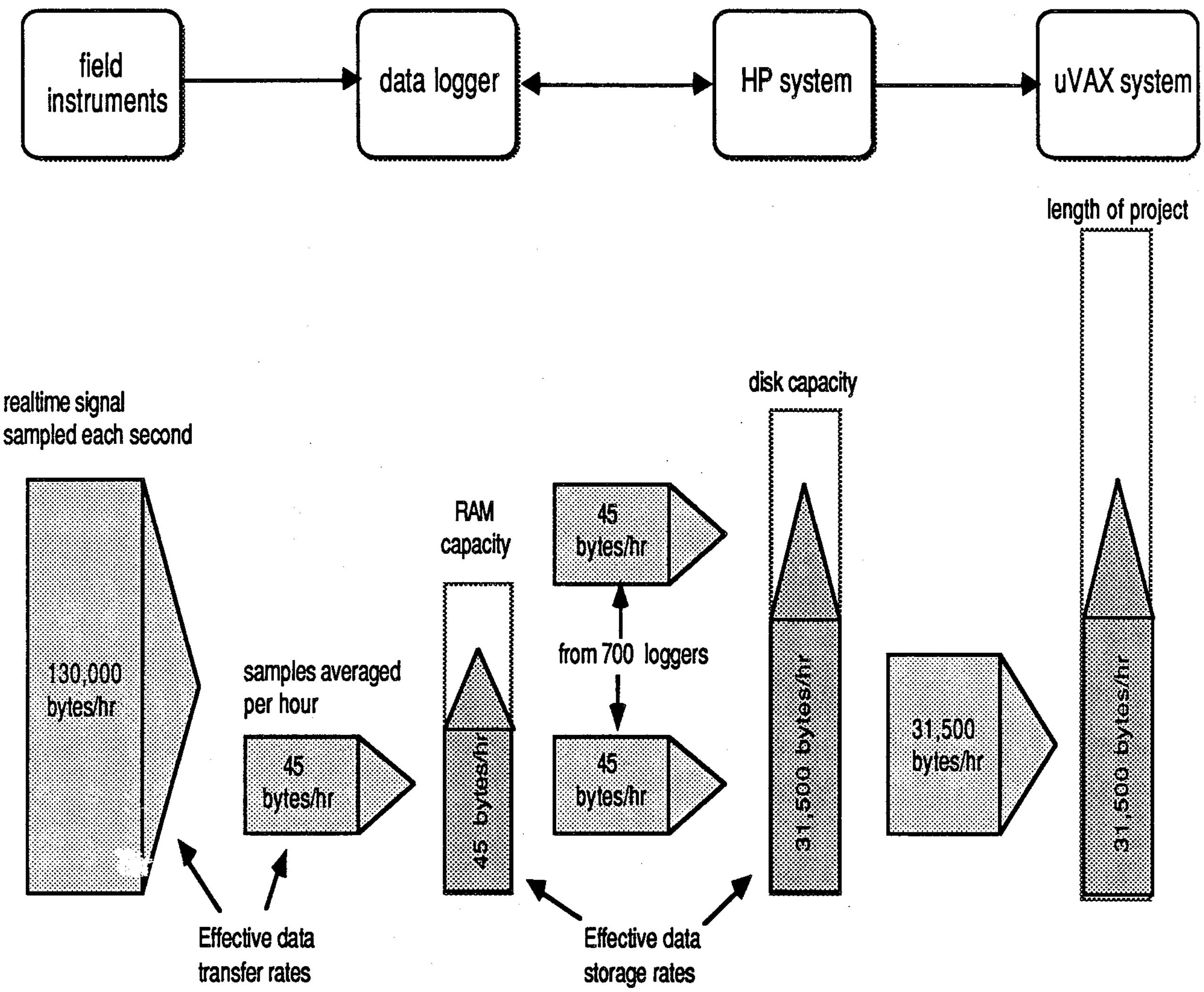
The data volume and flow rates were estimated for use in evaluating the system performance requirements. The data volume and flow rates were calculated at four different locations in the data flow path: at the field instruments, the data loggers, the HP system, and the microVAX.

Figure 6 summarizes the data volume and flow rate calculations for the simplified model of ELCAP. The details of these calculations are described in the following paragraphs.

4.3.1. Field instruments

The whole ELCAP process has its roots in the field measurements. The field instruments have a continuous data flow rate; that is, they provide a realtime signal proportional to the physical property being measured. The signal from each field instrument is connected to a specific channel on the data logger. The number of instruments per logger varies, from only several instruments to as many as 75.

FIGURE 6. ELCAP DATA FLOW RATES AND VOLUMES. AVERAGE LOGGER SIZE USED FOR CALCULATIONS.



There are two types of logger installations: commercial and residential/multi-family. Of the two types, commercial installations have the most instruments on the average - about 60 per logger. The residential/multi-family installations average about 25 instruments per logger. Table 1 lists the number of loggers per installation type.

Table 1. Number of Currently Active Loggers in ELCAP System

- 210 active commercial loggers
- 464 active residential and multi-family loggers
- *674 total currently active loggers*
- **Nearly 700 active loggers in ELCAP System**

The volume of primary data being acquired by ELCAP is directly related to the total number of active instruments. Using the breakdown of loggers per installation type and the average instrument count per logger, the number of instruments in the entire ELCAP system can be estimated. Table 2 lists the total number of instruments. The number of instruments change with time as field adaptions occur. The total is conservative, since the average numbers of instruments per logger type are rounded upward. (There are at present closer to 20,000 active instruments, thus overstating the current numbers by about 20 to 25%). Due to the approximate nature of these estimates, it is appropriate to overstate them for use in defining system upgrade requirements.

Table 2. Number of Instruments in ELCAP System

- Commercial: 12,840 instruments
  - about 60 instruments per commercial logger
  - about 214 active commercial loggers
  - about 60 x 214 = 12,840 instruments
- Residential and multi-family: 12,150 instruments
  - about 25 instruments per residential logger
  - about 486 active residential loggers
  - about 25 x 486 = 12,150 instruments
- **Total: 24,990 instruments**
  - 12,840 + 12,150 = 24,990 instruments
  - 214 + 486 = 700 active loggers
  - 24,990 / 700 = 35.7 or 36 instruments per logger

4.3.2. Data loggers

Data is captured in the field and temporarily stored in logger RAM. The size of RAM is 15,360 bytes; this determines the maximum volume of data that can be stored in a logger. The logger must be polled and the data transmitted to the data collection system before more than 15,360 bytes are captured; otherwise data will be lost. The rate data is captured and stored at each logger varies, and that rate must be known to the data collection system. The following paragraph calculates the *average data flow rate* into ELCAP loggers.

Each instrument channel is sampled once per second. That signal is averaged over the integration period assigned for the logger, with 60 minutes being by far the dominant integration period. The integrated values for all channels in the logger are stored together in a record. The record length in bytes equals the number of instrument channels plus nine(9). The nine bytes are for storage of important record information other than the data itself. Considering all 700 loggers, there is an *average* of 36 instruments per logger. An average record length then is 36 + 9 = 45 bytes. Therefore, the *average* data logger captures data at 45 bytes/hour.

In summary, an average ELCAP logger captures data at 45 bytes/hour. This means an average logger can hold over 14 days of data, without overwriting or loosing data. Actually, the data capture rate will vary for individual loggers depending on the number of instruments and the integration period. But, the average number is still valuable for estimating upgrade requirements.

4.3.3. HP system

The HP system collects data captured by the loggers. The loggers are polled for data at various intervals; thus, the data is collected in spurts. But, *on the average*, the HP system must collect data at the rate it is captured by the loggers. This data flow rate is 0.756 Mbytes/day (700 loggers x 45 bytes/hr-logger = 31,500 bytes/hr). This number includes raw data flow plus information for the data record header.

The data flow rate of 0.756 Mbytes/day is for unconverted data. This data is converted and stored along with the raw data. Assuming that data converted to engineering units take six (6) times the storage space of the original raw data, then an approximate volume of 5.3 Mbytes/day must be stored (1 + 6 = 7 times the incoming raw data). The actual volume archived may be more or less than this, depending on which loggers are polled that day. But this is a valid number to use for estimating disk space needed.

4.3.4. MicroVAX

All data collected and converted by the HP system is transfered to the microVAX. Converted data is stored in ASCII files for magnetic tape transfer from the HP to the microVAX.This data is stored in weekly files. Each week's converted data would occupy about 37 Mbytes, excluding file structure overhead. However, actual file space is significantly less than this since the data is actually stored in transposed compressed binary (TCB).

5. Major Costs of Operation

The major costs of operation identify which system functions should be evaluated in order to best lower costs. Current system operating costs are estimated in this section. System operating costs can be divided into three general groups: operator, telephone, and system maintenance costs. Actual staff time needed for system operation is by far the dominant cost. Four major tasks performed by the operators are defined to estimate how the operator cost is divided among different tasks.

5.1. Current System Operating Costs

The approximate operating costs are slightly over $144k/yr. The costs are separated into three general categories: operator, telephone services, and system maintenance.

Several qualifying comments are needed. First, these cost estimates apply only to *direct* operating expenses for data collection as detailed in the following paragraphs. System field expenses are not included, nor are expenses for system management.

Second, *estimated* charge rates were used only to calculate roughly how much money was at issue. For two years, the costs involved in system operation (as outlined below) are on the order of **$290,000**. Two years is the time frame used for payback estimates. The two-year time period was chosen as a reasonable operating life for ELCAP.

5.1.1. Operators

Since digitization has been absorbed into the operator's job and weekend work has been eliminated, there is about 1.1 FTE used for operating the system. (Note that 1.5 FTE were required until recent changes in weekend operation.) Shirley Bradymire and Peggy Leanderson share the 1.1 FTE, with Shirley accounting for the majority of that time. Estimate $45/hr x 40hr/wk x 52 wk/FTE x 1.1 FTE/yr = **$102,960/yr**.

5.1.2. Telephone Costs

Total telephone charges are **$21,360/yr**. Only about $2100/yr is fixed; the remaining portion is a variable cost depending on charges for long distance calling. Table 3 summarizes these costs.

Table 3. Summary of Telephone Costs

- Wats
  - average of 5 months = $900/mo
  - $900/mo x 12 mo = **$10800/yr**
- Fixed fees for 376 phones
  - 6 lines at $30/mo/line = $180/mo
  - $180/mo x 12 mo = **$2160/yr**
- Toll charges for 376 phones
  - average of 3 months = $700/mo
  - $700/mo x 12 mo = **$8400/yr**
- FTS
  - **$ 0** (paid as lab overhead)

5.1.3. System Maintenance

This cost is variable and a precise estimate is not possible. Software maintenance (Steve Lucas, 0.10 FTE) and hardware maintenance (hardware technician, 0.05 FTE) are combined for an estimate of 0.15 FTE. Thus, staff time is $55/hr x 40hr/wk x 52wk/FTE x .15 FTE/yr = $17,160/yr. Adding $4000/yr for the HP maintenance contract gives a total of **$21,160/yr**.

5.2. Operator Tasks Performed During System Operation

The tasks performed during the operation of the ELCAP data collection system were defined through interviews with the operators. The tasks were grouped into four general categories: 1) reporting, 2) manual interrogation of loggers, 3) support for field personnel, and 4) other activities such as system backup, data file transfer to microVAX, and meetings. A time/motion survey was conducted to estimate what portions of operator time where used per task. That survey covered 10 operator-days, and the results are summarized in Table 4.

Table 4. Percent of Operator Time Used per Task

- Report generation and review (40%)
- Manual polling of loggers (40%)
- Support for field personnel (10%)
- Other activities (10%)

5.3. Summary of Major Operating Costs

The definition of major operator tasks and of the time consumed by each task provides better identification of major operating expenses. Table 5 summarizes these expenses. *The costs are rounded, reflecting their approximate nature.* It is important to note that reporting and manual interrogation (polling) of loggers account for over half of the operating costs.

Table 5. Summary of Costs for System Operation per Year

- Operator reporting activities = $40,000
- Operator polling of loggers = $40,000
- Operator support for field personnel = $11,000
- Other operator activities = $11,000
- Telephone charges = $21,000
- System maintenance = $21,000
- **Total operating costs = $144,000/yr**

6. Identification of Needs for Potential Upgrade

The major direct operating cost is operator labor. About eighty percent (80%) of operator labor is spent on two tasks: manual interrogation of loggers and reporting needs. Clearly, efforts to reduce system operating costs should address these operator tasks. Enhanced polling and reporting capabilities can reduce much of this cost. The data capture rate and the quality of data are both high and both shall be maintained or improved by any modifications to the system. This is essential to ELCAP's analytic goals.

Additional upgrade needs of lower priority are also identified below.

6.1. Reporting

Reporting capability should be enhanced to automatically provide reports now done by hand, and to allow operator access to more information about the system status. These actions would permit the operator or system manager to better manage the system.

A good basis of reporting capability exists on the current system; however, this capability should be improved. Operators spend about 40% of their time on various reporting functions. Much, but not all, of this time could be saved by improved reporting.

6.1.1. Data capture status

The reporting of data capture status should be broadened. Basically, the operator should be able to access *current* data capture status *on demand.* Operators (or system managers and others) should be able to direct the output to terminals for preview, or to printers for hardcopy. Status information should show the operator on demand what data and its associated time interval are stored in a logger and on the HP disk (in raw or converted form).

Maintaining a record of recent data capture intervals for the logger, raw data, and converted data will allow the operator to know exactly what data has been captured and when. Loggers that need to be polled can be easily identified, as can those recently polled. Such information could be maintained for several months, and serve as a basis for monthly reports. The chief example is "Shirley's bible"; it could be generated automatically instead of by hand.

Also, historical data capture information from the HP could later be compared with data capture information generated during data verification. The two should be similar, or their differences understood.

6.1.2. System error reporting

System error reporting involves various diaries and the Problem Identification Forms (PIFs). The preparation of diaries could be further automated. System messages are currently archived to disk files. Operators should be able to select and sort on demand messages according to message type, logger, time interval, or any combination of these. The operator should then be able to print or display the information.

Statistics showing communications activity are vital to the effective management of large-scale networks. Statistics simply mean a periodic summary of communication activity for each logger in the network. The statistics can be tabulated on a configurable, periodic basis. Current statistics should be reportable on operator demand. Examples of important communication activity to tabulate are: number of successful communications, number of failed communications, reasons for failed communications, time period of attempted communication, and the telephone exchange used. The capability for reporting such communication statistics should be developed.

Also, PIFs could be generated automatically, using communication statistics and data capture status information. Reports requiring operator input, such as the Corrective Action Reports, could be partially automated.

6.2. Interrogation of Loggers

The current capabilities for both automatic and manual polling of loggers need to be enhanced, primarily to reduce operator workload. Polling of loggers is the key to data collection. Polling schemes could be enhanced to handle a wider range of conditions, leaving fewer exceptions to be handled by the operators.

The single upgrade that would save the most operator labor is automating the current manual interrogation process. This process is conducted daily by the operators and consumes about 40% of their time. Manual interrogation is primarily conducted for CAP sites, 'call-in' loggers (power failures have occurred at these sites), and 'failed' loggers from the previous night's automatic polling efforts. The operators need the capability to activate individual loggers for polling based on: 1) time of day, 2) percent full, and 3) operator demand (i.e. poll that logger immediately).

All CAP sites are now polled automatically until the end of the month. On the first day of a new month, operators manually poll CAP sites. This is done to satisfy sponsor reporting needs, which require a monthly report promptly after the end of the month. CAP sites could be polled automatically by the polling program, if operators could easily activate these loggers for polling on a time basis, as well as percent full. Currently, an automatic scheduling program calculates which loggers to call based *only on percent full* status (the percent of logger RAM containing new data).

For the 'call-in' loggers, an additional feature should be considered. Any logger that 'calls in' should be immediately polled by the data collection system, automatically. In this case, the operator would not have to review reports and activate that logger; it would be activated automatically for polling.

In most cases, the 'failed' loggers from the previous night are polled *successfully* by the operator on the following day; the operators simply try again, try a toll telephone number, or use a different modem. This approach could be automated by allowing the automatic polling program to permit re-trys of this nature. Re-trys should be configurable for number of re-trys, delay between re-trys, alternate re-try telephone numbers (i.e. FTS, Wats, or toll numbers), and possibly alternate modems. Note that the current HP system does perform 2 re-trys, but does not alter telephone numbers or modems.

6.3. Field Support

Field maintenance activities supporting the large ELCAP network are extensive, with costs approaching $500,000 per year. By comparison, operating costs associated with the HP data collection system alone are about $144,000 per year. This comparison suggests any operator support for field efforts is important, even though field support is a small percentage of total operator time. As operator duties are automated to lower costs, a conflict arises with the function of operator support for field activities. Less operator time means operators will be less available to the people in the field. This conflict should be addressed.

At present, operators spend about 10% of their time supporting field activities. All other operator tasks take a back seat when field support is required, as should be the case. Operators perform three major activities in support of field personnel: make connect checks, enter new parameter sets, and identify field problems.

Connect checks are 'end-to-end' tests of logger communications. This is done after a logger has been worked on, *before* field personnel leave the site. These checks are important and should be maintained; however, such action may be at odds with reduced operator time. Rather than strict coordination of operator-field support activities, ELCAP data processing personnel should continue to perform these connect tests when the operator is not available. This currently is done when operators are unavailable for short periods during the day.

ELCAP has evolved a thorough approach for field maintenance. One aspect of this approach is clearly defined process for changing logger parameters. That process is effective and should not be modified. But, the actual implementation of new parameters by the operator needs to be simplified. They cannot enter and activate a parameter change directly. In order to avoid the need for operator presence during field visits, data processing personnel could be trained to implement parameter changes when required.

The identification of field problems is strongly supported by current procedures and equipment. Major savings in field costs are not likely; anyway, such analysis is not the focus of this review.

6.4. Other Operator Tasks

About 10% of the operator time is spent on this task. The only significant savings would be the electronic transfer of data files to the microVAX, instead of magnetic tape transfer. The time spent making the tape and copying its contents on the microVAX could be saved. This is a daily effort.

The electronic transfer of data from HP to microVAX has already been investigated by ELCAP staff. These investigations concluded electronic transfer was too time consuming; however, networking capability at Ethernet speed was not available as it is for the IBM workstations.

Activities such as system backup and meetings would remain.

6.5. Telephone Charges

There are three types of telephone calls: FTS, Wats, and regular tolls. FTS is free for the logger sites where it is available. Both Wats and regular toll charges vary with the number and length of calls. Assuming maximum use of FTS is being made, telephone charges can be reduced in three primary ways: fewer calls, 'lower-rate' calling, and less connect time. At present, telephone charges are approximately split between Wats and regular tolls, each costing about $10,000 per year.

Telephone costs could be reduced by polling loggers less frequently, but when they contain more data. This reduces the number of calls and the total connect time. Connect time is reduced because there is a percentage of poll overhead, or connect time not directly related to the amount of data to be transmitted. But, the capability to reduce polling is already available, and this is a system management decision. There is a valid tradeoff between less frequent polling and the potential for data loss.

Increased nighttime or lower-rate calling will lower telephone costs. This should occur if polling is further automated with additional automatic re-try capabilities, since a larger portion of loggers would be polled successfully and automatically at night.

Call-in loggers, which require polling due to a power outage, account for the Wats line costs. Question has been raised if this feature is needed. Does the potential loss of data warrant the cost? Currently, the Wats lines cost a total of about $10,000 per year. This question could be further examined.

6.6. System Maintenance

There is a primary need for better system support. There are two parts to the HP software: the interrogation program and the conversion program. Only two PNL staff understand the software - the authors Bob McBride (interrogation) and Steve Lucas (conversion). Furthermore, Bob and Steve only support their own software; neither has significant operational knowledge of the other's software. This separation of authorship was necessary during development, but it probably contributes to the desire not to 'mess with the system'.

System documentation and the availability of support personnel for the interrogation program definitely need improvement. Bob is often not available for prompt support, but he is the only person familiar with the interrogation program. An ELCAP-size project should not be dependent on one person for support of key system features, especially when that person is not easily available.

Steve currently does a good job of system support. However, Steve is not familiar with the interrogation program, but rather the conversion program and general system features. Most upgrade needs identified in this report are associated in some way with the interrogation program. Steve is currently funded by ELCAP at about 25%; his availability is expected to decrease in the future.

There are several important redundancy or fault-tolerance features not present in the current system that should be added. First, the system should automatically recover from a power loss. This permits unattended operation in the absence of an uninterruptible power supply.

Second, the system clock should be battery-backed and not be affected by power loss or reboot of the data collection system computer. Proper time-stamping of data is of obvious importance. The cost of such a clock should be small compared to its utility. For example, on DEC systems such a clock would cost less than $1000 (a clock currently exists on the microVAX). By comparison, a battery-backed clock on IBM/ATs is usually included on the enhanced memory cards for essentially no added cost (the added RAM board itself costs about $400).

Third, the failure of polling hardware should be expected and a plan exist for implementing corrective action. Hardware failure could involve telephone lines, modems, or the polling workstation itself. ELCAP has an important advantage in fault tolerance: data collection is not realtime. In fact, individual loggers can go for many days without polling and still maintain their data. This means that the polling hardware does not have to be fixed immediately; even several days could elapse in extreme cases with negligible to no loss of data. Available spare parts or workstations provide the best alternatives to backing up system hardware.

7. Evaluation of Option 1: HP Upgrade

The following is a list of options for upgrading the existing HP data collection system. These options were identified as having the highest apparent payback. Other upgrade options exist and would improve current system performance, but they did not have as high a payback.

Where appropriate, the percent of operator time potentially saved is stated, along with the FTE investment required to achieve that savings. All FTE investments include software design, coding, testing, implementation and documentation, as applicable.

7.1. Operator Training

With about 0.05 FTE investment, operators could be trained to save about 10% of their total time. The time/motion study indicated the operators performed individual tasks with different efficiences. Adapting the best procedures from both operators could save some time.

7.2. Reporting

Operators currently spend 40% of their time on reporting duties. About three-fourths or 30% could be saved with an investment of 0.40 FTE. A more detailed description follows.

7.2.1. Automated reporting: data capture status

With a 0.20 FTE investment, 20% of operator time could be saved by automating data capture status reporting. This effort would automate "Shirley's bible". The pertinent historical data would be generated, along with the report output program.

7.2.2. Automated reporting: system error reporting

With a 0.20 FTE investment, 10% of operator time could be saved by allowing the operator to sort and print diary messages as needed. Reporting would be more flexible and be available on demand, providing up-to-date information. Currently, operators spend about 20% of their time on this task. Much of the needed data is currently available, but the operators cannot sort and select messages automatically.

Better communication statistics should be developed as part of system error reporting. A basis of communication information to work from currently exists.

A program to generate PIFs automatically is also needed. The necessary information should already be available as part of the system error messages.

7.3. Interrogation of Loggers

With a 0.5 FTE investment, 30% of the operator time could be saved. Operators currently spend 40% of their time on this task. The polling program would have to be re-written to run continuously, while monitoring a poll queue (containing information describing the poll status of each logger). This is a major revision.

Various automatic polling parameters would have to be implemented, as defined in the identification of needs. Also, the capability to poll multi-family loggers with the same program needs to be developed.

7.4. Field Support

No savings are anticipated here.

7.5. Other Operator Tasks

No savings are anticipated here. ELCAP staff have tested electronic transfer of data to the microVAX and do not consider it a reasonable option. HP networking support was considered unavailable, but a detailed investigation was not performed.

7.6. Telephone Charges

Some savings should be realized by enhancing the automatic polling features (i.e. daytime calling by the operators should be minimized, thus reducing toll charges). Estimate $5,000 per year saved in toll charges.

7.7. System Maintenance

No savings are anticipated here, in fact, these costs may increase slightly with the addition of more software. The HP system is a specialized one that few people have a working knowledge of. Training new people to support the system would be more costly than for IBM or DEC systems. Special attention should be directed to the availability of software support personnel.

The current HP system has two important problems that cannot be reasonably solved: the lack of a battery-backed realtime clock and an automatic restart capability. HP simply does not provide support of these capabilites. It would be possible to specify, procure and install an uninterruptible power supply for the HP system, thus avoiding the need for a battery-backed clock and automatic restart. However, this would probably cost $5k-$10k, depending on what equipment needed backup power.

7.8. Summary

Table 6 summarizes the cost benefits associated with the potential HP upgrade. Note that the FTE saved is operator FTE; whereas, the FTE invested is software development personnel. The actual FTE invested will depend on who does the work. The assumption is that someone familiar with the system will perform the enhancements.

Note that 0.66 FTE of operator time are expected to be saved out of 1.1 FTE. **That leaves 0.44 FTE for operation after enhancement.**

Table 6. Summary of Cost Benefits for HP Upgrade

- Operator reporting (30% saved out of 40%, 0.40 FTE invested)
- Operator polling (30% saved out of 40%, 0.5 FTE invested)
- Operator field support (0% saved out of 10%; nothing invested)
- Other operator tasks (0% saved out of 10%, nothing invested)
- Telephone charges ($5k/yr savings estimated, nothing directly invested)
- System maintenance (no savings estimated, nothing invested)
- **Total of 60% x 1.1 FTE = 0.66 FTE/yr saved, 0.90 FTE invested**

8. Evaluation of Option 2: IBM/AT Upgrade

The evaluation of this option is based on the current systems used by the Building Sciences Section. They use IBM/ATs and PCDAS software to operate several networks of loggers. The loggers currently in use are the same type as the ELCAP loggers, but are not part of the ELCAP project. The PCDAS software is documented in PNL-6317, entitled **PCDAS Version 2.2, Remote Network Control and Data Acquisition** by M. J. Fishbaugher.

In general, the PCDAS software currently has wider capability than the HP system, but operates on a considerably smaller network of loggers. Many features that are identified for possible upgrade on the HP system are currently available to some degree on PCDAS systems. The use of multiple IBM/ATs, running an enhanced PCDAS and networked to the ELCAP microVAX, is examined in the following paragraphs. Three (3) IBM/AT workstations networked to the microVAX should be sufficient for ELCAP, but refer to Appendices 1 and 2 for a detailed assessment of workstation performance capabilities and requirements.

8.1. Operator Training

The Building Sciences' systems do not have dedicated operating staff. Technical staff operate these systems as needed. The largest operational network consists of 26 sites with an effective data acquisition rate of 450 bytes/hr. By comparison, ELCAP's effective data acquisition rate is about 31,500 bytes/hr, or *70 times greater.* At this point, no data exists to extrapolate operator labor from the non-ELCAP IBM/AT systems to a full ELCAP application.

8.2. Reporting

With an investment of 0.10 FTE to enhance PCDAS reporting, 30% of the operator time could be saved. Currently, the operator spends 40% of total time on this task. The following provides a breakdown of this estimate.

8.2.1. Automated reporting: data capture status

With an investment of 0.05 FTE, 20% of the operator time could be saved. The operator currently spends 20% on this task; thus, all could be saved.

The PCDAS software currently supports several required capabilities. Reports showing historical raw data capture per logger are supported, and the current logger 'percent full' status is also available. The history of converted data is not currently supported. A report format consistent with "Shirley's bible" would need to generated.

8.2.2. Automated reporting: system error reporting

With an investment of 0.05 FTE, 10% of the operator time could be saved. The operator currently spends about 20% of the time on this task.

The PCDAS software currently supports system error reporting, with the exception of automatic PIF generation. Reporting of communication statistics should be enhanced, such as maintaining a summary of communications errors per type over individual or groups of sites.

8.3. Interrogation

With an investment of 0.20 FTE, 30% of operator time could be saved. The operator currently spends 40% of total time on this task.

Note that with no FTE investment, 20% of the operator time could be saved since PCDAS currently allows an operator to manually select a logger for immediate or scheduled automatic polling. This is not possible on the HP system.

PCDAS main program continually monitors a queue for active (as opposed to inactive) loggers and polls them automatically, as needed. Loggers can be declared active or inactive for polling, and time of day or percent full can be used to schedule polling.

The PCDAS software performs 2 immediate re-trys, if needed, similar to the current HP system. However, some automatic polling parameters need to be added to PCDAS. Alternate telephone numbers, modems, or time-delays between re-trys are not supported.

Also, the ability to automatically poll multiple-family loggers needs to be developed. Currently, these are polled semi-automatically by a separate polling program initiated by the operators. This task is the most time-consuming part of the upgrade to PCDAS interrogation capabilities.

8.4. Field Support

With no investment, 5% of the operator time could be saved. The operator currently spends 10% of the total time on this task.

Field support time would be saved by the PARSET program. This program allows direct editing and download of the parameter sets from the polling workstation at the operator's command. Also, additional diagnostic reporting features that currently exist would assist in field support. An example is the CKSUM program for monitoring a logger.

Also, PCDAS prevents overwriting fresh data on disk from the previous night's polling. PCDAS maintains current information showing when the last successful poll was. On the HP system, this problem currently arises when operators support field efforts by interrogating a logger before work begins on the site. The goal is to prevent data loss, but the HP system offers no protection for overwriting fresh data, if the logger has been polled the previous night.

8.5. Other Operator Tasks

With an investment of 0.05 FTE, possibly 5% of the operator's total time could be saved. The operator currently uses 10% of total time for these tasks.

This system would transfer files of converted data directly to the microVAX by a high-speed connection, saving the time now associated with daily magtape transfer. System backups could be simplified by transferring important files to the microVAX disk, and performing a single backup operation. In fact, it may be practical to establish a batch command file on the microVAX that automatically performs the backup operations . (The only requirement might be that a magtape be mounted on the appropriate tape drive).

8.6. Telephone Charges

Some savings should be realized by enhancing the automatic polling features (i.e. day time calling by the operators should be minimized). Estimate $5,000 per year saved.

8.7. System Maintenance

With no investment, $10,000 per year can be saved. The HP maintenance contract accounts for $4k/yr. The other $6k/yr reflects an expected reduction in system software maintenance.

At present, this system has good documentation and is well supported by Mark Fishbuagher. It has not handled a large network like ELCAP, but has performed well on smaller networks. A drawback is that Mark is the only person capable of modifying PCDAS. However, it should be relatively easy to train someone in using an IBM/AT and BASIC. Both are widely used and easy to learn. System hardware and software support for IBM/ATs is good and it is relatively inexpensive.

An IBM-based system will have the capability for automatic restart and a battery-backed clock; this precludes the need for an uninterruptible power supply. Both capabilites exist now with IBMs; whereas, the HP lacks these important capabilities.

8.8. Transfer of Data to MicroVAX

At least several methods are available to electronically transfer data from the IBMs to the microVAX. The HP system currently accomplishes this transfer by magtape. The choice of a particular method will depend on how ELCAP staff want to operate the system, and this should be investigated during design. DECnet-DOS, a DEC software product, is recommended as a first choice; it has the functionality ELCAP needs at lower cost. The client/server software, also a DEC product, has only slightly more capability than DECnet-DOS but at greater cost. Ansynchronous communications is not recommended, since inexpensive networking is possible.

8.8.1. DECnet-DOS

DECnet-DOS allows IBM personal computers using DOS to be networked to microVAXs. DECnet-DOS permits task-to-task communications, file transfer, terminal emulation, and network management. DEC supplies a PC Integration kit for $1,200 that includes an Ethernet card, license, and software. Communication uses Ethernet at 10 Mbit/second. Ethernet communication is the fastest reasonable way to transfer the PCDAS data electronically to the microVAX.

To my knowledge, DECnet-DOS is not currently in use by C&IS. However, if a single package were procured, it could easily be tested. Joe Brothers has an IBM/AT and the thinwire Ethernet cable to a microVAX.

8.8.2. VAX VMS Client/server Software

An option for transfer of data is the VMS Client/server software. This option provides slightly more functionality than DECnet-DOS, allowing any node in the network to be configured as the server. The server software and license must be procured, which cost about $3900 total for a microVAX. Each node or workstation would require server software for MS-DOS, costing about $650 each.

Joe Brothers currently uses this software with several VAXmates, which are similar in performance to IBM/ATs with coprocessors. He is pleased with the system's performance.

8.8.3. Ansynchronous

Ansynchronous communication is less expensive than server or DECnet software, but it is slower and has less functionality than the other two. File transfer using ansynchronous communication at 9600 baud (bits/second) would not be sufficient for ELCAP. By comparison, 9600 baud is only 8 times faster than the 1200 baud used for polling loggers. Though there is less communication overhead in file transfer (as opposed to polling), converted data files (rather than raw data files) of larger size are transferred to the microVAX. Higher speed ansynchronous communication could be used, but file transfer would still take longer than desired. Ethernet's effective communication rates will be faster, though less than 10% of Ethernet's maximum bandwidth (10 Mbits/sec) is ever achieved in practice.

8.9. PCDAS Conversion to ELCAP

With an investment of 0.25 FTE, PCDAS can be converted to operate the ELCAP system. This investment is necessary to achieve the previously noted savings.

There are three types of conversion needs: the parameter database, network communications, and optimization. First and foremost, the measurement parameter database existing on the HP system needs to be converted to the IBM (0.05 FTE). A computer program could be written to accomplish this.

Second, in scaling up to an ELCAP-size network, communications will need to be adapted or tuned (0.10 FTE). This is probably the most important and unpredictable aspect of conversion. Experience gained in tuning the existing HP system should be used.

Third, optimization of PCDAS for ELCAP includes several tasks (requiring a total of 0.10 FTE). The capability to access report information across all polling workstations (similar to the shared resource manager of the HP system) will be developed. Also, it is recommended that PCDAS be optimized to reduce raw data file size, expand the maximum logger limit from 300 to at least 750, and complete the revision to structured BASIC.

8.10. Summary

Table 7 summarizes the cost benefits of the IBM/AT upgrade (the costs of IBM/ATs and networking software are not included). Note that the FTE saved is operator FTE; whereas, the FTE invested is software development personnel. The actual FTE invested will depend on who does the work. The assumption is that someone familiar with the system will perform the enhancements.

Note that 0.77 FTE of operator time is expected to be saved out of 1.1 FTE. **That means 0.33 FTE would be required for system operation.**

Table 7. Summary of Cost Benefits for IBM/AT Upgrade

- Operator reporting (30% saved out of 40%, 0.10 FTE invested)
- Operator polling (30% saved out of 40%, 0.20 FTE invested)
- Operator field support (5% saved out of 10%; nothing invested)
- Other operator tasks (5% saved out of 10%, 0.05 FTE invested)
- Telephone charges ($5k/yr savings estimated, nothing directly invested)
- System maintenance ($10k/yr savings estimated, nothing directly invested)
- Conversion to ELCAP (no direct savings, 0.25 FTE invested)
- **total of 70% x 1.1 FTE = 0.77 FTE/yr saved, 0.60 FTE invested**

9. Evaluation of Option 3: MicroVAX Upgrade

My evaluation of a microVAX upgrade was limited. There is little question that a microVAX could be adapted to perform ELCAP data acquisition functions. Such a system could be very effective, but its development would be a major effort. The probable cost and uncertainty associated with such an effort are significant. It is appropriate to ask, how would such a system fit into the larger picture of ELCAP? Considerations about such a microVAX upgrade are briefly examined in the following paragraphs.

9.1. System Hardware and Software Requirements

A microVAX II with peripherals operating under VMS would be a very capable platform for data acquisition. Considerable support exists at PNL for VMS systems, and a wide variety of public-domain and commercial software is available for enhancing such an ELCAP system, if desired.

A new microVAX II system would cost in the range of $30k-40k, depending on configuration. This 'new equipment' cost is significantly more than the IBM/AT or HP upgrade options.

If an existing microVAX were available, costs could be reduced somewhat. Less than $10k would be required for additional hardware and *system* software, depending on the configuration needed. This investment would provide the 'system level' capability to support ELCAP data acquisition; *all application software would still have to be re-developed for the microVAX.*

9.2. Application Software Development Needs

The polling and conversion software would have to be re-developed for an entirely new system. Those familiar with the original development effort on the HP system could better estimate the magnitude of this investment. The existing logic could be used to lower development costs. Still, the cost would probably be substantial and certainly would be greater than upgrading either the HP software or PCDAS.

9.3. Considerations for System Operation

There would be advantages to combining data acquisition and processing tasks on one system. Obviously, file manipulation, file transfer, and system backup procedures would be simplified along with system maintenance. But failures of this system might significantly impact both data acquisition and data processing. Redundancy and fault-tolerance considerations would have to be examined in detail. The end result would be added cost to achieve some level of redundancy and fault tolerance.

In the best case, a moderate investment would be needed to upgrade a microVAX for ELCAP data collection. The result should be an improved data collection system on the microVAX. However, a separate IBM-based data collection system exists for other metering projects. PNL's resources would be divided for operating, maintaining and enhancing two separate data collection systems. It is worth considering if the 'generic' data collection functions can be handled by one type of system. Software and hardware maintenance costs could be reduced by supporting one type of system. And, in general, IBM/AT systems are less expensive to maintain and support than DEC or HP systems.

10. Conclusions and Recommendations

This section describes the major conclusions associated with each of the three options investigated. The primary conclusion is that the IBM/AT option is the best upgrade path for ELCAP. The recommendations identify actions required to best implement the IBM/AT upgrade.

10.1. Conclusions

The HP system broke important ground in developing a large-scale data collection capability for ELCAP. The HP system performs its intended functions adequately. As expected, full-scale operation of this system has identified potential areas for improvement. *This would be the case with any software system of this sort; extensive operational experience and subsequent system modification are almost always required.*

PCDAS, however, has evolved an extensive capability in the meantime. Simply stated, PCDAS provides an effective, proven platform for data collection. In addition, IBM/PC hardware and software are widely supported and used, and they are less expensive than those for DEC or HP systems. Use of IBM/ATs for ELCAP can reduce operating costs with a payback period of less than 1.2 years, plus providing other important features.

The evaluation of each option consisted of two parts: a quantified payback estimate and a subjective assessment. The payback estimates compare the options directly, where that is possible. The subjective assessment deals with issues that are not directly comparable among the options.

10.1.1. Option 1: HP Upgrade

The HP upgrade option does not have the best payback, nor does it provide the best overall upgrade path for ELCAP. Table 8 summarizes the payback calculations.

Table 8. Payback for HP Upgrade

- Operator time saved (add 0.66 FTE/yr x $86k/FTE x 2 yr = $114k)
- Telephone costs saved (add $5k/yr x 2 yr = $10k)
- Development investment (subtract 0.90 FTE x $120k/FTE = $108k)
- **Net payback over 2 years = $16k**

Estimates for upgrading the HP system state that 0.66 FTE/yr of operator time can be saved. Using an FTE cost of $86k/yr, the two-year savings are about $114k. An investment of 0.90 FTE is needed for software upgrade. Using $120k/yr for software personnel, that investment is about $108k. Estimating a $10k savings in telephone costs and no increase in system maintenance costs, **the net payback over two years would then be $16k** (= $114k - $108k + $10k).

Stated another way, the HP upgrade would cost about $108k. Such an upgrade would achieve savings of $124k over two years. Therefore, costs would be paid back in 1.7 years.

The HP system is not the most flexible and easily supported system. These costs may go up, especially if key staff are unavailable for timely support. It is possible that much of the $16k payback could be lost to such cost increases in system support.

10.1.2. Option 2: IBM/AT Upgrade

The IBM upgrade path has the best payback and provides the most flexible and supportable system. Table 9 summarizes the payback associated with this upgrade option.

Estimates for upgrading the IBM/AT system state that 0.77 FTE/yr of operator time can be saved. This equates to a savings of $132k over two years, if operator time is valued at $86k/yr. The required software upgrade investment is estimated at 0.60 FTE or $72k over two years, if software personnel cost $120k/yr. Estimate that $10k in telephone costs can be saved over two years. System maintenance costs will decrease. The $4k/yr HP maintenance contract will not be needed, and software maintenance costs will drop $6k/yr. Thus, $20k over two years will be saved in maintenance costs. The total anticipated savings over two years is therefore $162k (= $132k + $10k + $20k). Subtracting an additional $20k for equipment and networking software, **the net**

payback over two years is $70k (= $162k - $72k - $20k).

Table 9. Payback for IBM/AT Upgrade

- Operator time saved (add 0.77 FTE/yr x $86k/FTE x 2 yr = $132k)
- Telephone costs saved (add $5k/yr x 2 yr = $10k)
- Maintenance costs saved (add $10k/yr x 2 yr = $20k)
- Equipment investment (subtract 3 ATs @ $5k/ea + $5k = $20k)
- Development investment (subtract 0.60 FTE x $120k/FTE = $72k)
- **Net payback over 2 years = $70k**

Stated another way, the IBM upgrade would cost about $92k. Such an upgrade would achieve savings of $162k over two years. Therefore, costs would be paid back in 1.1 years.

The IBM/AT upgrade option demonstrates the best payback, and it provides the most flexible position for supporting ELCAP. Basically, ELCAP can benefit from the developments for the IBM/AT systems used in other PNL metering projects. An IBM/AT-based system will be more flexible and thus better able to support the currently unknown future needs of ELCAP. *In addition, this upgrade path holds the most promise for further reducing operating expenses as experience with the system grows.*

10.1.3. Option 3: MicroVAX Upgrade

An effective microVAX-based system to perform ELCAP data collection certainly could be developed. But, the cost and uncertainty associated with such a major development effort prevents serious consideration when evaluated against two operational systems (PCDAS and the HP). Therefore, a quantified payback estimate for the microVAX option was not developed.

10.2. Recommendations

The recommendations have two parts: the steps for implementing the upgrade and several upgrade design considerations.

10.2.1. Plan of Action

The following steps should be taken in pursuing the upgrade. They are, in order:

1. Design of IBM/AT system for ELCAP.
2. Testing of key design concepts on existing PNL equipment.
3. Procurement of hardware and software.
4. Development of system.
5. Documentation of upgraded system.
6. Training of operators.
7. Implementation of the upgraded system.

It is important to note that an individual must be identified to assist Mark Fishbaugher in PCDAS adaption to ELCAP. That person should be able to support ELCAP as needed in the future.

Another very important consideration concerns implementation. The implementation plan must minimize the impact on current system operation, and still clearly establish that data quality and capture rate are not degraded. This will not be easy; however, PCDAS has the advantage of operating in a protected mode. Protected mode prevents PCDAS from modifying the loggers in any way. This capability is a useful advantage for transition and testing.

10.2.2. Design Considerations for IBM/AT Upgrade

Certain IBM features should be investigated during the design of an IBM upgrade. These features could potentially improve system performance and/or lower the costs associated with upgrading. Refer to Appendix 2.

Overall data flow processes in the current ELCAP are effective and well thought out. Improvements to this data flow are only possible by using the new IBM/microVAX networked architecture. The data flow analysis is outlined in Appendix 3. Data flow is examined for the overall data collection and processing tasks. Data flow concepts and recommendations for the IBM/microVAX network are described.

APPENDIX 1 - REVIEW OF PCDAS/IBM PERFORMANCE AND CAPACITY

The biggest concern of the IBM upgrade option is the size of the ELCAP network. Can IBM/AT systems adequately handle 700 loggers on a regular, continuing basis? Considerations for polling speed and database capacity are of primary importance. With the use of multiple IBM/ATs, it will be possible to poll the ELCAP network. Three IBM/AT workstations should be purchased and configured in a networked environment with the microVAX. For details on the configuration and use of these three workstations refer to Appendices 2 and 3. The following paragraphs describe the major points leading to the conclusion that three (3) IBM/AT workstations should be able to handle the ELCAP system.

1. Polling Speed and Number of ATs Needed

Three different loggers were polled with PCDAS and the polling times recorded. One logger was 50% full and had a poll time of 4 minutes and 20 seconds (or 260 seconds). The second logger was 43% full and had a poll time of 2 minutes and 50 seconds (or 170 seconds). A third logger was 28% full and had a poll time of 2 minutes and 40 seconds (or 160 seconds). These times do not include disk I/O before and after polling. If disk I/O time was included, the times would have been about 5 minutes (300 seconds), slightly over 3 minutes (200 seconds), and 3 minutes (180 seconds).

Mark Fishbaugher stated that the second and third loggers show the effect of a noisy line. Both took about the same time, but they transmitted different amounts of data (43% vs. 28%). The 50% logger, the first logger, also represents data transmission with a noisy line. For estimating purposes, a conservative approach will be taken. That is, the 50% logger times will be used. Note that ELCAP loggers are polled at 35%, not 50%. Plus, the 50% logger time has some effect from noisy transmission, a common aspect of ELCAP transmissions. Thus, the 50% logger times are conservative estimates for typical poll times.

Current ELCAP operations poll an average of about one hundred loggers per day, some automatically at night and some manually during the day. However, the upgraded system is to be capable of polling 200 loggers per day. *The following estimates are based on polling 200 loggers per day.* This requirement is conservative in that it exceeds typical operating conditions.

Using the 5-minute poll time for the 50% full logger, it would take a *single* IBM/AT about 1000 minutes or 16.67 hours to poll all 200 loggers. In any case, multiple IBM/ATs would be needed. Four (4) IBM/ATs theoretically could poll all 200 loggers in about 4 hours (16.67/4=4.17 hr). Three (3) ATs could poll 200 loggers in about 5.5 hours; two (2) ATs in just over 8 hours. Thus, polling time intervals can be less than the 8-hour period when regular toll charges are lowest.

The IBM/AT and HP systems poll the same type of loggers and therefore use the same protocol. Though the protocol is the same, the way logger commands are used in polling may differ. Mark Fishbaugher has stated that the polling method he uses is similar but not the same as the HP method. He suspects that his method is probably slower than the HP method, since he sends a number of extra individual commands to the logger during polling. These commands add time to the poll.

Poll overhead is high. Poll overhead is connect time spent *in addition to* actual transmission of raw data. For example, only about 64 seconds are required to actually transmit a *continuous*, *error-free* 7,680-byte stream of raw data (a 50% full logger, with 1 start bit and 1 stop bit at 1200 baud). However, conservative benchmark testing shows the PCDAS software to actually take 300 seconds for a 50%-full logger. Thus, almost four minutes are poll overhead. Though some poll overhead is always necessary, it may be possible to reduce this by modifying the polling software.

2. Database Size and Disk Capacity

The PCDAS database is currently limited to a total 300 loggers. Without increasing this limit, an IBM/AT-based ELCAP system would require a minimum of three ATs. Each AT would have a portion of the entire ELCAP database. However, the database size limit should be increased to about 750 loggers, so a single workstation could access the entire database if needed.

The flow of raw data was previously estimated at 0.756 Mbytes/day for all 700 loggers. This data flow is captured and stored by the loggers in the field. If 200 loggers are polled per day, then about 0.22 Mbytes/day will be captured by the central data collection system (200/700 x 0.756 MB = 0.22 MB).

Currently, the overhead of PCDAS file structure is high - increasing the actual raw data file size about 3 or 4 times. Even with this overhead, raw data flow still results in files of less than 1 Mbyte/day. If the IBM/ATs use 40-Mbyte hard disks, many days raw data could be stored locally before transfer to the microVAX, if needed. Also, data storage will be divided among at least 2 IBM/ATs; this further increases the amount of data that can be stored. Mark Fishbaugher is currently revising the structure of raw data files to significantly reduce file overhead. For these reasons, disk capacity should not be a problem.

3. Conversion to Engineering Units

Three points about conversion to engineering units are important: the processing time, data storage requirements, and when raw data is converted. First, Mark estimates that an IBM/AT (without coprocessor) does about 200 conversions per second. At that rate, 7680 bytes of raw data should take about 40 seconds to convert (7680 conversions / 200 conversions per second = 38.4 seconds). Conservatively, estimate that this adds about 1 minute to a 5-minute poll of a 50% full logger. For 200 loggers/day, the processing time (polling and conversion) increases twenty percent to about 20 hours (16.67 x 1.2 = 20.04 hr; note 20hr / 4 ATs = 5 hr/AT; 20 hr / 2 ATs = 10 hr / AT).

Second, converted data occupies about 6 times the space that raw data does, according to Mark. For all 200 loggers polled per day, about 1.3 Mbytes of converted data will be stored (0.22 Mbytes/day x 6 = 1.32 MB). File overhead on converted data is not large, as opposed to raw data file overhead. The 1.3 Mbytes/day will be divided among at least two ATs.

Third, conversion to engineering units can be done automatically at collection time (PCDAS version 2.2s) or at the operator's direction. The conversion program (TRANS) can convert all raw data or certain subsets of that data. Refer to the PCDAS documentation for details.

APPENDIX 2 - CONSIDERATIONS FOR DESIGN OF IBM UPGRADE

The following considerations for design could potentially improve system performance or lower the costs associated with upgrading. It is therefore recommended that they be investigated during design.

1. PS/2 Systems

First, the use of PS/2 Model 60 systems instead of AT systems should be investigated. The PS/2 is equivalent in price to the AT with required accessories. Benchmark tests indicate the PS/2 to operate MS DOS programs at twice the speed of an AT, with no modifications to the software. This claim could be inexpensively tested on existing PS/2 systems at PNL. The PS/2 support for networking software should be verified. Also, it has been reported that in the future ATs will be capable of upgrade to PS/2s.

2. Battery-backed RAM for RAMdisk Use

Consideration should be given to expanding RAM on the IBM workstations to more than 1.5 Mbytes. IBM/AT programs can only use 640k RAM directly; however, the additional RAM could be used as a RAMdisk. PCDAS reads and writes directly from disk in order to prevent loss of data should system operation be interrupted. Disk I/O accounts for nearly 20% of the 5-minute per logger polling time (50% full logger), and disk I/O is slow compared to RAMdisk I/O. Much of this 20% could be saved by using RAMdisk extensively. It may be possible to maintain most or all of a day's polling results in RAMdisk, *since only about 0.22 Mbytes/day of raw data will be archived for the entire data collection system.* Battery-backed RAM is available to maintain the contents of RAMdisk during interruptions in system operation.

3. Multi-tasking

The use of the MS Windows operating environment with PCDAS should be investigated. During polling, there is substantial idle processor time (Bob McBride estimates 80-90% idle processor time). The MS DOS operating system does not allow multiple tasks to be running; therefore, idle time cannot be used. MS Windows is a psuedo multi-tasking operating environment. Such tasks as conversion to engineering units could use idle processor time. This would increase workstation effective performance. This concept could easily be tested on existing systems at PNL. Eventually, the new MS OS/2 operating system will provide multi-tasking on IBM/PS systems. The first version of OS/2 is apparently already available.

4. Multi-channel Polling

Another possibility for increasing system performance is the use of 8-channel communication cards for the AT. Basically, this card allows COM1 to be used by up to 8 telephone lines at the same time. Since idle processor time is high, this could be a significant benefit. If, for example, it were possible to poll 2 or 3 loggers simultaneously with one AT, then fewer ATs would be needed. Such capability would require some program modification, but its cost-effectiveness should be briefly reviewed during design. C&IS staff are currently developing such a system.

APPENDIX 3 - DATA FLOW ANALYSIS

This appendix is a brief review of the ELCAP data flow from the logger to the microVAX. This review focuses on what happens to the data received from the logger up to the point it becomes available for use by the analysis routines.

This review is divided into five sections: 1) data flow through the system, 2) shared resources of a networked environment, 3) data transfer methods in a networked environment, 4) system operating modes, and 5) fault tolerance and redundancy. The first section reviews data flow in the current system. The remaining sections examine how the ELCAP system could be configured for networked IBM/ATs running PCDAS, the recommended upgrade path. The IBM/microVAX combination will significantly expand the capability and flexibility of the current data collection system. This will be accomplished primarily through networking directly with the microVAX and adopting a more user-friendly system.

1. Data Flow Through the System

The current data flow through the system is dependent on the capabilities of the HP system. The following paragraphs examine what actions are performed along that data flow path. Figure 3-1 shows the simplified, overall data flow path. Basically, the data collection system gets raw data from each logger, certain data processing steps are performed to assure data quality, and the data is presented to the data analysis routines. This review focuses on the data collection and validation steps.

There are two primary considerations for evaluation of data flow: 1) data quality and data capture, and 2) the efficiency of operation. Figure 3-2 shows the current data flow from logger through to analysis routines. As shown in the figure, data is accumulated and tranfered in discrete steps.

For an 'average' site, the logger accumulates data for about five days. Each logger is polled and the data transferred to the HP data collection system. The day after collection, the data is converted to engineering units and transferred to the microVAX. The REFORMAT program is run on the microVAX the same day that data is transferred; the purpose of REFORMAT is to perform certain data validation tasks on daily data from individual sites. The APPEND program takes data from REFORMAT and prepares weekly files for the analysis routines. Thus, 9 to 14 days after data is captured *at the logger*, that data is available for analysis routines.

FIGURE 3-1. MAJOR COMPONENTS OF ELCAP DATA ACQUISITION PROCESS

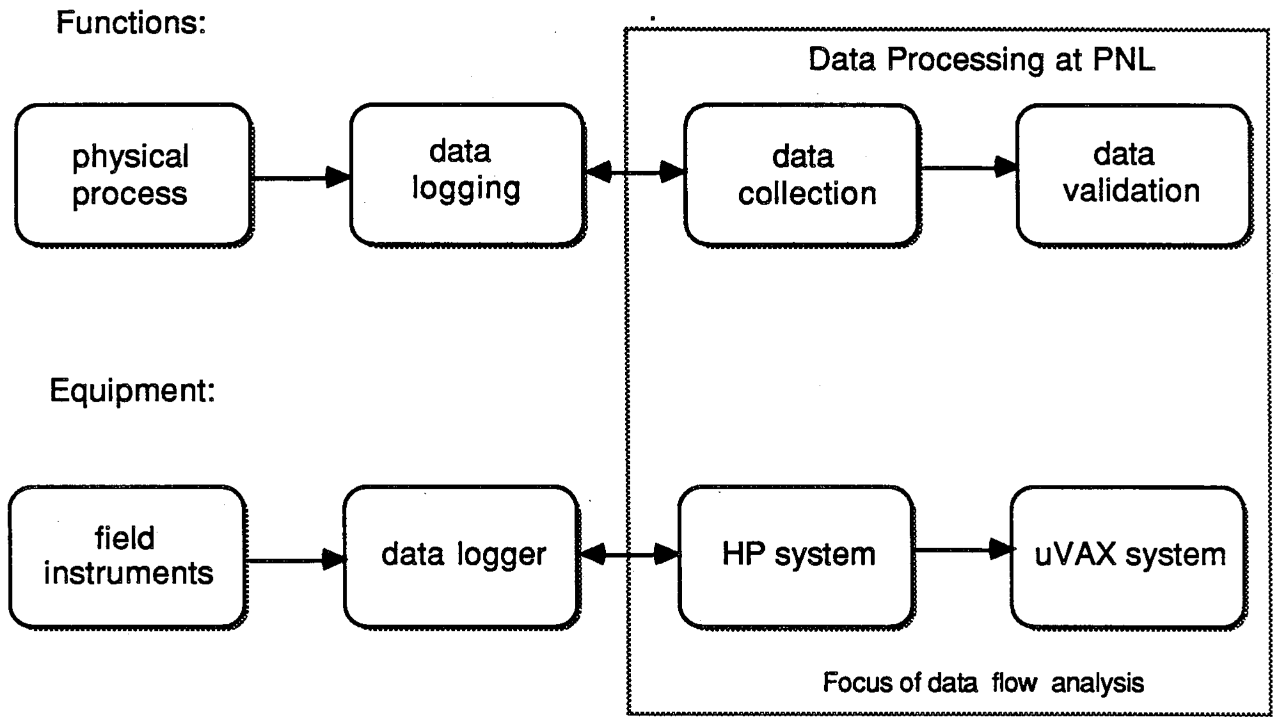
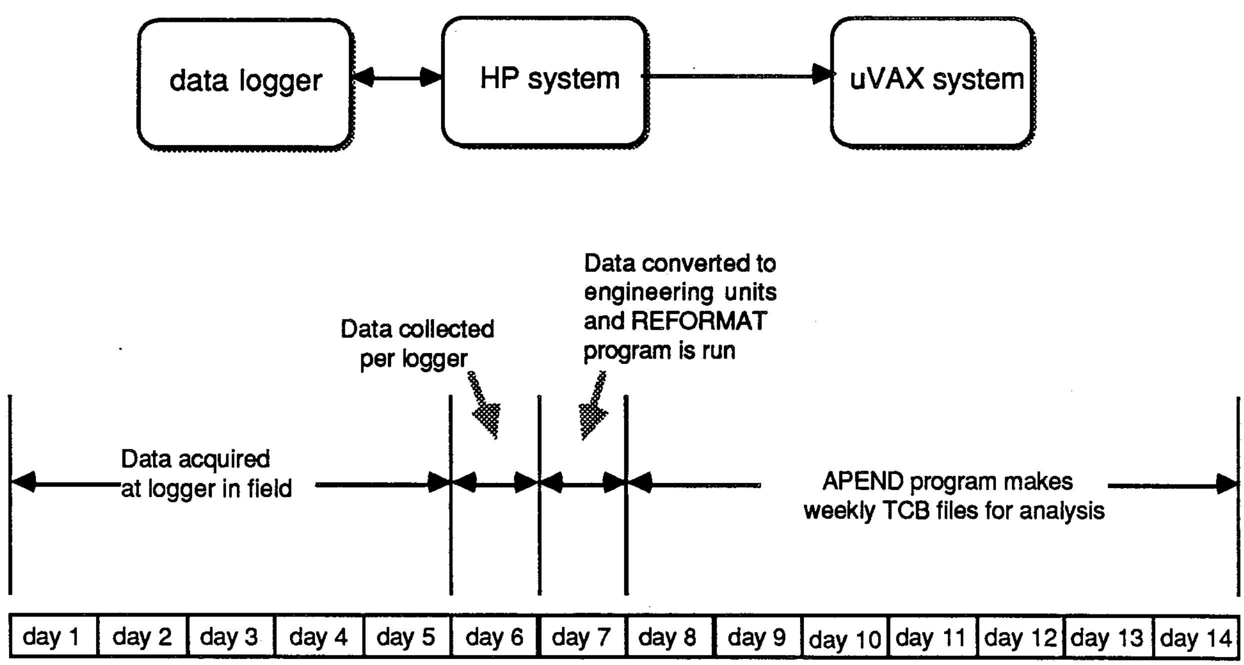


FIGURE 3-2. STEPS IN DATA FLOW FROM LOGGER TO ANALYSIS



1.1. Data Quality and Data Capture

Captured data can be corrupted in a number of ways. It is the job of the data collection and validation system to identify and correct these problems, if possible. In general, the sooner problems are identified and corrected, the better. There are two reasons for this. First, early identification should *minimize* the amount of bad data captured, by permitting earlier scheduling of field maintenance. Secondly, less bad data results in less data processing as required to recover useful information.

A valid question is: what benefits would be achieved if the approximate 2-week delay from field data capture to analysis were shortened? The answer is: not much would be gained. ELCAP has already developed a sound and effective approach suitable for such a widely distributed system. That approach has two fundamental bases: 1) make sure that every logger is operating properly before the maintenance people leave a site, and 2) be able to correct for problems encountered in field data capture, within reason.

Table 3-1 identifies major problems capable of corrupting data. Some are correctable by the central data collection or validation software. Several are not correctable, but require field maintenance before data can be collected again. The ELCAP system software design minimizes, within reason, the problems causing data corruption (by correcting data where possible) - in other words, data loss is minimized.

Consider the fact that ELCAP loggers are polled at 35% full. Table 3-1 shows why this is done; many problems are identified only by polling a logger (CPU, modem and instrument failures, and power supply drift). All require field maintenance, and are not correctable by software. Polling simply is not possible when the CPU or modem have failed. Instrument failures are identified during conversion to engineering units. Power supply drift is identified by the REFORMAT software.

Table 3-1. Major Problems Capable of Corrupting Data

- Power outages (correctable by software)
- Bad parameters (correctable by software)
- Clock drift (correctable by software)
- CPU failures (not correctable by software, but identifiable)
- Modem failures (not correctable by software, but identifiable)
- Instrument failures (not correctable by software, but identifiable)
- Power supply drift (not correctable by software, but identifiable)

1.2. Efficiency of Operation

The efficiency of operation of the data collection and validation system can be improved somewhat. The efficiencies are obtained from sharing equipment and reducing required physical space. Some current steps can be reliably automated, reducing operating staff time and forcing greater consistency of actions.

In the central facility at PSL, there are currently three groups of people to consider: data collection operators, data validation operators, and analysts. In the upgrade under consideration, the tasks of data collection and data validation would become more closely coupled or merged. This should provide the capability to compress current steps in verifying data. In addition, IBM workstations could be used for both data collection and validation tasks. Several steps in data transfer between systems would also be automated, like transfer of files with converted data.

Any problems with incoming data are best identified early in the process, where fewer people require coordination of efforts and where supporting information exists to determine the cause of a particular problem. Most major problems can thus be identified prior to analysis (leaving the more subtle ones to analysis). This is accomplished with the current system and will be enhanced with PCDAS.

2. Shared Resources of a Network Environment

An IBM/microVAX network will allow sharing of expensive resources such as disks, printers, terminals and magtapes. This lowers maintenance costs and reduces the floor space required for the system. Also, the operator working environment becomes more compact and accessible, permitting more efficient operation. Figure 3-2 illustrates the network.

Two DEC networking software packages are available, DECnet-DOS and VMS services client/server software. DECnet-DOS is less expensive and appears to have the functionality needed by ELCAP. However, the considerations outlined herein should be explored in detail in the design stage.

2.1. Disks

There are two considerations here: physical and virtual disks. First, consider the physical disks associated with the IBM/microVAX system. There are three: RAMdisk, local hard disk associated with the workstation, and remote hard disk associated with another node (microVAX, or another workstation). The RAMdisk is high speed and low capacity (could be several Mbytes or more). The local hard disk is moderate speed and moderate capacity (30 to 40 Mbytes standard, but larger disks available). The remote microVAX disk is low speed and high capacity (hundreds of Mbytes).

Second, consider the capability of virtual disks - the ability to have application programs write to a specific disk file that may be assigned *at run time* to any physical disk. This is a very valuable capability. Without modifying programs, the effective disk size and performance can be modified, depending on the desired operating mode.

2.2. Printers and Tapes

These can be shared to reduce space and lower equipment costs. Problems with the current HP magtape can be avoided.

2.3. Terminals

An IBM workstation can function as an 'end-node' on DECnet, or it can function as a terminal connected to the microVAX. The remote-terminal capability would permit data collection and validation tasks to be performed from the same location. Most data collection should occur at night, thus daytime data validation should not conflict with it. However, with Microsoft Windows software, data validation could be going on at the same time PCDAS software is functioning. Thus, daytime polling could occur while the data validation operators work.

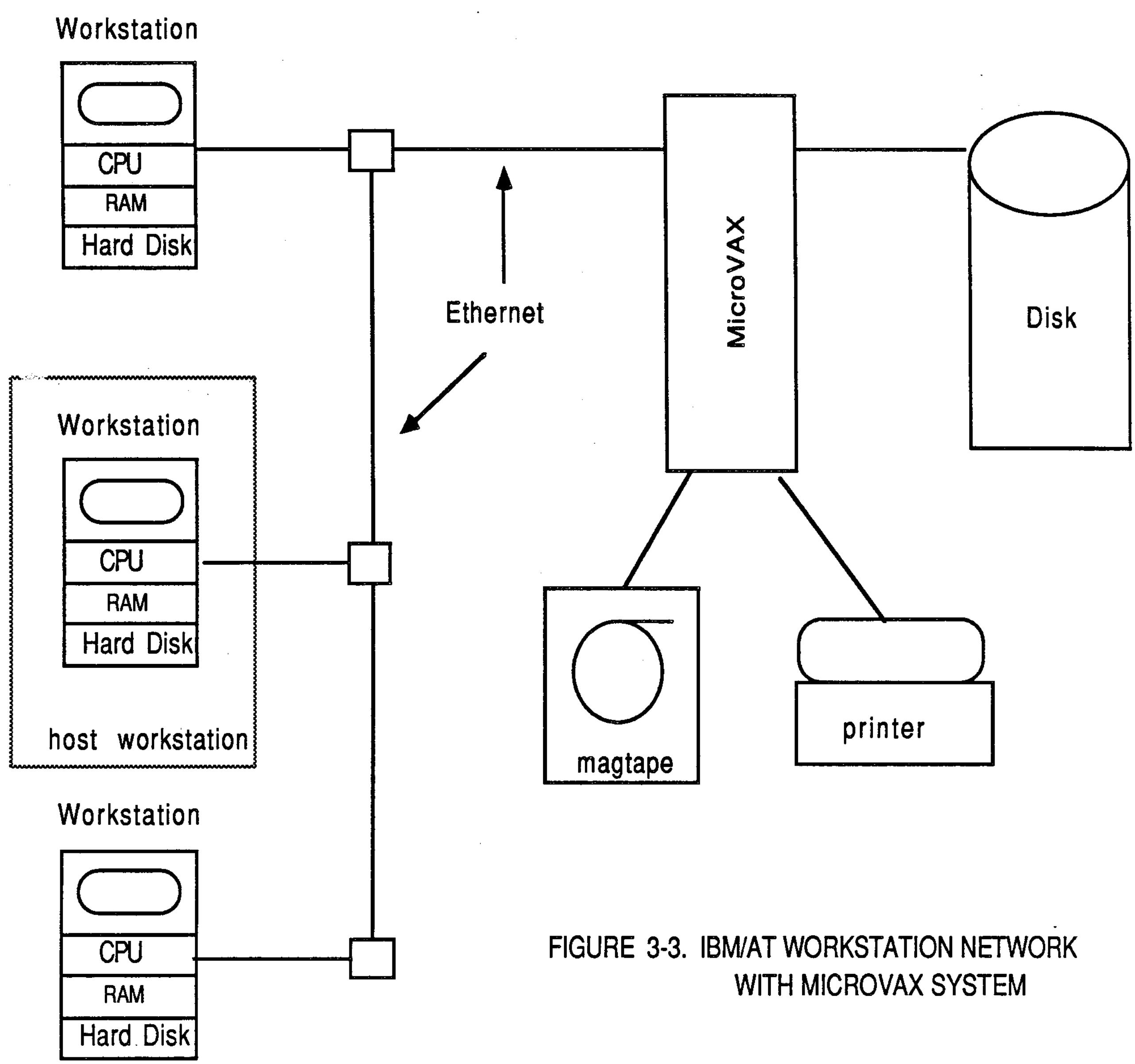


FIGURE 3-3. IBM/AT WORKSTATION NETWORK WITH MICROVAX SYSTEM

Since a workstation can function as an end node on DECnet, any person with access via DECnet to the workstation's network could log on to that workstation remotely. This capability would allow others, not located in the computer room at PSL, to access the system remotely. ELCAP technical staff should find this feature helpful in providing easier access to the system.

3. Data Transfer Methods in a Networked Environment

There are three types of data files pertinent to ELCAP: raw, converted, and support data files. The following paragraphs explain the differences between files, and how the IBM/microVAX network should handle data.

3.1. Raw and Converted Data Files

These data files are the primary end-use data consisting of energy consumption and other site measurements. The raw data files are not transferred to the microVAX. The converted files are now are transferred to the microVAX in ASCII format, via magtape. It will still be best to transfer this data as ASCII files, but transfer it electronically over Ethernet. In fact, the engineering conversion process could write directly to the microVAX disk (virtual disk assigned to the microVAX), thus circumventing the need for operator-directed transfer the converted ASCII files. The Ethernet speed should be sufficient for reasonable transfer.

PCDAS currently has three format options for converted data output; a fourth could be added for output to REFORMAT. All information required by REFORMAT is available on PCDAS, only the proper formatting is required. Preliminary tests indicate REFORMAT (VMS operating environment) should be able to open these files written by the conversion program TRANS (MS-DOS operating environment), with only a subroutine to correct for differences in the use and interpretation of line feeds and carriage returns.

3.2. Support Data Files

Support data files include the non-primary but essential information. Examples are diary messages and site information. Again, the virtual disk capability provides useful options. Each workstation could maintain a copy of this information locally - thus making the system more resistant to failures, but requiring coordination and upkeep of multiple site information files.

On the other hand, each workstation could use a single site information file located either on one of the workstation disks or on the microVAX disk. This system is not as resistant to hardware failures in communications media or remote CPUs; such failures could prevent access to necessary information. However, use of common disk files simplifies file maintenance and enforces consistency.

4. System Operating Modes

The following operating modes outline options for configuring the upgraded ELCAP system. The operating modes primarily address the use of virtual disks for storing necessary data. Each option will have tradeoffs between system maintenance and performance. It appears possible to reconfigure easily among these options, as desired.

As explained in section 2.1 of this appendix, disk access speed and capacity are important in system performance. Depending on the performance and disk-capacity needs of an application, different operating modes can be chosen. Placing all data files (for the system) on one disk makes system backup and maintenance simpler (less prone to human error during upkeep operations); however, that approach usually makes the overall system less fault tolerant.

The tradeoffs in system maintenance and performance relate directly to the choice of disks used for three general types of data files: raw, converted, and system support. System support data files can be subdivided into: 1) operating messages (like diary messages) and status information (like polling status per logger) and 2) site configuration information (like logger parameters). The option entitled 'Combination Hosts' is recommended, based on my current understanding of the desired system operation. However, other options are briefly discussed.

4.1. Standalone

In this case, each workstation stores locally all input and output information. Transfer of data files to the microVAX are performed by the operator or by batch command files. This method maintains system polling integrity with the loss of the network capability (for whatever reason; dead uVAX, failed central disk, etc.), but it requires more operator attention.

4.2. Host Workstation

In this operating mode, one IBM workstation's disk maintains selected data files. This is called the host workstation. It does not necessarily poll loggers, but serves as a spare in case the others fail. Failure of the microVAX should not affect polling under this configuration. Only the failure of involved communications media or interfaces should cause an inability to poll loggers, since necessary data would be inaccessible. This approach balances the simplicity of data file upkeep (single location) with system fault tolerance.

4.3. Host MicroVAX

The microVAX disk could be used for all common data files, thus establishing a single data file source. Disk space would be large, but disk access would be relatively slower. System backup and maintenance would be simplified.

4.4. Combination Hosts

Needed data files could be divided as required among the microVAX and host workstations. Raw data files should reside on the workstation performing the polling. Space is available in RAMdisk and this ensures the best performance. Converted

ASCII data files should be written directly on the microVAX disk. Automated transfer to the microVAX is more important than higher performance.

Supporting data files should reside on the host workstation hard disk. Lower performance is acceptable in order to gain single-point storage of important information. Report programs can be run from the host workstation, which will have pertinent information for all workstations. All sensitive site information will only have one source on the host workstation disk, simplifying backup procedures and avoiding the confusion of multiple copies.

5. Fault Tolerance and Redundancy

Before defining fault tolerance and redundancy in detail, it will be necessary to consider the likelihood of failure for system components and the cost of maintenance. Having considered these, then an acceptable level of fault tolerance and redundancy can be designed into the new IBM/microVAX network. A failure analysis is not done here, but is left to the design stage.

Fault tolerance pertains to the ability of the system to avoid fatal errors in performing system functions. Redundancy has to do with anticipating component failures and providing alternate or spare capability. For example, a failed modem can be replaced with a spare or redundant one. Brief discussion follows.

The microVAX and its peripherals are quite reliable. PNL staff have considerable experience with these systems, so ready internal support should be available. Failures that are not repairable by PNL staff are presumably covered by a DEC maintenance contract. Also, ELCAP has presumably obtained a system with adequate redundancy.

The IBM/AT workstations are reliable, but less so than the microVAX and peripherals. However, IBM hardware is relatively inexpensive. Procurement of a redundant workstation makes sense, and negates the need of a maintenance contract similar to the HP or microVAX systems.