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ENERGY MANAGEMENT AND CONTROL SYSTEMS AND THEIR USE FOR PERFORMANCE MONITORING IN THE LOANSTAR PROGRAM

Final Report

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Kristin E. Heinemeier and Hashem Akbari
Energy Analysis Program

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EXECUTIVE SUMMARY

In the Texas LoanSTAR Monitoring and Analysis program, pre- and post-retrofit energy consumption for each building is monitored using conventional field data acquisition systems. This report summarizes continuing investigations into the usefulness of existing Energy Management and Control Systems to perform this same data collection task.

One emphasis of this stage of the work was on formalizing the evaluation process, by developing guidelines to assess the usefulness of an EMCS for monitoring. These guidelines are based on criteria identified in the previous year's work. The guidelines are presented as fourteen issues to be considered, ranging from what data are monitored, to what format will the data be in when they are received by LoanSTAR. For each of the fourteen issues, methods are presented to guide the assessment process, and alternatives are provided in case an EMCS does not meet the original criterion.

A related part of the work involved using these guidelines to evaluate the EMCSs at three case-study sites, and to assess whether EMCS monitoring would be a suitable alternative in these cases; this also served as a test of the usefulness of the guidelines. In using these guidelines, we found that the EMCS at Texas A&M was the least convenient to use, due to the closed architecture of its network. At all other sites, however, one could potentially connect remotely, although some of these connections might require either purchase of an additional computer, or the use of proprietary software. The guidelines proved to be useful in assessing the characteristics of the EMCSs at the case study sites; facilitating discussions with building personnel; and providing a simple checklist to guide the investigations. Two issues came up that were not adequately addressed by the guidelines, however.

First, with a new generation of EMCSs, with complex network architectures, and multi-tasking capabilities, there are new methods for accessing the systems and transferring data. The method with the most promise is based on windowed software, where data are automatically written to an EMCS computer disk in a format designed to be read by other software, and remote access is made through a window running in parallel with the EMCS software on the same EMCS computer. This method allows use of generic communications software, error-checking, totally transparent connection, simple and quick data transfer, and an easily processed file format. Most EMCSs are not designed to be run under multi-tasking operating systems, although most of the newest versions are incorporating this capability. This should enhance the usefulness of EMCSs for monitoring in future years.

The second issue was that less tangible factors can override the technical aspects of EMCS monitoring covered by the guidelines. One emphasis of the work, then, focussed on investigating the non-technical issues that are quite important in using equipment that is owned by the building management, and was designed for control rather than monitoring functions. The people involved in energy management and EMCS operation at the case study sites were interviewed to explore some of the non-technical aspects. Access to information is crucial in determining how smoothly the monitoring process will be, and even in determining whether or not the EMCS can be used for monitoring. To use an inplace EMCS for monitoring requires assistance from on-site personnel for assessing capabilities, reconfiguring aspects of the system, and in helping in various ways while carrying out the ongoing monitoring. In all monitoring projects, but especially with EMCS monitoring, it is important to identify who, within the organization, has the information, resources, and incentive to be able to provide assistance. At all sites we investigated, between the energy manager, maintenance groups, and manufacturer's representatives, there was enough information. But also at all sites, no one person covered the range of required information, and several people had to be consulted. Since the new generation of methods of accessing data are more advanced, and in some cases can be more intrusive, a real partnership between the building personnel and the monitoring staff is required for a smooth monitoring project.

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I. INTRODUCTION

In a project carried out under the Texas LoanSTAR monitoring and analysis program during 1991, we investigated the use of in-place Energy Management and Control Systems (EMCSs) as an alternative method for building performance monitoring (see Heinemeier et al. 1992). EMCSs often contain the equipment that is typically installed by the LoanSTAR staff for monitoring building and system performance. In the earlier project, we carried out three case studies with LoanSTAR buildings that have in-place EMCSs. We used these EMCSs to collect LoanSTAR-type data. We concluded from that project that each EMCS installation is unique, requiring unique solutions, and that it is often somewhat difficult to assess the capabilities of an EMCS for monitoring. We also identified nine technical criteria which can be used to evaluate a site, and assessed the case studies according to these criteria.

Another conclusion from that earlier project was that it is often the non-technical issues that determine whether or not an EMCS is a good alternative for monitoring at a particular site. These non-technical issues greatly impact the technical EMCS characteristics, and the extent to which the building personnel will be able to provide assistance to personnel engaged in monitoring, both of which determine the feasibility of using the EMCS for monitoring. For example, in some cases, organizational issues, having to do with the agency's administrative structure or institutional philosophy, determined how open the system was to outside access, which determined whether it was possible to use the agency's EMCS for monitoring.

This report summarizes the work completed through 1992. The emphasis of this work was on formalizing the assessment process, and investigating the non-technical issues. In the first part of the project, we developed guidelines for assessing the usefulness of an EMCS for monitoring. These guidelines are based on the evaluation criteria identified in the previous year's work. The second part of the project involved using these guidelines to evaluate the EMCSs at three case-study sites, and to assess whether EMCS monitoring would be a good alternative in these cases. This was also an opportunity to test of the usefulness of the guidelines. In the third part of the project, we interviewed personnel involved in energy management and EMCS operation at the case study sites to explore some of the non-technical aspects.

II. GUIDELINES FOR EMCS MONITORING*

EMCS-based monitoring is, conceptually, a very straightforward matter: if all the required hardware and software are present at a site, they can be used for monitoring. In practice, however, it can become more complex. The fact that an EMCS is present at the site does not necessarily mean that it can be used for monitoring. Even if one knows that the EMCS model used at a site is the same as one that was used for monitoring at a previous facility, differences in installed options, or in the degree of utilization of the existing capabilities may prevent the system from being used. In our case studies, we found some systems that could begin collecting data immediately with little or no startup effort, and others that could not be used to collect data. In a few cases, it took considerable time to discover whether the system would work or not. Sometimes, if we didn't ask an EMCS operator a question about his or her system's capabilities in exactly the right terms, we did not get the correct answer. Since EMCSs are designed to be highly

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*This section was also presented in Heinemeier and Akbari, 1992a.

adaptable, capabilities and monitoring costs often must be evaluated on a site-by-site basis. However, knowing what questions to ask and what the answers mean makes determining a system's capabilities much more straightforward. Having the requirements for monitoring written down and as clearly specified as possible, in the form of guidelines, should help. Table II-1 summarizes guidelines that can serve this purpose.

The guidelines presented here can be used by monitoring contractors or monitoring program planners as a yardstick for evaluating whether an in-place EMCS at a particular site can be used for monitoring as is, whether it will require modification, or whether dedicated monitoring equipment must be installed. The guidelines could also be used as the basis for design specifications for EMCSs with monitoring capabilities, for use in monitoring programs.

Note that these guidelines do not represent the current technology: none of the systems that we encountered included all of these functions. (However, in each case the EMCSs were not the latest models available from the manufacturers). The guidelines can be thought of rather as a standard for comparison. The fact that a system does not fit these guidelines does not imply that it cannot be used. On the contrary, in most cases, some alternative means of achieving the objective can be worked out. For example, it may be possible to install additional hardware or software to supplement the existing system less expensively than installing an entire monitoring system. Just as the applicability of an EMCS for monitoring must be evaluated on a case-by-case basis, individualized evaluation of the feasibility and costs of supplementing the existing system may be required.

The guidelines are represented as fourteen specific issues, ranging from the data that are measured and how accurately they are sensed, to what the resulting data format looks like. These guidelines are presented below, along with points that need to be considered, and direction on how to assess the characteristics at a site, and what alternative methods may be available.

Data Points: The physical attributes necessary for analysis should be measured.

In most cases, the sensors used in an EMCS are very similar to those used in dedicated monitoring projects. They can include power transducers or pulse-counting energy meters, as well as temperature, pressure, and humidity sensors. Sensors are installed to meet the building's, and not the monitoring project's objectives. Hence, while certain variables such as whole-building energy consumption are often measured, submetered end-use consumption often is not measured.

To determine whether or not a system includes the sensors needed for monitoring, the EMCS operator can usually generate a list of all the points (input and output) connected to the system, and display the definition of individual points, including their engineering units, calibration constants, and sampling frequency. One should identify these points on EMCS or building plans, then tour the building to identify any obvious problems with the sensors. If the necessary points are not measured, one might be able to install ones own sensors, while making use of existing EMCS networking and data storage capabilities. Installing a few sensors may still be much less expensive than installing an entire data acquisition system. However, due to interference, electrical isolation, and liability considerations, the EMCS operator and building owner should be consulted early on. Alternatively, since EMCSs have access to a great deal of

TABLE II-1. Guidelines for EMCS Monitoring

- Data Issues
  - Data Points: The physical attributes necessary for analysis should be measured.
  - Data Accuracy: Data should be of sufficient accuracy to perform analysis.
  - Sensor Calibration: Sensors should be in proper calibration before monitoring begins.

- Storage Issues
  - Data Recording: Software and hardware should permit recording of historical data.
  - Data Averaging: Data should be available in the form of averages over user-selected intervals. Electricity should be reported either as the average power drawn or the total energy consumed over an interval.
  - Data Storage: The system should have an available data storage capacity sufficient for monitoring applications.
  - Data Time Format: Historical data should be recorded at specified times, not at specified intervals. If the system is restarted, it should begin collecting data at the correct time.

- Access Issues
  - Remote Connection: The user should be able to connect to the EMCS remotely, using generic communications software.
  - Remote Data Transfer: A mechanism should be available either to display a trend report on the screen of a remote computer that is running generic communications software, or to transmit an ASCII file from the host computer disk directly to the disk of the remote computer.
  - Simple Process: The user should be able to request historical data with a simple command.
  - Rapid Process: The time required to transmit the data should be as short as possible.
  - Error Detection: Any data transmission errors should be automatically detected and corrected.
  - Local/Remote Interference: Remote access to data should not cause conflicts with control of building or other EMCS operations, or require too much assistance from the EMCS operator. Conversely, the EMCS operator activities should not interfere with data collection.
  - Data Format: Data should be available in an easily processed format.

other information on building operation, it may be possible to achieve the analysis objectives with different input data. For example, monitoring lighting on-time rather than submetering lighting load may provide the necessary information for evaluation of the performance of a lighting controls retrofit program.

Data Accuracy: Data should be of sufficient accuracy to perform analysis.

Sensor accuracy is very important in a monitoring project. The required accuracy will, of course, depend on the analysis that will be performed. Since the same kinds of sensors are available for use in an EMCS as in a dedicated monitoring installation, the same accuracy should, theoretically, be possible. The accuracy of the installed sensors is specified by the EMCS contractor, in order to be adequate for control of the building. For those sensors used primarily for control, reasonable accuracy is usually required, and the building personnel have incentive to monitor whether or not the sensors are providing believable values. However, other types of sensors are used primarily for indication, and accuracy may not be as high a priority. Recently, more attention is being paid to sensor accuracy in EMCSs. In their Standard 114-1986, the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) has written guidelines for specifying measurement requirements and recommended methods of verifying accuracy of EMCS instrumentation (ASHRAE 1987). Standard 114-1986 provides typical values for accuracy required for different applications. The suggested accuracies for energy calculation applications are shown in Table II-2. For some applications, more accurate sensors may be required. For example, if the range of water flow is 1-30 feet per second, the error at full scale would translate to a significantly higher percentage error at low flow rates.

TABLE II-2. Data Accuracies Typically Required for Energy Calculation.

Space DBT	±0.5 °F
Hot Air Supply - DBT	±1 °F
Cold Air Supply - DBT	±1 °F
Outside Air DBT	±1 °F
Dewpoint	±3 °F
Hot Water - S&R	±2 °F
Chilled Water - S&R	±1 °F
Condenser Water - S&R	±2 °F
Temp. Difference - Water	±0.5 °F
Temp. Difference - Air	±0.5 °F
Flow - Water	±2.5 % of full scale
Flow - Air	±2.5 % of full scale
Pressure - Air Duct	±1.0 % of full scale
Pressure - Air Building	±1.0 % of full scale
Pressure - Refrig. Water	±2.0 % of full scale
Electric Meters	±0.25 % of reading

Source: ASHRAE Standard 114-1986.

Documentation of design accuracy should be made available by the EMCS operator. The accuracy of sensors, transducers, and analog-to-digital converters must all be considered. The "Measurement and Instrumentation" chapter in the *ASHRAE Handbook of Fundamentals* also provides information on sensor accuracy considerations (ASHRAE 1989). If documentation is not available, it may be necessary to perform on-site tests. Another alternative is to install new and calibrated sensors. The economic advantages of such an approach would have to be evaluated on a case-by-case basis.

Sensor Calibration: Sensors should be in proper calibration before monitoring begins.

It is important to calibrate sensors, or, at least, to compare EMCS values with some reference to determine their accuracy. This is especially important when data accuracy is not crucial to the operation of the building. In these cases, the building managers may not have incentive to double-check values or replace a sensor that is known to provide false values. In an earlier study, an electrical meter was miscalibrated by a factor of two (Heinemeier and Akbari 1987). Since they were only interested in changes from day to day, and not in the absolute value, the building personnel had never discovered the problem. It is important to note that quality assurance is a difficult issue even with dedicated monitoring, particularly in large programs with several monitoring contractors (see, for example, O'Neal et al. 1992, and Halverson et al. 1988). The cost of sensor validation must be figured into the total program cost whether dedicated or EMCS-based monitoring is being performed.

Sensor calibration is often performed at the factory, but many types of sensors should be periodically recalibrated. The frequency with which sensors should be recalibrated depends on the type of sensor. Sensors that are open to the environment, and sensors that include mechanical parts are particularly in need of periodic recalibration. The EMCS operator should have access either to information on factory calibration of sensors, or to documentation of subsequent recalibration. If this documentation is not available, one may have to calibrate the sensors in the field. Since calibration is important for controlling the building, the EMCS operator might be willing to participate in the calibration efforts. If it proves impossible to calibrate the sensors and accuracy is important, then one may want to install new sensors.

Data Recording: Software and hardware should permit recording of historical data.

The current value of all EMCS points is usually available for immediate use in control applications, (for example in a calculation to determine if more cooling is required). These data, then, can be stored for further analysis. Because of the usefulness of this type of data for building operation, most EMCSs have a facility for storing large amounts of data, often called "trending," (trends, also referred to as archives or history reports, are discussed later in this report).

The EMCS operator should know if the EMCS has a facility for trending, archiving, or collecting historical data. Copies of manual pages summarizing the trend facility may be required to determine if it is really applicable. It is also helpful to get a demonstration of the procedure for displaying or transmitting trend data. It is possible that the necessary software is available from the manufacturer, but has not been installed at the site. In that case, the software could be added. However, the cost of this software addition will most likely have to be borne by the monitoring project, and this cost should be compared with that of a dedicated data acquisition system.

Data Averaging: Data should be available in the form of averages over user-selected intervals. Electricity should be reported either as the average power drawn or the total energy consumed over an interval.

For some variables such as temperature, it might be acceptable to take a "snapshot" of the value once an hour. For most variables, such as power, however, this would be hopelessly inaccurate. There are several ways to measure electrical power and energy consumption. One method uses a pulse counter installed on a utility kWh meter or watt-hour transducer. Each pulse corresponds to a certain amount of energy. The EMCS accumulates pulses--or kWh--and reports cumulative energy: one reading is subtracted from the next to determine the total energy consumed over that period. In another method, power is measured directly using a watt-transducer, and an analog signal, proportional to the instantaneous power, is read by the EMCS. This instantaneous power must usually be averaged to be used for energy analysis. Although a very fast sampling rate would be required to catch quick variations in the load, fairly accurate hourly energy consumption values may be possible with typical EMCS sampling rates.

When monitoring electric power, the engineering units associated with the point definitions should provide the necessary information. If it is shown as kWh, then the data are average or total energy. If it is kW, then one needs to determine if the trend facility is capable of providing data on an averaged basis. If averaged data are not available, it may be possible to use instantaneous samples, depending on the analysis and the type of point. Some systems have a method of "totalizing" data over certain periods. But whether or not data totalized over an hour can be recorded each hour will have to be determined. Another novel way of averaging, used in some systems, is to record an instantaneous sample, only when the value has changed by some predefined level. This is referred to as Change of Value (COV) monitoring. COV monitoring has the characteristic that when the value is changing quickly, very short interval data are collected; and when the value is changing very little, very long interval data are collected. COV monitoring is discussed in greater detail in Heinemeier et. al, 1992.

Data Storage: The system should have an available data storage capacity sufficient for monitoring applications.

Before data are downloaded to the remote computer, they will be stored for some period of time on-site. Most systems have sufficient storage capacity for this, at least in theory. Capacity is usually specified as the number of points that can be trended, the maximum number of samples that can be stored per point, or the total memory capacity that is available to trend data. In practice, however, some systems may be limited by communication considerations rather than storage space. Many EMCSs have a distributed architecture with networked remote control units (RCUs) and the ability for a host computer to be connected in the network. Data can either be stored on the RCU, on the host computer, or on the host's peripheral data storage medium (hard or floppy disk or magnetic tape) for longer term storage. With this distributed architecture, information other than that being trended for energy monitoring is traveling along the network paths, and one must consider both the impact of energy monitoring traffic on other operations, and the impact of the other operations on energy monitoring. In these systems, networking concerns may be more important considerations than raw data storage space or absolute point limits in evaluating the usefulness of an EMCS for monitoring. Also, at some sites, the available trending capacity is more fully utilized than at others, leaving little capacity free for energy data. Availability of the trend capacity is therefore difficult to predict for a particular site by simply knowing the EMCS model.

One needs to find out what absolute hardware and software limits exist, and how much of the capacity is currently in use. The trend manual will have the absolute limits, but the system operator usually has the best knowledge of how fully loaded the system is, and if more points can be added. If there is not enough storage capacity, one alternative is to purchase more memory. Or, it may be that there is enough space on a temporary basis for short term monitoring. It may also be possible to download the data more frequently, or collect data at a larger recording interval, so that fewer data are stored. With COV monitoring, a relatively high COV level will result in less frequent data collection, although this will result in reduced accuracy.

Alternatively, it may be possible to install an additional computer in the EMCS network to collect the data. The cost of this additional computer may, in some cases, make EMCS monitoring not cost-competitive with dedicated monitoring. Usually, however, a fairly unsophisticated computer can be used for this purpose. This might be "last year's model," which can often be purchased quite inexpensively as surplus equipment. The cost of this computer would have to be weighed against the cost of dedicated monitoring equipment.

Data Time Format: Historical data should be recorded at specified times, not at specified intervals. If the system is restarted, it should begin collecting data at the correct time.

In order to be compatible with data from other monitoring projects, other buildings within a project, and with weather data, the data available from an EMCS should be reported at the top of each hour. Many EMCSs are reportedly capable of recording hourly data. However, in some cases, if the system is rebooted, the data collection time may shift to the time when the system was rebooted.

One can tell if the system will reliably collect data at the correct times by looking at how the trend point was defined. If it does not ask for the time to begin collection, it might not be reliable. Another way is to look at some collected hourly data. If the data are recorded at strange times, (for example, at 13 minutes after each hour) it has probably shifted. If the system collects data at specified intervals rather than at specified times, the only alternative is to periodically check the data, and reset the trend if it has shifted. This, of course, adds to the difficulty and costs of EMCS monitoring, and may make it impractical in some cases.

Remote Connection: The user should be able to connect to the EMCS remotely, using generic communications software.

In order to access the data remotely, one can make use of the fact that most EMCSs allow for a remote computer to be tied into the system's network. This remote computer can either be a "dumb" terminal or a microcomputer, equipped with a modem and communications software, and emulating a terminal with standardized protocols. Communication takes place over commercial telephone lines. Most EMCSs include the required hardware and software for communications, and have a telephone line dedicated to the EMCS use. These can usually be used by monitoring projects.

A demonstration of the system will show that it is possible to connect remotely. If it is not possible to connect to the host computer, it may be possible to connect through an RCU. If there is no way to connect to the EMCS remotely, it may suffice to visit the site periodically and collect the data on a diskette, or to have the operator do this and mail the diskette. While this might be impractical for large groups of buildings, it may be perfectly adequate for a smaller sample.

Another alternative is to take advantage of the existing EMCS sensors, while installing additional wiring and dataloggers. One might also be able to take advantage of the EMCS networking capabilities, and collect data from all over the building using a datalogger taking its input from the EMCS.

Remote Data Transfer: A mechanism should be available either to display a trend report on the screen of a remote computer that is running generic communications software, or to transmit an ASCII file from the host computer disk directly to the disk of the remote computer.

Simply being able to connect to an EMCS remotely is often not enough. One must also be able to access the EMCS's stored data. There are two ways of downloading data: displaying a report on the remote computer's screen, or transferring a data file. In the first method, one uses the remote computer to log onto the EMCS system, and run the trend utility, requesting that the data report be presented on the screen. The entire session is recorded in a log file on the remote computer, so that while the report is displayed on the remote screen, it is simultaneously recorded on the remote disk. In the second method, the data are stored to an EMCS disk file, and transferred to the remote computer, using some kind of file transfer algorithm. The file transfer algorithm can either be embedded in the EMCS computer software, or can be implemented in a communications program, running in parallel with the EMCS software. If communications software is running in parallel, the EMCS must be on a computer with an operating system that allows multiple processes, and the asynchronous communications must not conflict with the more essential EMCS tasks.

The EMCS operator should know if either of these methods are possible. If the EMCS operator suggests that the first method is possible, make sure the data can be displayed on the screen, rather than to a printer or disk. In some cases, the data can only be sent to a printer. At one such site, the system was reset so that a remote computer was configured to look like a printer. The EMCS thought it was printing data to a printer, but they were actually being displayed on a remote computer screen and stored in a log file. In such a situation, care must be taken to reset the port, otherwise it will still be configured as a printer for the next user.

Most EMCSs don't have the capability to transmit disk files. If an EMCS in question does have this capability, make sure the remote computer doesn't have to be running proprietary software. The cost of this software may be prohibitive, and the software can be used only for that particular EMCS model--potentially a problem. If neither of these methods are available, the datalogging functions of the EMCS probably cannot be used.

Simple Process: The user should be able to request historical data with a simple command.

When performing case studies, it is possible to log into an EMCS manually to download data. However, in a larger-scale project, a more automated method of data retrieval is needed. Most communications software packages allow the user to create a script file, which can automatically dial the phone, watch for cues coming from the EMCS, issue the appropriate responses, and then move on to the next building. Ideally, after dialing the phone, the script file should only have to provide the correct login name, and then issue one-line commands to request the data. Often, however, one has to specify information such as what points are of interest, what period of time the report is to cover, what recording interval should be used, and where to send the report (to a screen, printer, or data file).

A demonstration will indicate what commands are used to request data. This will give an indication of how complex the interaction is, and will also help, later on, creating a script. Often, the EMCS will have a "verbose" mode, in which a prompt is issued for each part of the command, and a "concise" mode, in which an entire command is entered on a command line. One needs to identify if there is a shorter concise command that can be used. A simple procedure is not an absolute requirement, but it makes automation much easier.

Rapid Process: The time required to transmit the data should be as short as possible.

The amount of time required for transmission of the data is also an important consideration in larger scale projects. Most EMCSs allow a dial-in connection at 1200 or 2400 baud. However, the speed of the transfer will depend to an even greater extent on other factors: whether the data are in a binary or ASCII raw data file, or are embedded in a report; how concise the report format is; whether or not the report is generated as it is being displayed; and how busy the EMCS is in accomplishing other tasks.

The time required for transfer can be determined from a demonstration, which notes the time before the data were requested, and after the transmission. Using this time along with the number of useful samples obtained (i.e., only the data of interest) and the number of ASCII characters per sample, one can calculate the average number of characters transmitted per second. This can be compared to a reference value of about 240 characters per second at 2400 baud, or 120 at 1200 baud. Ideally, the value obtained from the demonstration should not be less than about a tenth of the reference value. In our experience, many systems meet this criterion, although some systems are significantly slower than this. Alternatives, if the data transfer is too time consuming, are to download less frequently (so that there is proportionally less header information), to use a longer data interval (obtaining fewer samples), to use a higher speed modem (9600 baud modems are available, but may have accuracy tradeoffs, unless a proper protocol is used), or to find out if there is an archive facility that does not generate the report as it is being displayed, and may have less header information.

Error Detection: Any data transmission errors should be automatically detected and corrected.

Errors can occur, not only due to faulty or inaccurate sensors, but also when transmitting data from the site. Since data are traveling over commercial telephone lines, noise in the phone lines can obliterate data, or change values.

In systems that have the capability to transmit data files rather than display them on the screen, it may be possible to use a public-domain file transfer protocol, such as Kermit, which can both recognize and correct bad data. One needs to determine if the transmission uses a standard protocol, or if the protocol includes error detection and correction. Systems that only allow screen display are susceptible to communications errors. If data checking is not possible, one alternative would be to send the data twice and compare it. If differences are detected, the data should be sent again. This redundancy obviously requires tradeoffs with quick transfer and easy processing.

Local/Remote Interference: Remote access to data should not cause conflicts with control of building or other EMCS operations, or require too much assistance from the EMCS operator. Conversely, the EMCS operator activities should not interfere with data collection.

With current systems, there is a potential for energy monitoring to interfere with EMCS control operations. In particular, there can be a conflict if the EMCS phone line is used both for remote monitoring and EMCS operation. Also, since operators are working with the same data space, it is possible for them to delete or reset trend data. In some of our case studies, this was a significant problem.

Asking the EMCS operator is really the only way to determine if your connections will cause interference. Usually, if the connection is made at night, interference is minimized. If tying up the system's telephone is a problem, one could consider purchasing an additional phone line and modem. If the system has a distributed architecture, and tying up the host computer is a problem, it might be possible to call into an RCU instead. Another alternative is sometimes to install another computer into the EMCS network, dedicated to data collection and communications. The cost of this alternative would have to be carefully considered. Perhaps the best strategy is to develop the best possible relationship with the EMCS operators, so that they will feel comfortable with data-collection activities. The operators need to understand that the data are important, and should not be deleted or the trend log altered without warning. One needs to keep in constant communication with the operators to minimize occurrences of these kinds of problems. One way of accomplishing this is to provide feedback to the operators (for example, by circulating plots of the data to allow them to see what has been collected).

Data Format: Data should be available in an easily processed format.

Although data processing can be done on the remote computer, the easier the data are to process, the more viable this technique will be. The ideal format would be one column for each point, with no header or footer information. A header should indicate English-like point names and engineering units. Each line should be time-and date-stamped. Columns should be separated by spaces, commas, or tabs. Lines should not be longer than 80 characters. Missing data should be identified as missing, not blank or zero. Finally, each line should be concluded with a carriage-return.

Some additional types of processing that may have to be done are: parsing the date into day, month, and year; parsing the time into hour, minute, and second; subtracting cumulative values to obtain differences, removing the login, command line, and header lines from the log file; calculating the time for each sample, if only the beginning time and sampling interval are known; and transposing the data from rows to columns. All of this processing will add to the cost of collecting the data.

Some of the problems we encountered were that only the first 80 characters of a 132 character line displayed, carriage returns were not transmitted, a status line appeared periodically in the middle of the data, the data were not in conventional columnar format, the data were in COV rather than hourly format, missing data were blank, and numeric and alphanumeric data were mixed. All of these could be dealt with, but when taken together, made data collection rather cumbersome.

The format of the data collected should be evaluated during a demonstration. If the format is not appropriate, alternative formats are sometimes available. Sometimes trend data are available in a "spreadsheet compatible" format, which is easily imported into a spreadsheet program, and can easily be processed. One will need to make sure the data file can be transmitted--often it can only be recorded onto the EMCS disk.

III. EVALUATION OF EMCS MONITORING CAPABILITIES

In order to assess the use of EMCSs for retrofit monitoring, we closely studied the EMCSs at two LoanSTAR sites: the State of Texas Capitol Complex and Texas A&M University. We interviewed the Energy Managers and Maintenance Supervisors at both sites, and contacted the EMCS manufacturers to obtain as much information as possible about the systems. We also investigated the EMCS at the Compaq Computer Corporation headquarters. Although it is not a LoanSTAR retrofit site, it was an interesting contrast to the two other agencies.

III-A. State of Texas Capitol Complex

Most of the state buildings in Austin, the capitol of Texas, are a part of a five million square foot complex of 42 buildings. The complex is currently organized into five geographic zones. Some of the Complex buildings are listed in Table III-A-1. This table shows what type of EMCS is installed in the building, and in which zone the building is located. The EMCS and Zone are explained in the table Key. Also, the Code from this table refers to codes used on the map shown in Figure III-A-1. Several buildings are sites for LoanSTAR retrofits, and these are also indicated in Table III-A-1, in the column headed "LS". The buildings are maintained by the General Services Commission, and steam and chilled water are generated in several of the buildings, and distributed to the other buildings.

Previously, their EMCSs consisted of about 2800 points on a Honeywell Delta 1000 system. This system did not function properly, and they eventually removed the building controls elements, and use the system only for fire and security. About 35 buildings are on this system, with about 10,000 smoke sensors that use a customized front end. There are six major systems currently in use at the complex: the Honeywell security and fire system, a Landis & Gyr Powers System 600, a Honeywell Excel Classic, an Andover system, a Johnson Controls 85/40, and a Teletrol Integrator 286. The control room in the

TABLE III-A-1. State of Texas Capitol Complex Buildings.

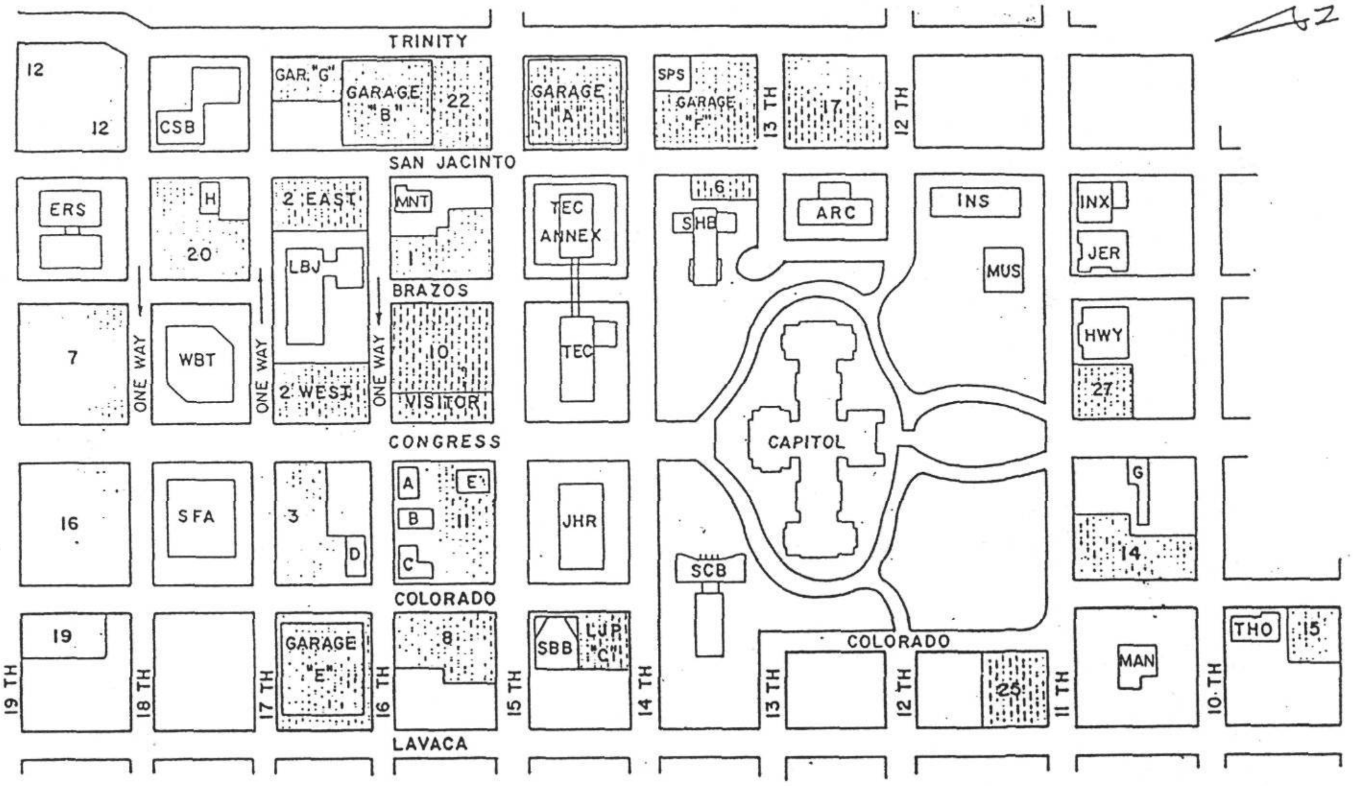
Code	Name	EMCS	Zone	LS	Floor Area (ft^2)
CPX	Capitol Extension (future)	TELE (future)	CAP	*	(future)
SHB	Sam Houston Building	TELE	CAP	*	182,961
BHB	Brown-Heatley Building	JC85	REM		260,913
OCS	One Capitol Square/Wm. Clements	L&GP	SFA		461,611
WBT	William B. Travis	EXCL	SFA	*	491,118
JER	James Earl Rudder Building	EXCL	REM	*	86,394
SCB	Supreme Courts Building	ANDO (future)	CAP		(renovation)
PDB	Price Daniels Building	ANDO	CAP		145,192
SFA	Stephen F. Austin	DELT	SFA	*	470,000
INX	Insurance Annex Building	DELT	REM	*	61,734
LBJ	Lyndon B. Johnson	DELT	SFA	*	308,081
JHR	John H. Reagan	DELT	CAP	*	167,756
CAP	State Capitol	DELT	CAP	*	369,445
INS	Insurance Building	DELT	CAP	*	102,636
ARC	Archives and Library	DELT	CAP	*	120,055
MAN	Governor's Mansion		REM		13,347
CSB	Central Services Building	PNEU	SFA		92,887
MUS	Museum	META	CAP		(renovation)
SAN	San Antonio		SAN		-
THO	Ernest O. Thompson	PNEU	REM		73,272
WIN	Winters Complex (3 Bldgs)	DELT	WIN	*	503,162

Key:

TELE	Teletrol Integrator 286	LS	LoanSTAR Site
JC85	Johnson Controls 85/40		
L&GP	Landis & Gyr Powers System 600	CAP	Capitol Zone
EXCL	Honeywell Excel	REM	Remote Zone
ANDO	Andover	SFA	S.F. Austin Zone
DELT	Honeywell Delta 1000	SAN	San Antonio Zone
PNEU	Pneumatic controls--no EMCS	WIN	Winters Zone
META	Johnson Controls Metasys		

basement of the Sam Houston building had 6 CRTs to keep in touch with these different systems. Most of the systems have modems and phone lines. They are used 24 hours a day to communicate with this control room.

We have focussed on the Teletrol system, because it is the most monitoring-capable EMCS installed in a LoanSTAR building (the Sam Houston Building and, in the future, the Capitol Extension). Also, this seems to be the system of choice for the Capitol personnel. We will also discuss draft EMCS specifications since these specifications will define the characteristics of future EMCSs.



ARC - ARCHIVES AND LIBRARY
(LORENZO DE ZAVALA)
CAP - STATE CAPITOL
CSB - CENTRAL SERVICES BUILDING
ERS - EMPLOYEES RETIREMENT SYSTEM
HWY - HIGHWAY BUILDING
INS - INSURANCE BUILDING
INX - INSURANCE ANNEX BUILDING
JHR - JOHN H. REAGAN
LBJ - LYNDON B. JOHNSON
LJP - LEON JAWORSKI PLAZA
MAN - GOVERNOR'S MANSION
MNT - MAINTENANCE SHOP BUILDING
▨ - PARKING LOTS

MUS - MUSEUM
SBB - STATE BAR BUILDING
SCB - SUPREME COURTS BUILDING
SFA - STEPHEN F. AUSTIN
SHB - SAM HOUSTON BUILDING
SPS - SENATE PRINT SHOP
JER - JAMES E. RUDDER
TEC - TEXAS EMPLOYMENT COMMISSION
THO - ERNEST O. THOMPSON
WBT - WILLIAM B. TRAVIS

A- GETHSEMANE CHURCH
B- ARCHEOLOGY LAB
C- CARRINGTON-COVERT HOUSE
D- EL ROSE

E. - AMERICAN LEGION BUILDING
F. - EPPRIGHT BUILDING
G. - OLD BAKERY
H. - SAN JACINTO WAREHOUSE

BUILDINGS OUT OF CAPITOL COMPLEX
ANSON JONES BLDG. 410 EAST 5TH. ST.
COSMETOLOGY BLDG. 1111 RIO GRANDE ST.
JAMES HARPER STARR 107 WEST 6TH. ST.
STATE WAREHOUSE 401 EAST 1ST. ST.
JOHN H. WINTERS COMPLEX 701 WEST 51ST. ST.
AIRCRAFT POOLING BOARD 4900 OLD MANOR
COMM. FOR THE BLIND ADMINS. BLDG. 4800 N. LAMAR
HUMAN SERVICES WHS. 1111 NORTH LOOP
STATE PURCHASING & GENERAL SERVICES COMMISSION

FIGURE III-A-1. Map of State of Texas Capitol Complex, in Austin. The building codes are used in Table III-A-1 to indicate which buildings have EMCSs installed.

Teletrol Systems

The Teletrol Integrator 286 was chosen for the Sam Houston Building because it is essentially a PC, and it can "talk" to other EMCSs from different manufacturers. This building previously used a Johnson Controls pneumatic control system. When the Teletrol system was installed, they installed a switch to switch between the pneumatic system and the new DDC system. This was used while debugging the programming. The Teletrol system can be programmed in C, a high-level programming language, which the personnel are comfortable with. Teletrol supplies numerous commonly used subroutines, such as schedules or PID loops. When the system was installed, it was programmed by Teletrol, and then the onsite personnel adapted it as necessary. In the Teletrol Controller box are a PC motherboard, A/D boards, and modem. The Controller can communicate via a 250 kBaud LAN, phone lines, or RS232 connection to a Workstation (personal computer, or equivalent). Figure III-A-2 illustrates the architecture used by Teletrol, and the type of equipment available for this system. The Workstation runs software referred to as *MCP (Management/Communications Package)*. Teletrol uses an open protocol bus, so that it can talk to equipment made by others (for example, VAV controllers).

Data Recording: For the Teletrol system, any point within the system can be trended, using the History facility. Data are stored in the Controller's memory, and they can be retrieved to the Workstation at any time. To view collected data on the Workstation, one must first retrieve the data from the Controller, and then store them in a disk file. Then the disk file contents can be viewed using *MCP* software.

Data Averaging: The Teletrol system can sample data at any interval from once every second to once every 24 hours, or it can be recorded on every scan. The system can also collect average data. When a point is selected to be monitored, the system needs to know what "attribute" of the point is to be monitored. This can be the actual value, the setpoint, or a statistic on the point: the maximum, minimum, or average value of the point over some specified interval. The average statistic is the attribute that would be used in LoanSTAR monitoring. The time interval can be anywhere up to 90 minutes.

This system can also collect COV data, by creating a virtual point which takes it's input from the analog input, but which has a "flux," or granularity, of the desired value. The flux, similar to precision, is the amount by which the analog input value must change before the value of the virtual point changes. It can also be programmed to collect data only when a point's value is outside of a predefined range. While these forms of data collection do not conform with protocols for data collection within the LoanSTAR program, they would be innovative means of collecting very informative data for use in building and system diagnostics.

Data Storage: The Teletrol history facility can record up to 999 samples per point, and can monitor any point within the system. The total number of samples that can be stored in the memory of the controller is 20,000.

Data Time Format: When specifying that the average statistic is to be calculated over an hourly interval, one also specifies at what time the calculations are to begin. It is possible that if the system were restarted, it would stray from the original schedule. However, since the Teletrol system is geared towards flexible user programming it is also possible to custom-program the system to perform the sampling and averaging, and specifically to avoid this problem. The technical support representative of Teletrol

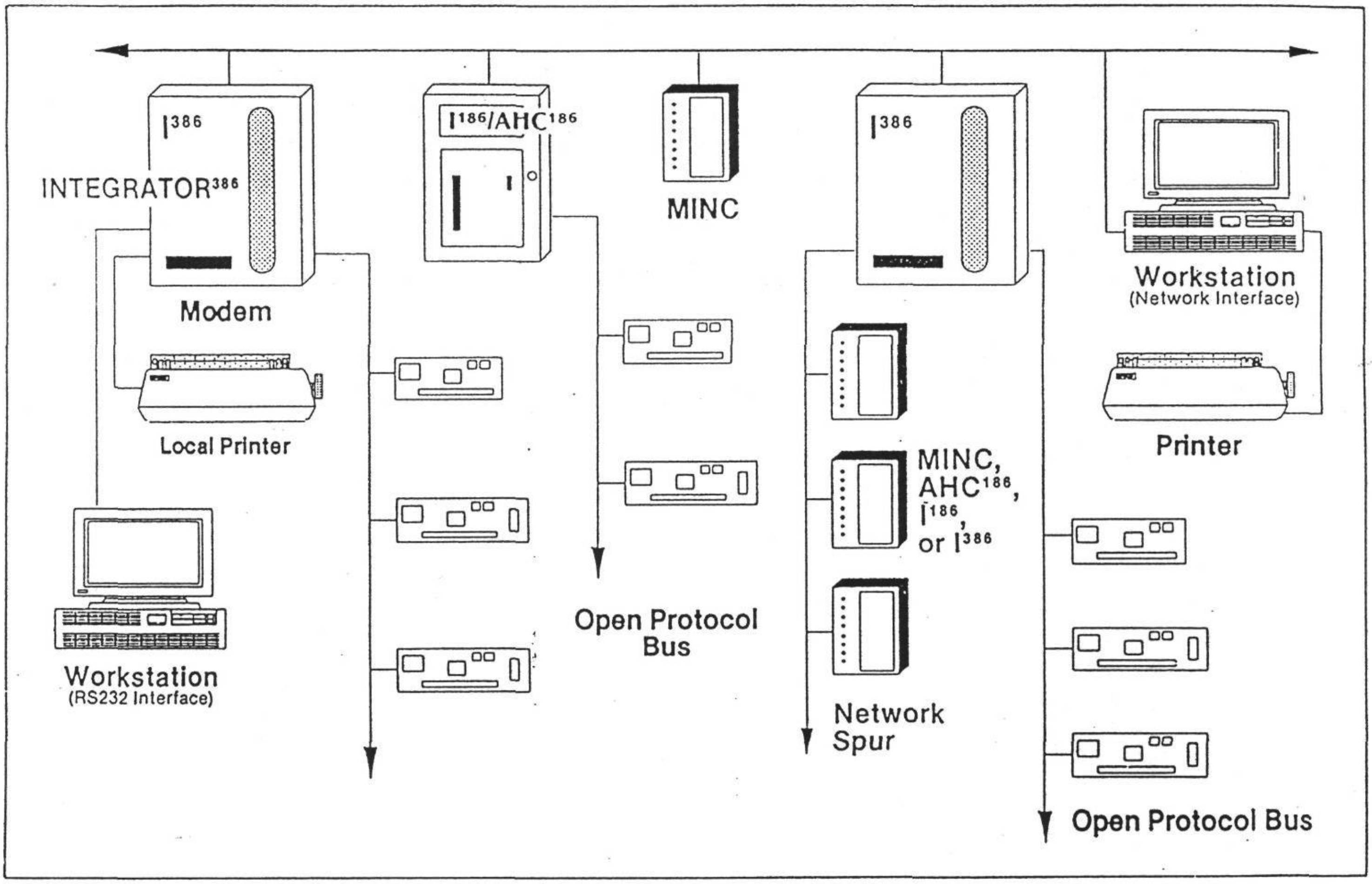


FIGURE III-A-2. Architecture of a Typical Teletrol Integrator Energy Management and Control System. (Source: Reprinted with permission from Teletrol Systems, Inc.)

estimated that this would require on the order of ten to fifteen lines of C code.

Remote Connection: There are several ways in which one might be able to connect to the Teletrol system. These methods are illustrated in Figure III-A-3. Teletrol does not support a generic terminal connection into the Controller, so their proprietary *MCP* software must be running on the connecting computer. This is due to Teletrol's concern for robust and reliable communication with the controller, and a CRC (Cyclical Redundancy Check) error checking protocol is used by *MCP.* The connection can be made via a LAN, RS232, or modem/telephone connection. Since RS232 communication can only be carried out over a limited distance, this requires the polling computer to be on-site. With a LAN connection, similarly, the computer would have to be on-site. Researchers in the Energy Systems Laboratory (ESL) at Texas A&M University are currently investigating the communications and data format issues involved with the Teletrol system by using this method of connection to a dedicated Teletrol Controller, installed in their laboratory. For remote monitoring, a modem connection would be used (see Proprietary Method, in Figure III-A-3). This is not an ideal method of collecting data, since it would require LoanSTAR to install onto its polling computers a different proprietary program for each building it monitors.

Another method (Remote Control, shown in Figure III-A-3) uses the *pcANYWHERE* program. This program essentially allows remote control of a computer. A "host" computer initiates *ahost,* which is a TSR (terminate/stay resident) program, and then invokes the EMCS program. The resident *ahost* program, runs in the background, constantly watching for a modem connection from a remote computer running its counterpart program *aterm.* Once *ahost* detects the presence of another computer running *aterm,* it allows the person using the remote computer to issue commands to the local computer. It is possible to password protect this connection. Any remote computer, then, can run the software on the local computer. The result of all this is that the remote polling computer can run a common and commercially available program to make a connection to the Teletrol EMCS and run the proprietary *MCP* software. Several EMCSs use *pcANYWHERE* for remote communication, so it could be used fairly generally.

A Teletrol Integrator 286, such as the one at the Capitol Complex, can have up to four serial ports: COM1 is used for a modem, COM2 is used for a direct connect to a MCP computer, COM3 is used for the open protocol bus, and COM4 is used for diagnostics. At the Capitol complex, a modem is installed in COM1, but it is in constant use to communicate with the remote MCP console. One possible solution is to install another device in the system. At a minimum, this could be an IBM PC (or compatible) with at least 210K of free RAM, a disk drive large enough to hold the collected data (probably not much), and a modem and phone line to communicate with LoanSTAR polling computer. This computer then could use an RS232 connection to the Controller (a serial card may have to be installed in the Controller, at an estimated cost of $220). This has a limitation that the computer would have to reside within fifty feet of the Controller. Alternatively, a LAN card could be installed in the computer (this card has an estimated cost of $710, and another card may have to be installed in the Controller as well, at the same cost). In both cases, the proprietary *MCP* software would have to be installed. If this must be purchased, it has an estimated cost of $3000. This cost is roughly equivalent to the cost of a data logger.

Remote Data Transfer: When using the Proprietary Method, the retrieved data are stored on the disk of the remote polling computer. In the Remote Control Method, the same procedure is used to retrieve the data, although they are stored to the *local* disk. The data must then be displayed on the remote screen, and simultaneously captured into a log file on the remote computer disk.

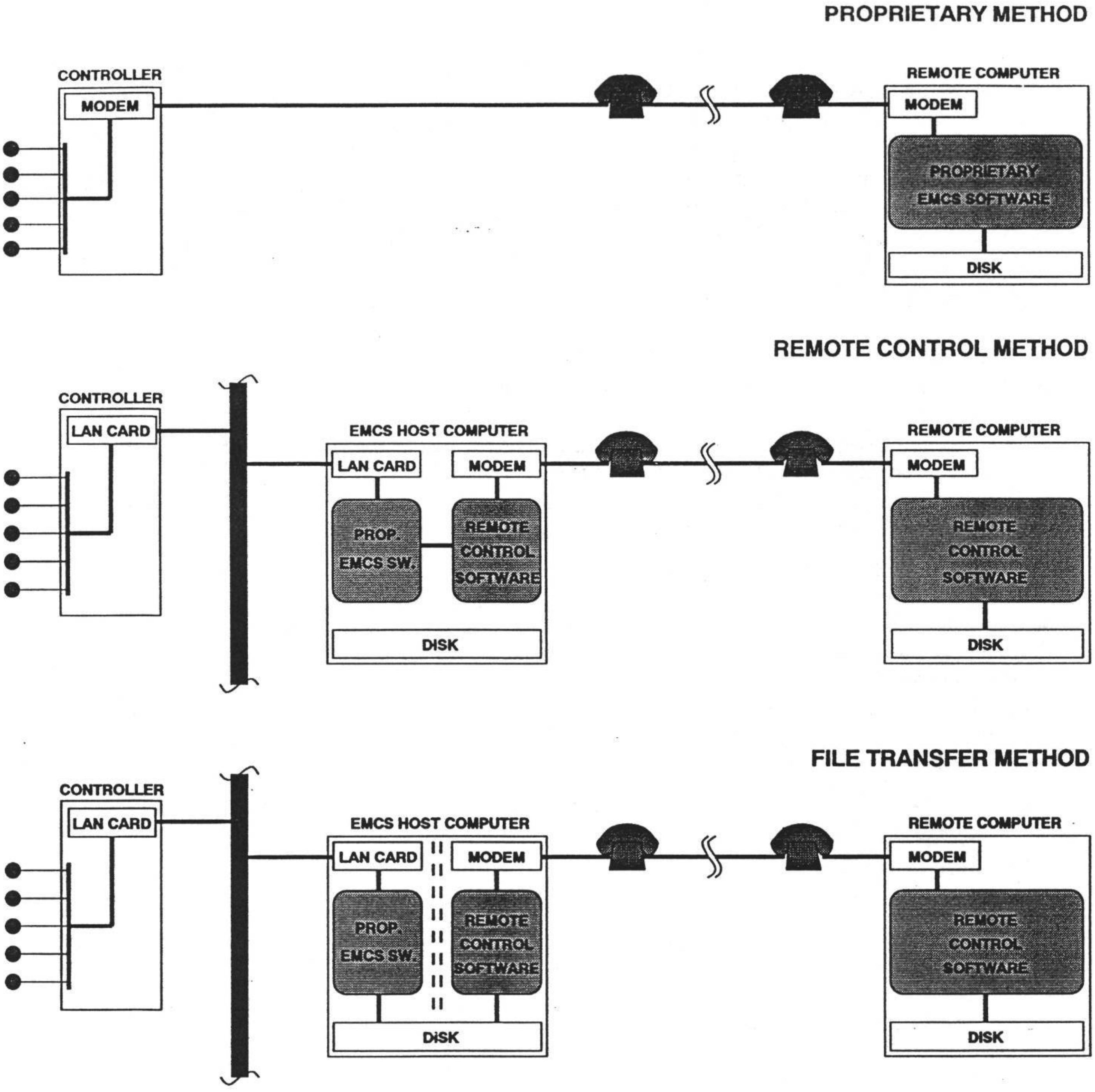


FIGURE III-A-3. Methods of Connecting to a Teletrol EMCS and Transferring Data. In each case, equipment on the left is at the building site, and equipment on the right is at the LoanSTAR monitoring headquarters. In the Proprietary Method, data are collected directly from the EMCS controller, using proprietary software on the monitoring computer. In the Remote Control Method, a monitoring computer operates the EMCS host computer remotely, to transfer data from the EMCS controller directly to the monitoring computer. In the File Transfer Method, the EMCS host computer transfers collects data from the EMCS controller, and stores them on its hard disk. The monitoring computer then operates the EMCS host computer to transfer the data from the host's hard disk.

A simpler variation on this method is possible (File Transfer Method, shown in Figure III-A-3). It is possible to program *MCP* to automatically retrieve data from the Controller once a day, and store the data in a disk file. This is done by programming the Controller to issue an alarm once a day, and having that alarm initiate a keyboard macro which carries out the retrieval procedure. Once the data are on the disk, *MCP* can be exited, and the file can be transferred. We have successfully used this same method, and the *pcANYWHERE* program, to collect data from the Barrington Systems EMCS that is installed in buildings at LBL. If a dedicated computer is added to the network, this would work well. However, if a connection is established with the existing computer, taking over and exiting *MCP* would not be a reasonable option.

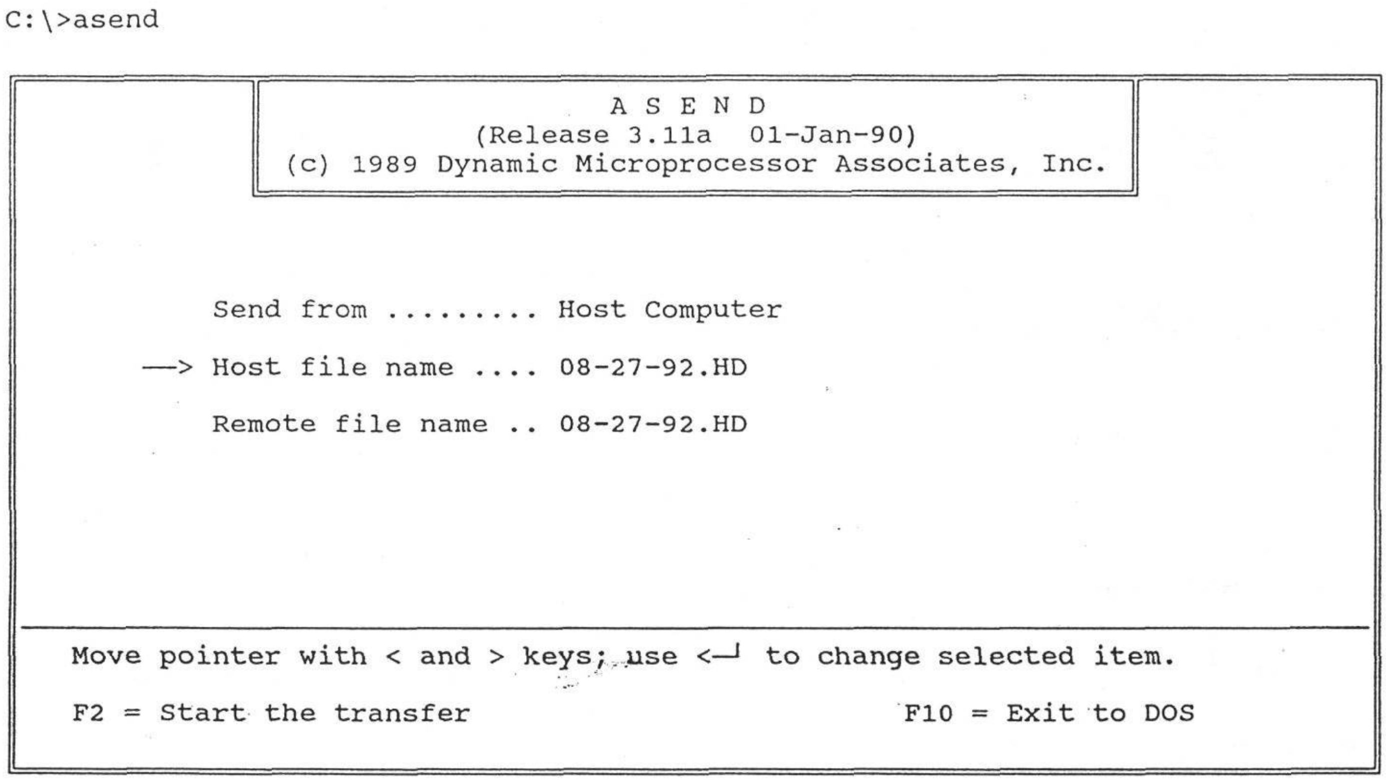
Soon, Teletrol will offer a version of the MCP software that runs under *Microsoft Windows*, and takes advantage of Dynamic Data Exchange. This would allow the EMCS computer to run *MCP*, and also run a communications program at the same time, within another window (iconified). This could be essentially any communications program that allowed files to be transferred, and supported a "host" mode. It would then be possible to transfer the data without *MCP* being interrupted, and without an operator even noticing the connection. This would be referred to as a Window-based Method. The speed and reliability of this form of transmission would have to be established.

Simple Process: As Table III-A-2 illustrates, the interaction with *MCP* software is fairly simple. However, it is menu driven, and uses arrow keys or a mouse to navigate the system, so it would be more difficult to automate. Using the File Transfer Method, however, no interaction with *MCP* is required, and the simplicity of requesting the data depends on the file transfer procedure of the communications program being used. The procedure used by *pcANYWHERE* to transfer a disk file is illustrated in Figure III-A-4, taken from another study using the Barrington Systems EMCS at LBL. This was quite simple to automate.

TABLE III-A-2. Method for Downloading Data from Teletrol EMCS.

C:> SMCP	Run EMCS Software
name	Specify Username
password	Provide Password
<Dn-arrow>	Select Controller
<Rt-arrow>	Move to Report Menu
<Dn-arrow>	Select History Utility
R	Retrieve Data from Controller
filename or <CR>	Specify Datafile Name or Default
V	View Data Samples
filename or <CR>	Specify Same Datafile or Default
<ESC>	Leave History Utility, and Report Menu
<Rt-arrow>	Move to MCP Menu
<Dn-arrow>	Select Exit to DOS

Rapid Process: **The fastest way to transfer files would be with a dedicated line into the Controller. This communication could take place at up to 150 kBaud. Using a modem, the transfer is limited to 2400 or 9600 Baud. If the data must be retrieved from the Controller before accessing, the transfer would be**



```
C:\>asend

                         A S E N D
               (Release 3.11a  01-Jan-90)
   (c) 1989 Dynamic Microprocessor Associates, Inc.


      Send from ......... Host Computer

  ——> Host file name .... 08-27-92.HD

      Remote file name .. 08-27-92.HD


Move pointer with < and > keys; use <—┘ to change selected item.

F2 = Start the transfer                        F10 = Exit to DOS
```

FIGURE III-A-4. pcANYWHERE's Facility for Transferring Files.

slower. Using the File Transfer Method, the transfer would take place fairly quickly, since the data have already been retrieved to the EMCS computer.

Error Detection: In the Teletrol system, the Remote Control Method is susceptible to undetected communications errors, since data are "captured" and rather than being transferred using an error-checking protocol. Using the File Transfer Method, error detection would depend on the file transfer protocol used. Most protocols include robust error detection. *pcANYWHERE* includes error checking as an option in its file transfer mechanism. Transfer is slower when error checking is selected.

Local/Remote Interference: The Remote Control Method would require that the operator allow the monitoring team to take over operation of *MCP* software periodically. This is far from ideal. When it is possible to run *MCP* under a multitasking operating system, it should be possible to transfer data without interfering in any way with *MCP* operation.

Data Format: Data from the Teletrol system can be stored in a comma separated ASCII format, to facilitate importing into spreadsheet and data base programs. A sample of one data format is shown in Figure III-A-5. However, if the data are captured rather than transferred, more processing will be required to remove other information from the transaction from the log file.

EMCS Specifications

The General Services Commission has prepared specifications to be used for future EMCS acquisitions, and these specifications cover most of the characteristics that are required for EMCS monitoring. The capabilities of future systems are therefore determined by these specifications so it is informative to investigate how the specs compare to the guidelines. Below are excerpts from the specifications.

Data Points: Not discussed in specifications.

This will depend on the particular project.

Data Accuracy: All sensors and controller shall be commercial grade quality and shall be installed according to the manufacturer's recommendations. Temperature sensors shall be of the wire wound resistive element type (RTD) or thermistors. Duct air sensors shall use a bulb type element, except for where averaging type elements are indicated. Room air sensors shall be of a bulb type mounted beneath a thermostat cover. Chilled water sensors shall be insertion type. Provide averaging type elements for cooling coil discharge air temperature sensing. Sensors shall have accuracy of 0.5 degree. Pressure sensors and differential pressure sensors shall be piezoresistive strain-gauge with temperature compensation. Sensors shall not require external power sources. Sensors shall be selected to provide linear indication with an adequate span for the application. Sensor shall be 0-10V, 4-20 mA or resistive output. Insure sensors are rated to operate at temperature of sensed media. Sensors shall have an accuracy of 1% of full scale. Space and duct humidity sensors shall have sensing span of 10% to 90% relative humidity. All sensors shall be corrosion resistant and temperature compensated. Adjustments shall be factory calibrated. Sensors shall

```
teletrol.dat        Fri Nov  6 07:26:47 1992          1

5   Point Data       RTD          value       64   100 000:05 09/23 18:36
54.1 09/23/92 18:31:29
54.1 09/23/92 18:31:34
54.1 09/23/92 18:31:39
54.2 09/23/92 18:31:44
54.2 09/23/92 18:31:49
54.1 09/23/92 18:31:54
54.2 09/23/92 18:31:59
54.2 09/23/92 18:32:04
54.2 09/23/92 18:32:09
54.2 09/23/92 18:32:14
54.1 09/23/92 18:32:19
54.2 09/23/92 18:32:24
54.1 09/23/92 18:32:29
54.1 09/23/92 18:32:34
54.2 09/23/92 18:32:39
54.1 09/23/92 18:32:45
54.1 09/23/92 18:32:50
54.2 09/23/92 18:32:55
54.2 09/23/92 18:33:00
54.1 09/23/92 18:33:05
54.1 09/23/92 18:33:10
54.1 09/23/92 18:33:15
54.1 09/23/92 18:33:20
54.1 09/23/92 18:33:25
54.1 09/23/92 18:33:30
54.1 09/23/92 18:33:35
54.1 09/23/92 18:33:40
54.1 09/23/92 18:33:45
54.1 09/23/92 18:33:50
54.2 09/23/92 18:33:55
54.1 09/23/92 18:34:00
54.2 09/23/92 18:34:05
54.1 09/23/92 18:34:10
54.1 09/23/92 18:34:15
54.1 09/23/92 18:34:20
54.2 09/23/92 18:34:25
54.1 09/23/92 18:34:30
54.1 09/23/92 18:34:35
54.1 09/23/92 18:34:40
54.1 09/23/92 18:34:45
54.1 09/23/92 18:34:50
54.2 09/23/92 18:34:55
54.1 09/23/92 18:35:00
54.1 09/23/92 18:35:05
54.2 09/23/92 18:35:10
54.2 09/23/92 18:35:15
54.1 09/23/92 18:35:20
54.2 09/23/92 18:35:25
54.1 09/23/92 18:35:30
54.2 09/23/92 18:35:35
54.2 09/23/92 18:35:40
54.1 09/23/92 18:35:45
54.1 09/23/92 18:35:50
54.1 09/23/92 18:35:55
54.1 09/23/92 18:36:00
54.1 09/23/92 18:36:05
54.2 09/23/92 18:36:10
54.1 09/23/92 18:36:15
54.1 09/23/92 18:36:21
```

FIGURE III-A-5. Logfile Collected from Teletrol Integrator 286, at ESL.

have an accuracy of 3%.

These sensor specifications are sufficient for most monitoring applications.

Sensor Calibration: Temperature sensor assemblies shall be readily accessible and adaptable to each type of application in such a manner as to permit quick, easy replacement and servicing without special tools or skills. Complete installation and proper operation of the DDC control system shall include debugging and calibration of the entire control system. The contractor shall prepare a test procedure and perform testing calibration and adjusting of entire system. Submit written report. Demonstrate satisfactory operation of points randomly selected by the Engineer. If more than 10% of the selected points fail to perform as expected, repeat entire testing procedure.

This allows a substantial fraction of sensors to be out of calibration. It also says nothing about recalibration. However, it does indicate that a report of calibration be filed, so that at least the calibration efforts are documented.

Data Recording: A variety of Historical data collection utilities shall be provided to automatically sample, store and display system data in all of the following ways: Continuous Point Histories: Standalone DDC panels shall store Point History Files for all analog and binary inputs and outputs. The Point History routine shall continuously and automatically sample the value of all analog inputs. Samples for all points shall be stored for the past day (minimum) to allow the user to immediately analyze equipment performance and all problem-related events for the past day. Point History Files for binary input or output points and analog output points shall include a continuous record of changes or commands for each point.

This ensures that data can be recorded.

Data Averaging: Analog/pulse totalization: Standalone DDC panels shall have the capability to automatically sample, calculate and store consumption totals on a hourly, daily, weekly, or monthly basis for user-selected analog and binary pulse input-type points. Totalization shall provide calculation and storage of accumulations of up to 99,999.9 units (e.g., KWH, gallons, KBTU, tons, etc.).

This type of totalization is necessary. However, it is not always possible to collect trends on totalized data, which is what is needed for hourly averages.

Data Storage: Each DDC panel shall have sufficient memory to support its own operating system and databases including historical/ trend data for all points. Measured and calculated analog and binary data shall also be assignable to user-definable trends for the purpose of collecting operator-specified performance data over extended periods of time. Sample intervals of 1 minute to 2 hours, in one-minute intervals, shall be provided. Each standalone DDC panel shall have a dedicated buffer for trend data, and shall be capable of storing a minimum of 5000 data samples. Trend data capability for all input and output points shall be stored at the Standalone DDC panels, and uploaded to hard disk storage when archival is desired. Uploads shall occur based upon either user-defined interval, manual command, or when the trend buffers become full. Sufficient hard disk bulk storage shall be provided to accommodate all fully configured point data bases, all application *databases, all graphics data bases, all user-defined reports, and all historical data archival.*

5000 samples is sufficient for energy monitoring, but availability will depend on what else is being trended for building operation purposes. Uploads to archival media however, ensure that overflows will not occur.

Data Time Format: In the event of the loss of normal power, there shall be an orderly shutdown of all standalone DDC panels to prevent the loss of database or operating system software. Non-Volatile memory shall be incorporated for all critical controller configuration data, and battery back-up shall be provided to support the real-time clock and all volatile memory for a minimum of 72 hours. Upon restoration of normal power, the DDC panel shall automatically resume full operation without manual intervention. Should DDC panel memory be lost for any reason, the user shall have the capability of reloading the DDC panel via the local area network, via the local RS-232C port, or via telephone line dial-in.

This does not necessarily ensure that data collection will occur when it is expected. It may collect data at specified intervals and not at specified times.

Remote Connection: Auto-dial/auto-answer communications shall be provided to allow at least one standalone DDC panel on the LAN to communicate with remote operator stations on an intermittent basis via telephone lines, to communicate information from any LAN panel to a remote PC. Operators at dial-up workstations shall be able to perform all control functions, all report functions, and all database generation and modification functions as described for workstations connected via the local area network. Routines shall be provided to automatically answer calls, and either file or display information sent from remote DDC panels. The fact that communications are taking place with remote control systems over telephone lines shall be completely transparent to an operator. Dial-up communications shall make use of Hayes compatible 300/1200/2400 Baud modems and voice grade telephone lines. Each standalone DDC panel may have its own modem, or a group of Standalone DDC panels may share a modem. Each DDC panel shall have sufficient memory to support its own operating system and databases including dial-up communications from at least one panel.

This ensures that a remote connection will be possible, although it may still require proprietary software. It does not address the possibilities of the alternative methods of connection.

Remote Data Transfer: Not discussed in specifications.

This does not ensure that data can be accessed remotely.

Simple Process: Not discussed in specifications.

This does not ensure that the process will be easily automated.

Rapid Process: Not discussed in specifications.

This does not ensure that the process will be rapid.

Error Detection: The design of the Facility Management System shall network operator workstations and Standalone DDC panels. Inherent in the system's design shall be the ability to expand or modify the network either via the local area network or auto-dial telephone line modem connection. The LAN shall have error detection, correction, and retransmission to guarantee data integrity.

This ensures that communications over the LAN will be robust, although the remote transfer of data may still be susceptible to communication errors.

Local/Remote Interference: A PC workstation may serve as an operator device on a local area network, as well as a dial-up workstation for multiple auto-dial DDC panels or networks. Alarm and data file transfers handled via dial-up transactions shall not interfere with local area network activity, nor shall local area network activity keep the workstation from handling incoming calls. Password protection shall be provided, and three levels of access shall be provided, including one which allows only data access and display.

This will prevent some forms of conflicts, although it does not address more basic forms of interference, such as the requirement to remotely take over the system in order to access data.

Data Format: All trend data shall be available in disk file form for use in 3rd Party personal computer applications. Data shall be stored in ASCII format, in addition to any other common formats provided.

This ensures that the data will be readable.

III-B. Texas A&M University

The campus of Texas A&M University, at College Station, Texas, consists of roughly 200 buildings (see Figure III-B-1). The LoanSTAR retrofit program currently covers projects in the Zachry Engineering Center, although applications have been submitted for projects in the Kleberg Animal and Food Sciences Center, the Eller Oceanography & Meteorology Building, and the campus Power Plant. Texas A&M's Energy Systems Laboratory (ESL) has the primary responsibility for monitoring and analysis for the LoanSTAR program, so this site is their home base.

Since the Zachry Engineering Center is the only building on campus that both has an EMCS and has received LoanSTAR retrofits, it is the focus of the first part of this investigation. The power plant is in the process of installing customized control and data acquisition systems. While this is not truly an EMCS, it has many of the same characteristics of a building-based control system, and it will also be covered in this discussion.

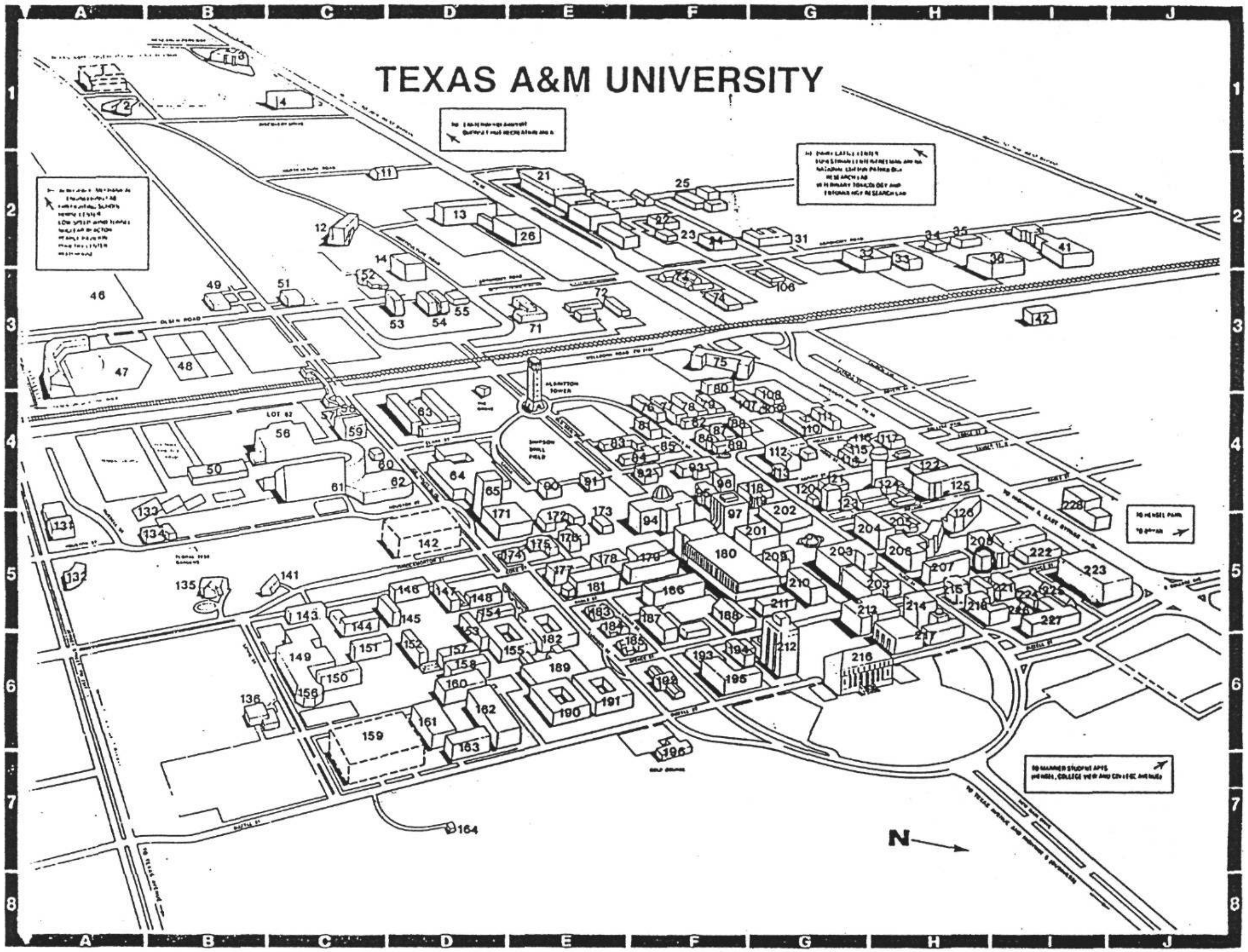


FIGURE III-B-1. Map of Texas A&M Campus in College Station. The building numbers are used in Table III-B-1 to indicate which buildings have EMCSs installed.

There are several different EMCS models installed in different buildings throughout the campus, as listed in Table III-B-1. There was originally a Honeywell Delta 2000 system installed in 53 buildings, but it never worked as required, and is no longer functional. There are currently about 17-18 buildings with Johnson Controls EMCSs, and there is a JC Metasys in the Medical Sciences Library. There is a Honeywell Excel system in each of two buildings. The principal system, however, is a Landis & Gyr Powers System 600. About 25 buildings have Landis & Gyr equipment installed, and the University has a National Purchase Agreement to purchase their equipment (essentially a Sole Source Contract, enabling them to avoid the costly and time-consuming bidding process). The campus has separate fire and security systems, which are not in any way integrated with the EMCS.

TABLE III-B-1. Buildings on Texas A&M Campus with EMCSs.

Building	Location	EMCS
Medical Sciences Library	26	Johnson Controls
Engineering/Physics Building	208	Johnson Controls
Laboratory Animal Resources Building	24	Honeywell
Duncan Dining Hall	149	Honeywell
New Offshore Technology Research Center	1	Landis & Gyr Powers
Ocean Drilling Project Building	2	Landis & Gyr Powers
Biochemistry/Biophysics Building	14	Landis & Gyr Powers
Physical Plant Offices and Shops	41	Landis & Gyr Powers
Bolton Hall	95	Landis & Gyr Powers
Legett Hall	96	Landis & Gyr Powers
Forest Science Building	106	Landis & Gyr Powers
Fountain Hall-Residence Hall 4	147	Landis & Gyr Powers
Kiest Hall-Residence Hall 2	148	Landis & Gyr Powers
Harrington Hall-Residence Hall 11	150	Landis & Gyr Powers
Whiteley Hall-Residence Hall 9	151	Landis & Gyr Powers
Leonard Hall-Residence Hall 7	152	Landis & Gyr Powers
Briggs Hall-Residence Hall 3	153	Landis & Gyr Powers
Spence Hall-Residence Hall 1	154	Landis & Gyr Powers
Gainer Hall-Residence Hall 5	157	Landis & Gyr Powers
Commons Area-Krueger/Dunn	189	Landis & Gyr Powers
Chemistry Building	203	Landis & Gyr Powers
Halbouty Geosciences Building	206	Landis & Gyr Powers
Richardson Petroleum Engineering Building	215	Landis & Gyr Powers
System Administration Building	216	Landis & Gyr Powers
Langford Architecture Center	217	Landis & Gyr Powers
Old Civil Engineering Building	218	Landis & Gyr Powers
CE/TTI Building	221	Landis & Gyr Powers
Heep Center for Soil & Crop Sciences	54	Landis & Gyr Powers (new)
Blocker Building	126	Landis & Gyr Powers (new)
Harrington Complex	150	Landis & Gyr Powers (new)
Oceanography & Meteorology Building	212	Landis & Gyr Powers (new)
New Veterinarian Building	21	Landis & Gyr Powers (upcoming)
Plant Science Biotech Building	186	Landis & Gyr Powers (upcoming)

Landis & Gyr Powers

There are 230 System Control Units (SCU's) on the campus, and eleven host computers, referred to as *Insight AT's*. Each of these controllers and hosts has a modem, and the entire system is networked using a PBX telephone system. Figure III-B-2, is a diagram showing a typical System 600 network architecture.

The Zachry Engineering Center recently upgraded its EMCS with Landis & Gyr equipment. This building was built in the early 1970s. It consists of classrooms, auditoriums, labs, and staff offices, and it operates 24 hours a day, although most intensively during weekdays. Under the LoanSTAR program, the system was retrofitted from DDCV to VAV operation.

Below we discuss the characteristics of the Landis & Gyr System 600 EMCS, as it is installed at the University, and in particular, in the Zachry building. We use the guidelines discussed in the previous section for evaluating the EMCS for monitoring applications.

Data Points: Since May of 1989, the LoanSTAR monitoring team has monitored pre-retrofit consumption, using a dedicated monitoring system. Since April 1990, they have also extensively monitored one of the air handling units (Katipamula and Claridge 1992). Some of the points being monitored are shown on the left-hand side of Table III-B-2.

The EMCS in the Zachry building has tens of thousands of points in 96 zones: the building has 400 VAV boxes, each of which has 99 points. Many of the points monitored by LoanSTAR are also available from the EMCS (see the right-hand side of Table III-B-2). Researchers at ESL have begun collecting data from the EMCS at Zachry. The points they are collecting are: building chilled and hot water temperature differences and flowrates, whole-building electricity consumption, and for one air handling unit, cold and hot deck temperatures, mixed air temperature, fan speed, and static pressure. These are equivalent to Level 1 or Level 2 monitoring (see Claridge et al. 1991).

Data Accuracy: For the hot and cold water flow, Dieterich Standard's Annubar flow meter and Rosemount transmitters are used. For the VAV box air flow rates, they use Naylor Industries pitot tube sensor, with a transmitter that is integral to the VAV controller. Temperatures are measured with RTDs. The electrical power is measured using current transformers, and watt transducers.

Researchers at ESL have compared the data collected by this EMCS with the more conventional LoanSTAR monitoring equipment. Most of the temperature, the fan speed, and static pressure data were very close to the LoanSTAR data. The flow data for the building's hot water supply were incorrect however. It was discovered that the LoanSTAR paddle-wheel flow sensor was installed on the pipe supplying the entire building, while the EMCS Annubar sensor was installed on a recirculation line, and hence they were not reading the same values. The water flow data on the building's chilled water supply was also incorrect. Upon closer investigation, however, it was discovered that the EMCS data were being reported in gallons per minute, not gallons per hour as the EMCS indicated. A scaling factor was applied to correct this discrepancy. The data still did not match the LoanSTAR flow data, and it was discovered that the LoanSTAR flow data were incorrect by a factor of 100. When this was corrected, the chilled water data matched well. The whole building power readings were obviously erroneous, and when this was

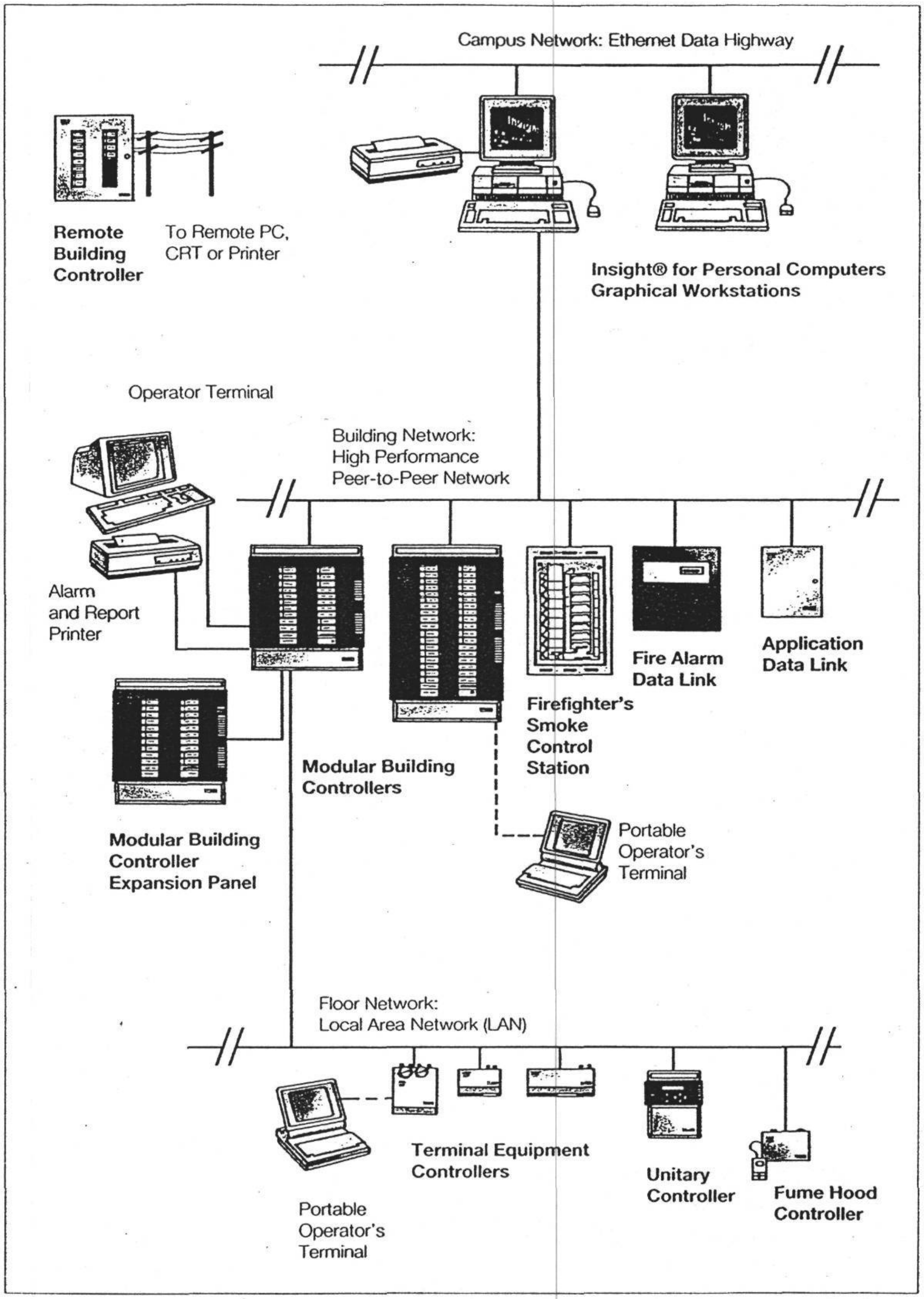


FIGURE III-B-2. Architecture of a Typical Landis & Gyr System 600 Energy Management and Control System. (Source: Reprinted with permission from Landis & Gyr Powers, Inc.)

TABLE III-B-2. Available Data in the Zachry Engineering Center.

LoanSTAR Monitoring	EMCS
Whole building electric kWh	Whole building electric kWh
Whole building hot water Btus	Whole building hot water Btus
Whole building chilled water Btus	Whole building chilled water Btus
Hot water pump run time	Hot water pump run time
Chilled water pump run time	Chilled water pump run time
Outdoor air dry-bulb temperature	Outdoor air dry-bulb temperature
Outdoor air relative humidity	-
Horizontal solar radiation	-
Wind velocity	-
AHU fan kWh	AHU fan speed (% of full speed)
AHU return air temperature	-
AHU return relative humidity	-
AHU hot deck temperature	AHU hot deck temperature
AHU air flow rate	Individual VAV boxes air flow rate
AHU fan pressure drop	-

brought to the attention of the management, the equipment was replaced, after which the data were within about 10% of the LoanSTAR data.

Sensor Calibration: The campus does not have a specific program for recalibrating sensors, although their maintenance contract with Landis & Gyr Powers includes calibration. They are considering sending one of their Annubar flow meters to the Energy Systems Laboratory for calibration.

Data Recording: The Landis & Gyr Powers System 600 has three facilities to record and report data: trending, remote trending, and archiving. The trending facility is capable of recording data for 50 variables: five groups at ten points each. These data are originally acquired by the remote control unit, but then are immediately transmitted over the network to be stored on the host computer's disk. Few of the available trend points are being used at the site, so trend capacity is not a problem.

Remote trending is a facility very similar to trending, except that the data are stored in the local memory of a remote control unit, and are only transferred to the host computer upon request. With remote trending, the limitation on the amount of data that can be collected comes from the amount of memory available on the remote unit. This is the method used in the SCU's at the Zachry building.

In the archive facility, the data are transmitted just as in the trending facility, and are then stored in a dynamic file, to be archived to a more permanent disk file once a day. Only this permanent file can be accessed, so data within the last day are not available.

Data Averaging: In the Landis & Gyr Powers EMCS, it is somewhat difficult to obtain hourly averages. There is a command called "TIMAVG" which allows averaging of sampled data. However, it can average a maximum of only 10 samples. Therefore, it was set to sample once every six seconds,* and average ten such samples to obtain an average value for every minute. Ten of these one-minute averages are then averaged to obtain a ten-minute average, and six of these ten-minute averages are averaged to obtain an hourly average.

Data Storage: Researchers at ESL have been collecting data on ten points from the EMCS, and they are saving 192 samples (8 days) per point. The data are stored on the SCU, and the available storage space depends on amount of memory left over after programming. Storage capacity has not been a problem at this site.

Data Time Format: It is possible to record data on either a scheduled or a change of value (COV) basis (for a more complete discussion of COV monitoring, see Heinemeier et al. 1992), although scheduled data are used almost exclusively. The timing of the samples is not as crucial as the timing of the averaging, due to the way data are averaged. In fact, the hourly averages only change once per hour, so they can be sampled at any time during the hour, or they can be sampled using a COV basis. The timing of the averaging process is crucial, and so far has not been a problem.

Remote Connection: The SCU's are connected by modem and a PBX telephone system, and there is only one outside phone line to enter this system. It was possible to call into one of the SCUs using this phone line, although this caused conflicts (see #13 below), and is no longer considered feasible. Since the LoanSTAR monitoring team is located in the building next door to Zachry, it was possible to establish a hard-wired connection into one of the SCUs, using a 4800 Baud RS232 connection.

Remote Data Transfer: As was done with other sites, data transfer was achieved by displaying the trend report onto the remote computer screen, and capturing it to a log file as it comes through.

Simple Process: The method used to request data is shown in the log file in Figure III-B-3. Responses to a lengthy series of questions must be supplied, although it is not difficult to automate. The polling carried out by ESL researchers uses a script file to automate the transaction.

Rapid Process: In a previous case study using a Landis & Gyr Powers System 600, the transaction took quite a bit of time. The phone connection between the remote and host computers was somewhat slow. However, the limiting factor was probably due to the fact that the host computer had to retrieve the data from an SCU, and the polling procedure was somewhat slow. Since ESL researchers have a hardwired connection to the SCU, however, communication takes place at a relatively high speed: 4800 Baud, and there is no intermediate host computer.

Error Detection: Since the transfer is simple capture of data as it comes to the screen, there is no error detection.

Local/Remote Interference: There is only one outside telephone line into the PBX system. This line is used periodically by Landis & Gyr Powers personnel to troubleshoot the system from their offices in College Station and in Houston. Therefore, it is considered unacceptable to tie up this line for energy

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[*] For comparison, LoanSTAR data acquisition systems scan approximately every six seconds.

```
>Point, Time, Message, Cancel, Hello ?P
>Log, Display, Monitor, Trend, Subptlog ?T
>Display, Listpoints, Multipoint ?M
>Here, Printer ?H
>Hours of Report period?48
>Minutes between data lines?60
>Point name?B10SPT
>Point name?B10CST
>Point name?WATTTT
>Point name?CHWFTO
>Point name?HWFTO
>Point name?
Command successful
Trend Multi-point Report                                     09:39 05-Nov-92
----------------------------------------------------------------------------
        B10SPT   B10CST   WATTTT   CHWFTO   HWFTO
         MA       IN       MWH      GAL      GAL
          COV      COV      COV      COV      COV
03-Nov
09:35   11.19    7.958    893.1    32767.0  32767.0
10:35   11.19    7.958    1005.7   32767.0  32767.0
11:35   11.19    7.958    1080.2   32767.0  32767.0
12:35   11.19    7.958    1112.3   32767.0  32767.0
13:35   11.19    7.958    1124.8   32767.0  32767.0
14:35   11.19    7.958    1123.5   32767.0  32767.0
15:35   11.19    7.958    1130.9   32767.0  32767.0
16:35   11.19    7.958    1154.6   32767.0  32767.0
17:35   11.19    7.958    1159.5   32767.0  32767.0
18:35   11.19    7.958    1129.6   32767.0  32767.0
19:35   11.19    7.958    1057.2   32767.0  32767.0
20:35   11.19    7.958    982.4    32767.0  32767.0
21:35   11.19    7.958    947.9    32767.0  32767.0
22:35   11.19    7.958    933.6    32767.0  32767.0
23:35   11.19    7.958    916.9    32767.0  32767.0
04-Nov
00:35   11.19    7.958    900.4    32767.0  32767.0
01:35   11.19    7.958    838.1    32767.0  32767.0
02:35   11.19    7.958    825.3    32767.0  32767.0
03:35   11.19    7.958    809.2    32767.0  32767.0
04:35   11.19    7.958    794.7    32767.0  32767.0
05:35   11.19    7.958    787.7    32767.0  32767.0
06:35   11.19    7.958    786.5    32767.0  32767.0
07:35   11.19    7.958    798.5    32767.0  32767.0
08:35   11.19    7.958    835.5    32767.0  32767.0
09:35   11.19    7.958    884.3    32767.0  32767.0
10:35   11.19    7.958    1001.2   32767.0  32767.0
11:35   11.19    7.958    1081.7   32767.0  32767.0
12:35   11.19    7.958    1113.7   32767.0  32767.0
13:35   11.19    7.958    1126.6   32767.0  32767.0
14:35   11.19    7.958    1119.7   32767.0  32767.0
15:35   11.19    7.958    1126.4   32767.0  32767.0
16:35   11.19    7.958    1145.0   32767.0  32767.0
17:35   11.19    7.958    1157.0   32767.0  32767.0
18:35   11.19    7.958    1134.2   32767.0  32767.0
19:35   11.19    7.958    1051.0   32767.0  32767.0
20:35   11.19    7.958    979.1    32767.0  32767.0
21:35   11.19    7.958    934.3    32767.0  32767.0
22:35   11.19    7.958    920.5    32767.0  32767.0
23:35   11.19    7.958    906.2    32767.0  32767.0
End of Report
```

FIGURE III-B-3. Logfile Collected from Landis & Gyr Powers EMCS at Texas A&M.

monitoring purposes. Also, polling the SCU in the Zachry building requires tying up the only connection to the Zachry SCU. Therefore, no one either on the campus or offsite could connect to the SCU. This again is considered unacceptable. The campus is considering installing additional modems in some of the SCUs, since the limitation of allowing only one user to communicate with a building at a time is a problem for them as well. If it were possible to install an additional outside telephone connection to the PBX system, it may be possible to use this system to remotely poll data. However, for the time being, it is not a possibility.

With the hardwired connection between the LoanSTAR monitoring team and the Zachry SCU, there is no potential for conflict, and this connection could be used to obtain data from any of the campus' Landis & Gyr SCUs. However, this method has one drawback in that only one of LoanSTAR's computer's is connected to the SCU, and thus only this computer could be used for polling the data. Also, one should remember that the only reason this method is a possibility is that the monitoring team is permanently on site. Thus, this could not be considered a viable alternative for any other sites.

Data Format: The log file in Figure III-B-3 shows the data format, which is not difficult to process.

Central Power Plant, Custom Data Acquisition System

The power plant on the campus of Texas A&M is also in the process of installing a system to monitor and control its equipment. This power plant supplies electricity, chilled water, hot water (for heating), domestic hot water and steam to about 200 buildings on campus. Equipment at the power plant includes three 3350 ton steam-driven centrifugal chillers, one 3350 ton electric chiller, five 1015 ton steam-fired absorption chillers, three 950 ton Trane steam-fired absorption chillers, one four-cell cooling tower, one 15 MW gas-fired cogeneration turbine, one 12.5 MW generator, one 5 MW generator, four boilers, and two hot water steam turbine pumps. Retrofits considered for the LoanSTAR program include retubing three steam driven chillers, replacing gas fired absorption chillers with absorption chillers run off of heat from the campus' gas-fired cogeneration plant, and replacing a steam turbine pump with electric drive pump. In addition to LoanSTAR retrofits, the plant's control and data acquisition systems are currently being revamped. All of the design and labor is being done in house.

The first phase of their controls work consisted of a Westinghouse Distributed Processing Family (*WDPF*) data acquisition system (DAQ), completed in August of 1992. This DAQ system is a standalone unit, and has built in programming languages which include block configuration and ladder logic, in addition to higher level programming languages. The next phase is scheduled for completion in March or April of 1993. The control and data acquisition system are a complex interconnection of networked computers (see Figure III-B-4). One of the boilers is about to undergo a retrofit to a variable frequency drive on it's 300 HP motor. They will take advantage of its downtime to install new control and DAQ equipment. Another boiler will be down soon for its annual maintenance, and this device will also be instrumented. They plan to do this for all the equipment eventually.

Currently, pneumatic signals come into the control room, and information is displayed on mechanical strip charts. Strip charts are being phased out, so CRT displays are currently being installed, next to the older strip charts. The operators have all had quite a bit of experience in this field, and follow written

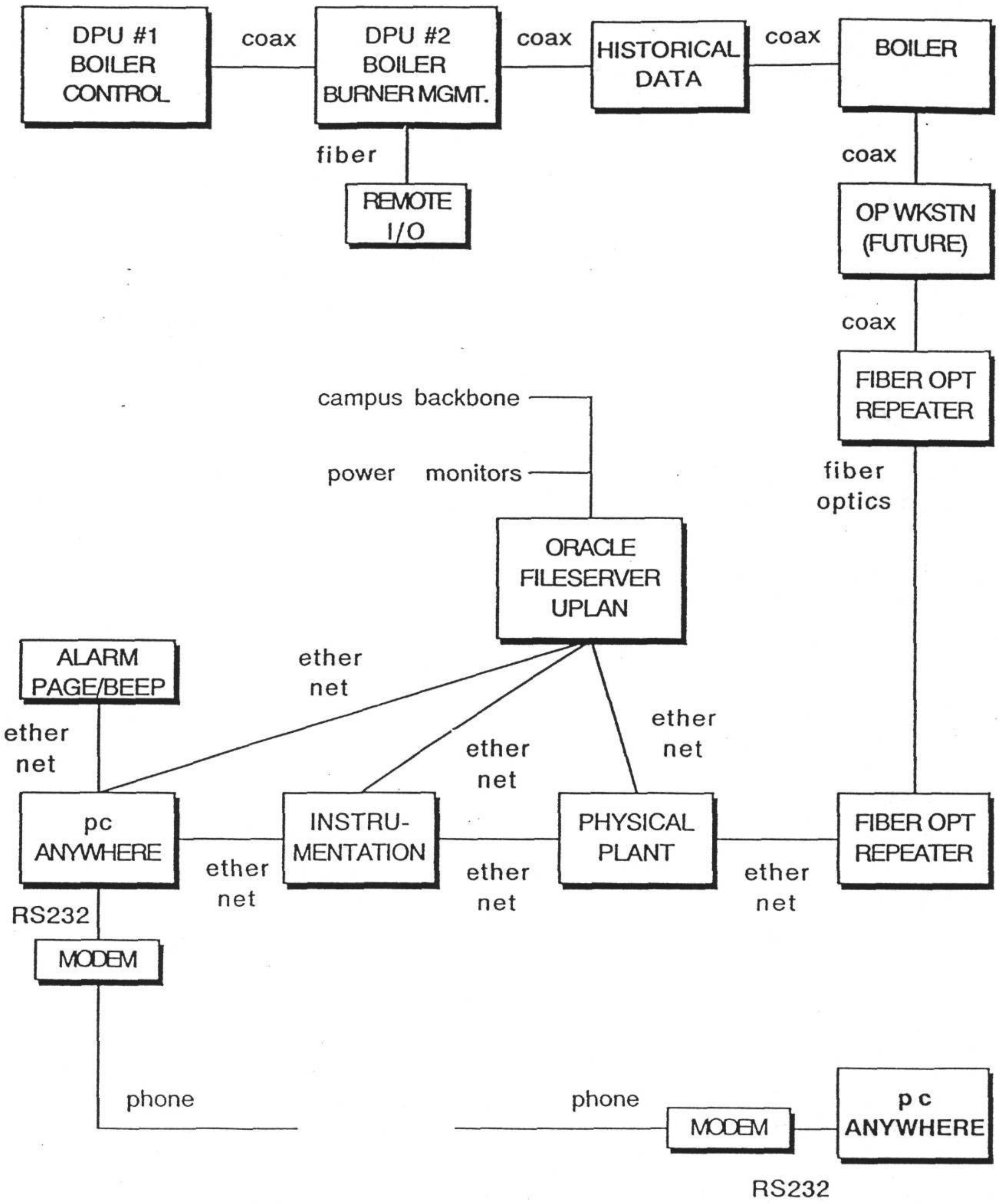

FIGURE III-B-4. Architecture of the Data Acquisition System Used at the Power Plant at Texas A&M.

procedures--which have also been useful for training. The instrumentation designers are using these written procedures, as well as interviews with the operators to determine appropriate person-machine interface for the new control system. They are asking not only how do they do what they do, but also how *could* they do what they do?

Eventually, there will probably be one screen for each boiler, since it would be a problem to switch back and forth between screens, particularly when bringing two boilers up at the same time. The information on the screens will be bar charts along with limits, for eight parameters, primarily for starting up equipment. For normal operation, the display will look like a strip chart, very similar to what they're using now. There will be an Auto/Manual Station with buttons, and tabular data. The interface will include a keypad, but a mouse was not considered acceptable. Clearly, much thought is going into making sure the system is as familiar as possible to the operators.

This new control system will not be mixed with the data acquisition (DAQ) functions, particularly for the large equipment. Their DAQ system will enable them to do trends and graphs, and hourly data is not enough resolution. They will also have a mathematical model, for plant optimization. It will recalculate every five minutes, and be integrated with DAQ.

Below are discussed the capabilities of this system for remote monitoring of the plant.

Data Points: Monitoring at this facility will include a large number of system variables.

Data Accuracy: Accuracy is a high priority in this type of application. They will record temperatures to +/- 0.1 F, and differential pressures to +/- 0.25 PSI.

Sensor Calibration: They will follow standard industrial procedures for calibration.

Data Recording: The Westinghouse *WDPF* data acquisition system records historical data.

Data Averaging: The DAQ system will scan five times per second, and will keep 15 minute average, minimum, and maximum data.

Data Storage: They will store data on CDROM--which will have sufficient capacity for monitoring.

Data Time Format: The *WDPF* has redundant processors and the power supplies are run off of a UPS (uninterruptible power supply).

Remote Connection: It will be possible to connect to the system using *pcANYWHERE*. (For a more thorough discussion of *pcANYWHERE*, see section III-A.) This *pcANYWHERE* connection is illustrated in Figure III-B-4.

Remote Data Transfer: pcANYWHERE can be used to remotely connect to the system, and to transfer data. (For a more thorough discussion of *pcANYWHERE*, see section III-A.)

Simple Process: pcANYWHERE can be used to remotely connect to the system, and use the Oracle Database to select the required data. A disk file can be transferred from the local disk to the remote disk, using *pcANYWHERE*'s file transfer utility. (For a more thorough discussion of *pcANYWHERE*, see section III-A.)

Rapid Process: The system currently communicates at 2-10 MBaud. In about two years, it will be upgraded to communicate at 100 MBaud.

Error Detection: pcANYWHERE's file transfer utility allows error checking.

Data Format: They will be stored using an *Oracle* database, and can be reported using *SQL-Forms*, (an *Oracle program)*, or any other report builder, such as *Power Builder*.

III-C. Compaq Computer Corporation

The headquarters site for Compaq Computer Corporation is located in Houston, Texas. This facility has a total of 3.7 M ft^2 in 13 administrative buildings, and 7 manufacturing buildings (see Figure III-C-1). There are 6500 employees at this site. These buildings house manufacturing, shipping, engineering and administrative functions. The facility was originally organized into three zones: North, South and West. There is a Johnson Controls Metasys EMCS in the North Zone, and a Staefa Phoenix system in the West and East zones. The West zone also has a Trane Tracer chiller control panel, and all buildings in the West zone are monitored, using a hardwired connection to a Hewlett Packard data acquisition system and a SuperSymmetry system that collects and displays data at intervals of one minute.

Although this is not a LoanSTAR site, they are a very forward-thinking and environmentally responsible corporation, and studying their EMCS is instructive. We will focus on the Johnson Controls Metasys system.

Johnson Controls Metasys

Compaq is a beta-test site for some of Johnson Controls' software—they are helping to develop new software by trying out programs and and are providing feedback on what they find useful, and what else would be of use to them. Burt-Hill-Kosar-Rittelman Associates were hired to write the specifications for their future EMCS.

There are 2 Metasys boxes per building, although most of the control is done by the control panels from an earlier JC/85/40 system. The Metasys uses two levels of communication, (see Figure III-C-2), and at this site the EMCS communicates using a fiber optic network between buildings, and coaxial cable within buildings. The fiber optic network is referred to at the N1 LAN, and uses the industry standard ARCNET (TM), developed by Datapoint Corporation. This is a 2.5 MBaud peer-to-peer token passing network used in office automation and industrial control applications, and it is a de facto industry standard, with

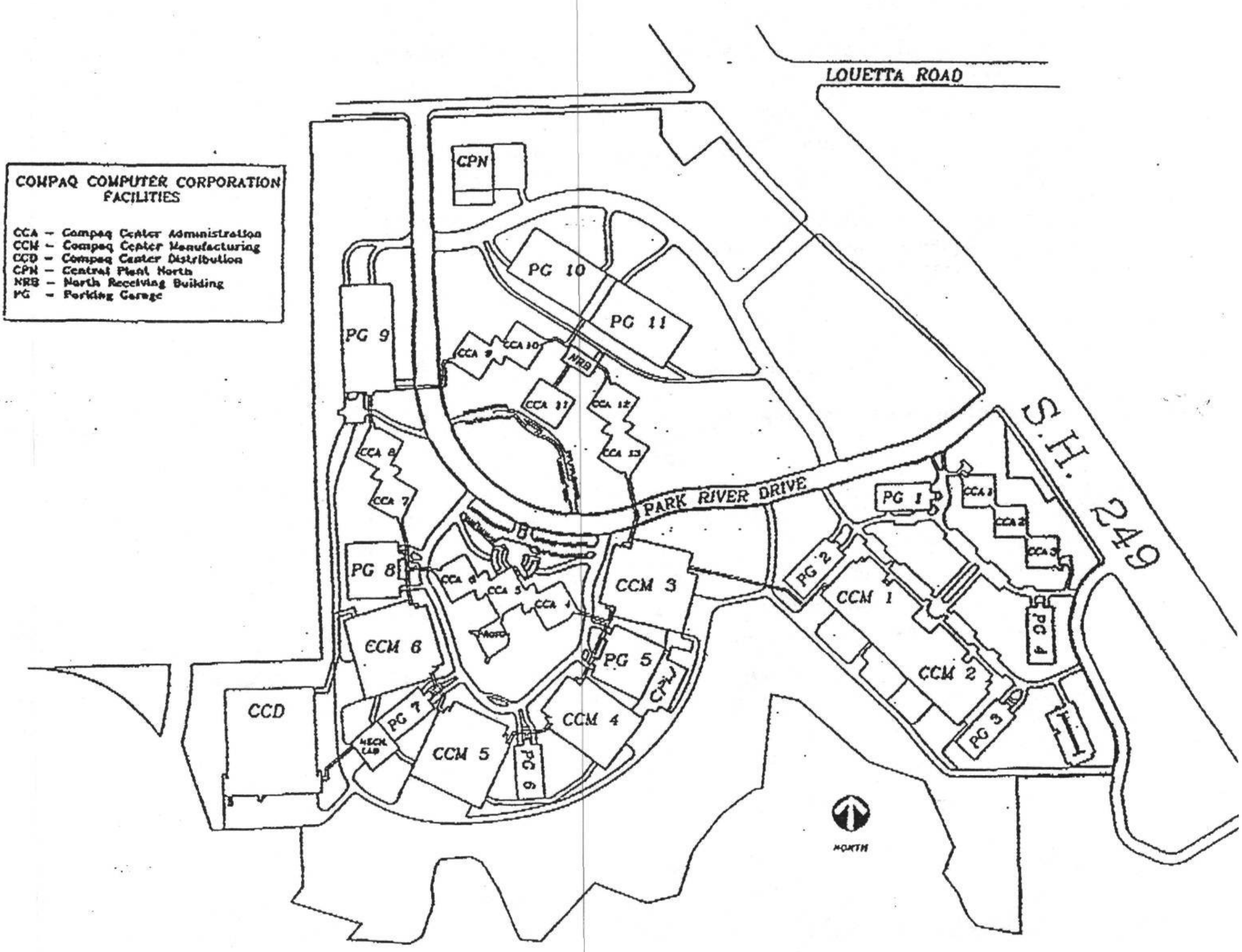

FIGURE III-C-1. Map of Compaq Computer Corporation complex, in Houston.

over a million connected devices worldwide. This network connects the Network Control Units (NCUs) and Operator Workstations.

The other network is referred to as the N2 Bus. It utilizes the Optomux communication network, to connect modules within the NCU, and also to connect to local application-specific controllers. This is a third-party published protocol, developed by Opto-22 for use in factory settings. It is a multidrop (daisy-chain) bus, that uses RS485 connections (three wire phone cable) and runs at 9600 Baud.

At this site, they collect hourly energy consumption data, and keep the data on the EMCS for a period of one year. All data within the system are stored in a *DBase* format. The Metasys software operates under *Microsoft Windows,* and makes use of the Dynamic Data Exchange server, in a utility called Metalink. Using this utility, data collected by the EMCS can be viewed in another program, such as *Lotus 1-2-3*, or *Excel.* The graphics displays are dynamic, meaning that as new data are collected, the display is automatically updated.

We now discuss the capabilities of this EMCS for monitoring.

Data Points: Compaq measures whole-building electricity consumption, and chilled water tons consumed. All plant variables are collected whenever the chillers operate. Thus, this does not represent continuous time-series data. However, this may be a compact way of collecting data that are of the most interest for diagnostics and tracking.

Data Accuracy: Flowrates are measured, for calculating chilled water tons delivered to the buildings, using insertion-type turbine flowmeters.

Sensor Calibration: Compaq does not have a contract with Johnson Controls to recalibrate sensors, although they monitor the values they record closely.

Data Recording: There are two different programs in the Network Control Module (NCM, the main processor in the NCU). First is Point History, which automatically samples every point at 30 minute intervals, and stores the data for 24 hours in the NCU. It also records the last ten changes for every binary point. These data can be automatically uploaded to the Operator's Workstation for more permanent storage. User Trend is a program that allows the user to create custom history files.

Data Averaging: Totalization is carried out in the NCM. Analog and Pulse Totalization are used to monitor consumption of chilled water, steam, gas, electricity, or other variables monitored with either analog or pulse input sensors. Totalized values are kept on an hourly, daily, weekly, or monthly basis, and they can be automatically uploaded to the Operator Workstation.

Data Storage: Any number of points can be trended. When the NCM's memory fills up, it can automatically send it to the Operator Workstation. Any number of points can be totalized, limited again by NCM memory. One of the Metasys Operator Workstations at Compaq has a 640 Mbyte disk.

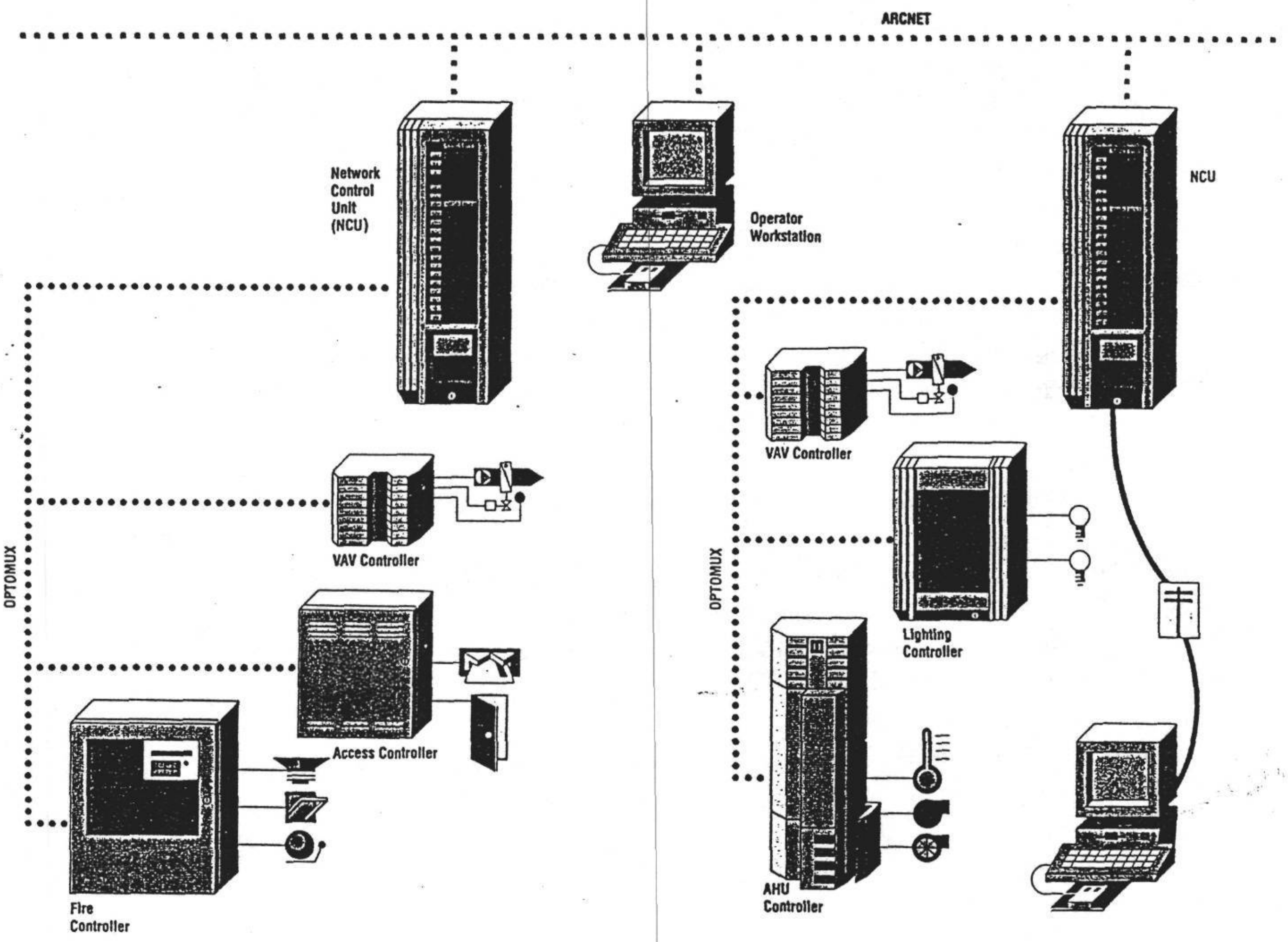

FIGURE III-C-2. Architecture of a Typical Johnson Controls Metasys Energy Management and Control System. (Source: Reprinted with permission from Johnson Control, Inc.)

Remote Connection: There are several ways to connect to this system, most of them identical to methods discussed in section III-A. They do support a Generic Terminal connection, using standard VT100 terminal emulation. This method was used in several earlier case studies (see Heinemeier et al 1992). Another possible method is the Proprietary Method, using proprietary Operator Workstation software on a remote computer. The Remote Control Method, using *pcANYWHERE*, can also be used with this system. It might be possible to use a Window-Based Method to connect to the Operator Workstation, within a window, and transfer a disk file. Johnson Controls engineers are currently investigating this technique.

Remote Data Transfer: It is not yet known whether it would be possible to capture data using a Generic Terminal connection. Using any of the other methods, however, it should be possible to transfer the data.

Simple Process: As discussed in section III-A, the simplicity of the data transfer will depend on the method chosen, and the communications software used.

Rapid Process: As discussed in section III-A, the speed of the data transfer will depend on the method chosen.

Error Detection: As discussed in section III-A, error detection will depend on the method chosen.

Local/Remote Interference: As discussed in section III-A, the degree of operator interference will depend on the method chosen.

Data Format: Data can be stored in virtually any format desired. Figure III-C-3 is a sample of one format used at Compaq Computer Corporation.

IV. ORGANIZATIONAL ISSUES

The guidelines have been very helpful in determining the appropriateness of an EMCS for monitoring. However, since all systems are different, and many require minor modifications, it is also important that there be someone within the agency willing and able to provide some assistance in assessing the capabilities of the systems for monitoring. As seen in previous sections, the methods for accessing data range from being entirely transparent to the operator, to requiring the remote computer to completely take over the host computer. These methods also often require setting the system up to do something it hasn't been used for before. Since the remote monitoring staff is necessarily using an agency's equipment, there must be a great deal of cooperation, interest, and teamwork. There must be information on the EMCS, resources to devote to the project, and incentive to work cooperatively with the monitoring team. These issues are often determined more by the structure of the organization than by any characteristics of the EMCS, the site, or the individuals. They are also often quite difficult to assess, since they are non-technical in nature, and not easily quantified. We investigated some of these organizational issues at these case study sites, by interviewing Energy Managers and Maintenance personnel involved with EMCS operations. Here, we outline the administrative structures of each of the agencies as they relate to energy and facility management, and then we discuss how this impacted our ability to use the EMCSs, or to assess the use of the EMCSs. Thesese administrative structures are also summarized in Table IV-1.

6/23/92 1:22 PM

BUILDING MONTHLY KWH SUMMARY

CCA9

TIME	DATE	TOTAL
0:00	5-May-92	12,373
0:00	6-May-92	12,400
0:00	7-May-92	12,414
0:00	8-May-92	12,138
0:00	9-May-92	7,970
0:00	10-May-92	7,389
0:00	11-May-92	12,345
0:00	12-May-92	12,338
0:00	13-May-92	12,310
0:00	14-May-92	12,545
0:00	15-May-92	12,248
0:00	16-May-92	8,101
0:00	17-May-92	7,921
0:00	18-May-92	12,366
0:00	19-May-92	12,269
0:00	20-May-92	12,345
0:00	21-May-92	12,138
0:00	22-May-92	11,792
0:00	23-May-92	7,901
0:00	24-May-92	7,472
0:00	25-May-92	7,424
0:00	26-May-92	11,951
0:00	27-May-92	12,234
0:00	28-May-92	12,124
0:00	29-May-92	11,944
0:00	30-May-92	8,156
0:00	31-May-92	7,880
0:00	1-Jun-92	12,020
0:00	2-Jun-92	12,006
0:00	3-Jun-92	12,068
0:00	4-Jun-92	12,131
TOTAL	KWH	338,712

CCA10

TIME	DATE	TOTAL
0:00	5-May-92	11.792
0:00	6-May-92	12,062
0:00	7-May-92	12,020
0:00	8-May-92	11.668
0:00	9-May-92	8,398
0:00	10-May-92	7,990
0:00	11-May-92	11,771
0:00	12-May-92	11,813
0:00	13-May-92	11,896
0:00	14-May-92	12,055
0:00	15-May-92	11.481
0:00	16-May-92	8,115
0:00	17-May-92	7,797
0:00	18-May-92	11.647
0:00	19-May-92	11.757
0:00	20-May-92	11,806
0:00	21-May-92	11.792
0:00	22-May-92	11,474
0:00	23-May-92	8.059
0:00	24-May-92	7,527
0:00	25-May-92	7.859
0:00	26-May-92	11,502
0:00	27-May-92	11,744
0:00	28-May-92	11.516
0:00	29-May-92	11.281
0:00	30-May-92	7,728
0:00	31-May-92	7,583
0:00	1-Jun-92	11 564
0:00	2-Jun-92	11,495
0:00	3-Jun-92	11,412
0:00	4-Jun-92	11.550
TOTAL	KWH	328.151

FIGURE III-C-3. Data Format used in the Metasys EMCS at Compaq Computer Corporation.

Table IV-1. Institutional Organization at EMCS Sites.

	State of Texas Capitol Complex			
	General Services Commission Building Property Services			
	Energy Manager	Utilities	Planned Maintenance Managers (1-5)	Controls
Responsibilities	Develop Conservation Projects, Education	Pay Energy Costs, Fund Conservation Projects	Perform Building Maintenance	Support PMM "Customers"
Funding	No Project Budget	Appropriation (based on previous use)	Expense Budget, Deferred Maintenance (too little)	From Planned Maintenance
EMCS Role	Partial Responsibility	No Responsibility	Partial Responsibility	Primary Responsibility
	Texas A&M University			
	Physical Plant Department			
	Energy Manager	Utilities	Area Maintenance	
Responsibilities	Develop Conservation Projects, Education	Power Plant Ongoing Operations and Capital Projects	Building Ongoing Maintenance and Capital Projects	
Funding	No Project Budget	Appropriation (based on previous use), Auxiliary Enterprises are Recharged	Expense Budget, Deferred Maintenance (too little)	
EMCS Role	Partial Responsibility	Sole Responsibility for Power Plant Controls	Partial Responsibility	
	Compaq Computer Corporation			
	Central Management			
	Facilities Department	Plant Utilities	Building Operation (Admin/Mfg)	
Responsibilities	Develop Conservation Projects, Education	Run Central Plants, Services up to Transformers	All Services Inside Buildings	
Funding	Maintenance, Capital Budgets (based on forecasts), Cost Centers are Recharged	Operations Budget	Operations Budget	
EMCS Role	Partial Responsibility	Partial Responsibility	Partial Responsibility	

Table IV-1. Institutional Organization at EMCS Sites.

	State of Texas Capitol Complex General Services Commission Building Property Services			
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EMCS Role	Partial Responsibility	No Responsibility	Partial Responsibility	Primary Responsibility
	Texas A&M University Physical Plant Department			
	Energy Manager	Utilities	Area Maintenance	
Responsibilities	Develop Conservation Projects, Education	Power Plant Ongoing Operations and Capital Projects	Building Ongoing Maintenance and Capital Projects	
Funding	No Project Budget	Appropriation (based on previous use), Auxiliary Enterprises are Recharged	Expense Budget, Deferred Maintenance (too little)	
EMCS Role	Partial Responsibility	Sole Responsibility for Power Plant Controls	Partial Responsibility	
	Compaq Computer Corporation Central Management			
	Facilities Department	Plant Utilities	Building Operation (Admin/Mfg)	
Responsibilities	Develop Conservation Projects, Education	Run Central Plants, Services up to Transformers	All Services Inside Buildings	
Funding	Maintenance, Capital Budgets (based on forecasts), Cost Centers are Recharged	Operations Budget	Operations Budget	
EMCS Role	Partial Responsibility	Partial Responsibility	Partial Responsibility	

IV-A. State of Texas Capitol Complex

The agency responsible for energy and facilities management at the Capitol Complex is Building and Property Services, within the General Services Commission. The organization is currently undergoing a restructuring, to implement total quality management (TQM) principles.

Energy Manager

The Energy Manager is responsible for developing and implementing energy conservation projects, as well as energy education with state employees. The Energy Manager has no project budget, and all conservation projects are paid for by Utilities and Planned Maintenance. One result of the restructuring is that the new Division Director is quite familiar with energy management, and will be more supportive of energy conservation projects. Within Building and Property Services is an Energy Manager, a Controls Group, and several Planned Maintenance Managers. The Energy Manager works cooperatively with the Controls Manager and Planned Maintenance, and does not interact with the EMCSs on a day-to-day basis. The Energy Manager was primarily responsible for drafting the EMCS specifications discussed in an earlier section.

Planned Maintenance

There is currently one Planned Maintenance Manager for each of five geographic zones. In the restructuring, this will be reduced to three zones. Maintenance & Operations staff are under each of the Planned Maintenance Managers. They have estimated that they receive about 20% of the maintenance budget they need, and they have a backlog of approximately eighty million dollars in deferred maintenance projects. Small EMCS upgrades, if they were used as a maintenance tool, would be funded by Planned Maintenance, not Utilities money. The Planned Maintenance staff in each of the buildings use the EMCSs, although with varying degrees of enthusiasm and scepticism.

Controls Group

The Controls Group's role is to provide support to the Planned Maintenance Managers, who are their "customers". Other areas under the domain of the Controls Group include sprinklers, automatic doors, key access, and security. They do most controls development in-house, and have a controls workshop. There is a separate Telecommunications Group that handles telephones. They do have interaction with them, since fire and security systems operate over phone lines.

All the chillers and boilers have only local controls, and they were not interested in integrating that control with the other EMCS functions. The Controls Group felt that EMCS manufacturers tend to be "tight lipped" about their systems, so that they will be called in for maintenance. Their plan is to obtain training from EMCS manufacturers, but then to take over maintenance themselves, and the Controls Manager will hold classes for operators on all the different systems. They also didn't want to be "married" to any one manufacturer: they chose Teletrol because it is essentially a PC, it can talk to products of other manufacturers, and it is programmed in C, which they felt more comfortable with than block programming. This probably reflects their controls background, in contrast to the user-friendly but less flexible block programming often favored by those with a background primarily in facilities operation and maintenance.

IV-B. Texas A&M University

At Texas A&M University, the Energy Office, Area Maintenance, and Utilities are all located within the Physical Plant department.

Energy Office

The Energy Office is responsible for developing and managing energy and water conservation projects on the A&M campus, as well as carrying out energy education and awareness programs aimed at the campus community. The Energy Office was created in July 1991, and it currently consists of one manager. The Energy Office has no project budget per se, although it develops projects paid for by Area Maintenance and Utilities funds.

Since this is a relatively new position, the relationship between the Energy Office and Area Maintenance is not clearly defined. For example, currently, if a building occupant informs Area Maintenance that she would like more cooling in a space, Area Maintenance can reset the temperature setpoint to change the air volume, using the EMCS. In another example, if a department needs an additional air-conditioning unit for a laboratory, they can purchase it, and it will be installed and maintained for them. However, the Energy Office is hoping to change the procedures so that requests such as these would go through the Energy Office. The Energy Office is working with other entities to better define how they would have input into decisions such as these. Once a year, the Energy Office will produce a document entitled *Annual Report and Comprehensive Energy Management Program,* describing it's programs and plans.

Individual departments do not pay for their own power requirements, with the exception of what are called "Auxiliary Enterprises." These are facilities that generate fees, such as sports facilities, food services, and dormitories. These facilities represent about a third of the campus' energy consumption. They are metered and billed for electricity consumption. Chilled water and hot water, however are not currently metered, and Auxiliary Enterprises are charged a campus average rate for these utilities, based on their square footage. This provides no incentive for conservation, however, and and the Energy Office is considering installing Btu meters in these facilities. The EMCS may be used as a backup for this metering, although it will not be used as the basis for billing.

Beyond metering these buildings, for the Energy Office, the role of the EMCS is to maintain the integrity of energy projects. The Energy Office manager has an EMCS host computer on his desk, which he uses frequently. He is hoping to hire an EMCS operator and an EMCS technician, to be shared by the Energy Office and Area Maintenance: currently there is no single person whose primary responsibility is operation of the campus-wide EMCS. These staff members would receive training from Landis & Gyr Powers in Chicago, and the Energy Office manager will also obtain training from Landis & Gyr Powers.

Although Area Maintenance is currently the primary user of the EMCS, the Energy Office is rapidly becoming a bigger user, and the relationship between Area Maintenance and the Energy Office is very cooperative. Any upgrades to the systems might be shared: for example, Area Maintenance would pay for sensors used in building maintenance, and the Energy Office would pay for metering aspects of the system. The EMCS has an electronic mail facility which will allow close communication between the Energy Office and Area Maintenance. The Energy Office manager would like to reconfigure the system so that only the main EMCS operator, and a couple of others would have access to certain EMCS functions. Currently, there are about 15-20 EMCS users with this high priority, including the manufacturer's representatives. He would like to assign priority according to need and understanding of the system.

Area Maintenance

Area Maintenance is responsible for maintaining all buildings and facilities, with the exception of the central steam plant. Area Maintenance is currently organized into seven areas: six geographical areas (four on the central campus, two in remote locations), and one area that consists of specialties such as roofing, elevators, boilers, ammonia systems, and wall units. Each area has a supervisor, and there is one Superintendent of Area Maintenance, overseeing all areas. Each of the six geographical areas is staffed by air conditioning technicians, electricians, plumbers, carpenters, clerks, foremen, and assistant foremen. The Area Maintenance Superintendent considered the areas to be understaffed.

Area Maintenance operates with an annual expense budget to cover ongoing maintenance work, although they estimated that they receive only about 60% of the budget that is needed. Any capital projects are covered under Special Projects, Deferred Maintenance, or Public University funds, but again funds are quite limited and the list of deferred maintenance projects is long. An example of the consequences of this method of funding is that they could not carry out a compact fluorescent retrofit program, since this would be considered an *upgrade*. They could, however, *replace* burned out incandescents with fluorescents, since this could be considered a maintenance expense.

The Area Maintenance Superintendent has access to an EMCS host computer down the hall from his office, and he uses it only once or twice a month. Each of the geographical areas has a host computer, and they use it more frequently, to keep tabs on the systems and space conditions. Any alarms generated by the EMCS are reported to the area supervisors, and it has been proposed that the alarms should be differentiated, so that alarms only go to the correct supervisor, and that additional alarm printers be provided in the campus Communications Center and at the Energy Office. Several Area Maintenance staff have received training on the EMCS, although it was quite a long time ago, and retraining is probably needed.

Utilities

The engineer in charge of power plant operations is the Deputy Manager for Utilities. He was intimately involved in design of the new control system. Since they had funding to pay for this project, he was able to hire several students and other staff for the design and installation phases. This engineer has a background in facilities control, including EMCSs.

Natural gas is consumed in the power plant to fire boilers, which produce steam that is used for several purposes: to run the turbines that provide much of the electrical power for the campus, to run absorption and centrifugal chillers, and to provide heating and domestic hot water for the campus buildings. Electricity, chilled water, and hot water are distributed to the buildings from the power plant. Utilities receives an appropriation for energy costs, and the difference between this appropriation and the actual expenses incurred during a given year can sometimes be spent on facilities. In recent years they were able to finance the changes in the control system at the power plant, and some other conservation projects within the power plant and the buildings. Subsequent years' appropriations, however, will be adjusted. So the only incentive to save energy is to beat the projections for the current year.

The University purchases natural gas, although they are also a producer of natural gas. The only gas meter for entire campus' gas consumption uses a pen-and-ink chart recorder. The charts thus produced are digitized by the gas company. The campus purchases electricity to supply about 35% of its needs.

An interesting comparison can be made between the Physical Plant at A&M and a regulated utility. Physical Plant is in the role of both energy supplier and facilities manager, so their role is to provide energy services as well as to provide energy. Both the power plant and the buildings are on the same side of the meter, so they are equally interested in optimizing power plant operations and optimizing facilities. This seems to be the direction in which many electric utilities see themselves moving, although it is not an easy transition to think of optimization of customer facilities as an integral part of utility operations. The University is therefore in a much better position to carry out conservation projects than a utility.

There is another interesting parallel between the University and a regulated utility: under conventional utility regulation, costs are recovered in rates, leaving little incentive to conserve either in power plant operations or in customer facilities. In several places in the country, however, regulation is changing to allow utilities to keep any savings they realize due to conservation. This same type of change in legislative appropriation procedures, allowing the campuses to retain energy savings, would provide the University with much more incentive to conserve. If they were given this incentive, they would be in the best possible position to conserve energy: they could choose whether to spend money on fuel and power plant capital investments or on facility conservation programs, and since both are within their domain, they could fairly choose the least cost option. Another important link should be established, however. Some of the retained Utilities savings should be spent on the Area Maintenance arm of Physical Plant, so that this part of operations, so important to the success of conservation projects, will also have part of the incentive to conserve.

IV-C. Compaq Computer Corporation

At Compaq Computer Corporation, there are four entities involved in energy management. They are the Senior Facilities Engineer, Plant Utilities, and two groups responsible for buildings operations.

Senior Facilities Engineer

Compaq has a very serious commitment to energy conservation and environmentally responsible operations, and they have a "Good Neighbor Policy". They are concerned about facilities primarily for financial accountability, but the corporate culture is also such that they also have a very strong concern for the environment. The conference room in which we met had a framed plaque on the wall outlining their environmental policies, covering a wide range of activities. One example of their energy conservation program is a waste-to-energy plant, firing a 600 ton absorption chiller. This plant was shut down because it was no longer economically feasible to operate, due to increased recycling efforts that reduced the waste stream. However, it may be reactivated, due to rising costs for both landfill and energy. Another example is their Energy Responsive Building Process, in which energy considerations are made during several steps of the building process: pre-design analysis, schematic design, design development, construction documents, construction, and post-occupancy evaluation (Robbins and Brown 1990). Thus, the buildings on their campus are all designed from the beginning to be energy efficient. Staff at this Houston site also handle facilities design for overseas plants. For example, they estimate they have cut three-quarters of a million dollars off the annual energy costs in the design of a new building in Madrid.

The Facilities Department consists of four groups with distinct but overlapping and supporting functions. The *Operations* group is responsible for the daily operations and maintenance of all facilities. The *Facilities Resource Development* group is responsible for planning, programming, and designing of all new support facilities. They are also involved in research and development of building technology that can be applied to either new or existing facilities. The *New Construction* group is responsible for coordination and administration of all new construction. Lastly, the *Financial* group provides financial support and assistance in tracking costs and analysis of Build vs. Lease decisions, life-cycle costing, and returns-on-investment.

Gas and water bills go to central management, and electricity bills go through the Senior Facilities Engineer. Several times, during our interview, the Senior Facilities Engineer said "You can't manage what you don't measure," and they do whole-building electricity monitoring of the buildings. Electricity bills are recharged to about about 12 cost centers, depending on what activities are going on in the buildings. For example, a manufacturing project would have to pay for it's own electricity. Each group does annual forecasting, and requests a maintenance and capital budget. The site's total energy bill has been reduced from $526,000 to $400,000 per month, resulting mostly from low-cost/no-cost measures. For example, the security staff works with facilities, so facilities was in a position to request them to turn off lights as a part of their walk-through plans.

Their EMCS is a state-of-the-art system, and they are being used as a beta-test site for the EMCS manufacturer. Hence, they are providing valuable feedback on how useful the system is, and how it could be made more useful. They also use a state-of-the-art graphics system to perform data acquisition and visualization tasks. While the vision of the Senior Facilities Engineer was instrumental in acquiring these unique systems, he does not have day-to-day interaction with the system.

Plant Utilities and Building Operations

Before November of 1991, facilities management was organized into three geographical (and chronological) sites, each site having its own site manager, crew, central plant, and list of vendors. This organization was changed, due to a need for workforce reductions. In the current organization, Plant Utilities is responsible for operation of all central plants and services up to the building transformers. The two Buildings Operations groups are segmented according to whether the buildings house manufacturing or administrative functions. One example of the benefit of this restructuring, is that previously, two plants in different zones would be running at part load. Now they are interconnected, so that one can be baseloaded. The facilities staff, currently numbering about 250, have been reallocated along functional lines. This new, more centralized, organization is working well, despite a 30% smaller workforce, due to increased efficiency of operation. The group facilities supervisors work very closely with the EMCSs.

IV-D. Discussion

Each of these sites has a slightly different administrative structure when it comes to energy costs and facilities management, and these differences have implications for EMCS-based monitoring, as well as for retrofit programs, and EMCS operations. Several of these implications have already been discussed.

As Cebon discussed (1990), in successful conservation programs, the conservation technologies chosen will be well matched to the structure of the organization. Some of the most important characteristics of that structure are the degree of centralization, and the distribution of information, incentive, and resources among the different branches of the organization. Likewise, EMCS-monitoring will be most successful when it is well matched to the structure of the organization. To use an agency's EMCS for monitoring requires assistance from on-site personnel for assessing capabilities, reconfiguring aspects of the system, and in various ways while carrying out the ongoing monitoring. Thus, it is important to identify who, within the organization, has the information, resources, and incentive to be able to assist in monitoring. It is also important, in some cases, that these characteristics overlap in some of the personnel.

Information

At least two kinds of information are important in energy management: technical information and contextual information. Technical information is essentially awareness of potentially applicable technologies, and how to evaluate and obtain them. In the case of EMCSs, this relates to understanding of the EMCS operation, its potential applications, the architecture of the system, and the availability of additional capabilities. Both the Capitol Complex and the Power Plant at A&M had substantial in-house expertise in this area. At the Capitol Complex this expertise was located in the Controls Group, and at the Power Plant it was in the power plant engineer himself, as well as the pool of well-educated control students available at this nationally recognized engineering school.

For the buildings side at A&M, there was less expertise, and the EMCS manufacturer was relied upon heavily to provide support. For example, there was one occasion when occupants complained of discomfort, and the EMCS manufacturer was called in. The manufacturer simply used the in-place system to determine what the problem was, which could have easily been done by on-site personnel. The fact that they will be requesting additional training indicates that this situation may soon be changing. At Compaq, they have a very good idea of what technologies are available, and are, in fact, leading the manufacturers by serving as a beta-test site.

Contextual information, however, is another crucial element. This refers to hands-on knowledge of what is going on within the organization. For example, one might have very good technical information, and yet be not be well informed about what is needed by individuals within the organization. In every case, the Energy Manager (by whatever name) was the least involved in day to day operations, and therefore had the least contextual information. The Maintenance groups, however, were very informed about what was going on with all the buildings and systems, but often knew little about how much energy was being consumed.

Both technical and contextual information are important for EMCS monitoring, during the assessment of the usefulness of the system, during any reconfiguring of the system, and during ongoing monitoring. Often, if the on-site personnel do not have the necessary information, the manufacturer's representative will be able to provide it. Access to information is crucial in determining how smoothly the monitoring process will be, and often even in determining whether or not the EMCS can be used for monitoring. At all sites, between the Energy Manager, maintenance groups, and manufacturer's representatives, there was enough information. But also at all sites, no one person covered the range of required information, and several people had to be consulted.

Resources

Even if the information is available, in order to carry out remote EMCS monitoring requires that several people on site spend some time explaining the system, determining what additional applications it may be capable of, and possibly reconfiguring various aspects of the system. These all require resources—usually in the form of time: presumably any monetary resources would come from the monitoring budget. and they require that those with information also have resources. For example, at the Capitol Complex, they have considerable expertise, but little time to spend on projects such as this, due to budget constraints. The Controls Group had the most expertise, but the least available time, and no budget for projects such as this. At A&M, again, information and time did not overlap. We obtained some assistance from the manufacturer, but since they were not being paid to assist us, their ability to assist us was limited. At the Power Plant at A&M, there was more overlap, and thus we were able to obtain more information. At Compaq, as well, the people with the information had a little more leeway with their time, and were able to provide assistance.

Incentives

Particularly when resources are limited, incentives are quite important. Do the people with the information and the resources have any incentive to assist with this project? This will depend on whether or not they pay (directly or indirectly) for energy costs, whether they receive funding for energy management projects, and if it is in their job descriptions. At Compaq, end users of energy (cost centers) pay for their energy use. At the Capitol Complex and Texas A&M, there is little incentive for *anyone* to conserve energy--reductions in energy costs will simply result in a reduction in the next year's allocation. In no case is the maintenance arm (presumably the group with the greatest effect on energy consumption) much influenced by the energy costs. Therefore, no one with a real stake in reducing energy costs has direct interaction with the EMCS. In every case, the Energy Manager, because of his job description, had incentive to save energy and to monitor the savings. The Energy Manager was always the easiest person to obtain assistance from. At Compaq and the Power Plant at A&M, the managers also had financial incentives to save energy, since to some extent savings could be used to finance additional improvements. In

fact, in both of these cases, information, resources, and incentive overlapped, and they were able to be quite forward-thinking about their control systems. Both of these managers were also able to provide us with assistance.

V. CONCLUSIONS

This report summarized work investigating the possibility of using EMCSs to collect building performance data at several sites in LoanSTAR's monitoring program. Beyond this primary assessment, the emphasis of this work was on formalizing the process of assessing the feasibility of using EMCSs, as well as investigating the non-technical issues.

We developed guidelines for assessing the usefulness of an EMCS for monitoring. These guidelines were based on the evaluation criteria identified in earlier phases of this research. We then used these guidelines to evaluate the use of the EMCSs at three sites. In the course of this research, we interviewed eight individuals involved in energy management and EMCS operation at the case study sites to explore some of the non-technical aspects.

The guidelines are presented as fourteen issues to be considered, ranging from what data are monitored, to what format will the data be in when they are received by LoanSTAR. For each guideline, methods are presented to guide the assessment process, and alternatives are provided in case an EMCS does not meet the original criterion.

Table V-1 summarizes the guidelines and our assessment of the use of the EMCS in each of these sites, organized according to the guidelines. In this table, a "+" indicates that the characteristic was met, a "-" indicates that it was not met, and a "?" indicates that more information is needed to make an assessment. The EMCS at Texas A&M was the least convenient to use, due to the closed architecture of its network. At all other sites, however, one could potentially connect remotely, although some of these connections might require either purchase of an additional computer, or the use of proprietary software.

These guidelines proved to be useful in assessing the characteristics of the EMCSs at the case study sites. They facilitated discussions with building personnel, and made a simple checklist to guide the investigations. Two issues came up that were not adequately addressed by the guidelines, however.

First, with a new generation of EMCSs, there are new methods for accessing the systems and transferring the data. With complex network architectures, and multi-tasking operator systems running on host computers, there is now a wider range of methods, and each has different characteristics. These methods are illustrated in Figure III-A-3. By far, the method with the most promise is the Window-Based Method, in which data are automatically written to an EMCS computer disk in a format designed to be read by other software, and a remote access is made through a window running in parallel with the EMCS software on the same EMCS computer. This method allows use of generic communications software, error-checking, totally transparent connection, simple and quick transfer, and an easily-processed file format. Most EMCSs are not designed to be run under multi-tasking operating systems, although most of the newest versions are incorporating this capability. This should enhance the usefulness of EMCSs for monitoring in future years.

TABLE V-1. Assessment of Monitoring Capabilities in Case Study Sites. A "+" indicates that the characteristic was met, a "-" indicates that it was not met, and a "?" indicates that more information is needed to make an assessment.

Characteristic	A&M L&GP	Steam Custom	Capitol Teletrol	Compaq Metasys
Correct Points	+	?	?	+
Accuracy	+	+	?	+
Calibration	-	+	?	?
History	+	+	+	+
Averaged	+	+	+	+
Capacity	+	+	+	+
Top of Hour	+	+	+	+
Connect Remotely	-	+	+	+
Transfer	+	+	+	+
Simple Command	+	+	+	+
Quick Transfer	+	+	+	+
Error Detection	-	+	+	+
No Conflicts	-	?	+	+
Data Format	+	+	+	+

The second issue is that less tangible factors can override the technical aspects of EMCS monitoring covered by the guidelines. Access to information is crucial in determining how smoothly the monitoring process will be, and often even in determining whether or not the EMCS can be used for monitoring. To use an agency's EMCS for monitoring requires assistance from on-site personnel for assessing capabilities, reconfiguring aspects of the system, and in various ways while carrying out the ongoing monitoring. Thus, it is important to identify who, within the organization, has the information, resources, and incentive to be able to assist in monitoring. It is also important, in some cases, that these characteristics overlap in some of the personnel. At all sites we investigated, between the Energy Manager, maintenance groups, and manufacturer's representatives, there was enough information. But also at all sites, no one person covered the range of required information, and several people had to be consulted. Since the new generation of methods of accessing data are more advanced, and in some cases can be more intrusive, a real partnership between the building personnel and the monitoring staff is required for a smooth monitoring project.

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