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Texas LoanSTAR
Monitoring and Analysis Program
Draft Plan

Submitted to:

Energy Management Center
Office of the Governor
State of Texas

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EXECUTIVE SUMMARY

Major objectives of the LoanSTAR Monitoring and Analysis Program (MAP) are to:

- verify energy and dollar savings of energy conservation retrofits in state, school and local government buildings.
- reduce energy costs by identifying operational and maintenance improvements at facilities receiving retrofits
- improve retrofit selection in future rounds of the LoanSTAR Program
- provide a detailed data base of energy use in commercial/institutional buildings located in Texas.

The monitoring and analysis program is being conducted by:

- monitoring and Analysis Contractor (MAC)-- the Energy Systems laboratory (ESL) at Texas A&M University.
- data Acquisition System Subcontractors (DASS).
- monitoring Advisory and Review Committee (MARC).

Monitoring and data analysis will be conducted at three primary levels:

- facility/whole building utility data.
- facility/whole building short-term demand and consumption data.
- sub-metered retrofit data.

The major tasks of the monitoring and analysis contractor are to:

- develop a comprehensive monitoring and analysis program plan.
- coordinate a workshop at which the monitoring advisory and review committee outlines modifications to the program.
- specify data reporting format.
- test sensor and system types to be used in the program.
- develop an approved list of monitoring equipment for use in the MAP and negotiate quantity discounts, with assistance from the Governor's Energy Management Center (GEMC).
- qualify three to six firms as data acquisition system subcontractors and supervise their performance.
- design and implement a system to archive data collected.
- analyze data to determine savings realized by retrofits.
- analyze data and examine facilities to determine whether further retrofits and operational savings are

practical.
- conduct training for facility operators to implement findings of the MAC that will improve the efficiency of building operation.

The data acquisition system subcontractors will:

- assist the MAC in design of an instrumentation plan for each monitored site.
- install the hardware and calibrate sensors.
- provide data/guarantee data to the MAC.
- maintain hardware for the duration of the monitoring in each building.
- periodically recalibrate sensors and report on hardware condition.

The monitoring advisory and review committee will:

- provide input and expertise from national monitoring and analysis efforts to preclude costly MAP errors and needless duplication of effort.
- participate in a workshop to refine and improve the comprehensive MAP Plan.
- meet at six- to twelve-month intervals to review progress of the mMonitoring and analysis program, to ensure that it fully integrates appropriate input from other monitoring projects and to recommend future directions of the program.

Contents

Chapter 1

Introduction and Background

In 1988, the Governor's Energy Management Center (GEMC) of Texas received approval from the U.S. Department of Energy to establish a $98.6 million statewide retrofit demonstration program, the LoanSTAR (Loan to Save Taxes and Resources) Program. The LoanSTAR Program is designed to demonstrate commercially available, energy-efficient retrofit technologies and techniques.

The program will use a revolving loan financing mechanism to fund energy-conserving retrofits of state, public school and local government buildings. Retrofit projects will be identified by energy audits conducted according to the guidelines of the Texas State Energy Conservation Program (SECP). Each retrofit will compete for funds on the basis of the estimated payback period, ability to repay the loan through energy savings, engineering assessment of the viability of the retrofit, and the GEMC's ability to monitor the project effectively. The projects will apply the latest cost-effective energy saving technologies for commercial and institutional buildings.

The LoanSTAR Program will be implemented in two phases. Phase I targets state agencies and institutions that received energy audits conducted by engineering firms for the GEMC through the Texas Energy Cost Containment Program (TECCP). Capital intensive energy-conserving improvements recommended by the TECCP auditors are candidates for funding in this phase. Loan recipients will repay the loan from energy savings projected from the retrofit projects.

Public schools and local governments are targeted for Phase II of LoanSTAR. Previous engineering audits of these facilities conducted under the Institutional Conservation Program (ICP) revealed potential energy savings similar to those in state buildings.

The projects funded by LoanSTAR primarily will include retrofits to lighting, HVAC systems, building shell, electric motors, energy management and control systems (EMCS), boilers and thermal energy recovery systems. Other retrofits using alternative or renewable energy systems and load management also will be considered.

LoanSTAR will establish a monitoring and analysis project to measure energy and cost savings at selected sites and to increase the effectiveness and savings from the program. Because the program is expected to involve eventually hundreds of retrofits (and monitoring installations) in buildings throughout the state, it is extremely important to

prepare a plan that provides overall direction to the monitoring and analysis component of the LoanSTAR Program. Failure to do so could result in unnecessary metering and added program cost.

This is the first draft of that plan. It is intended as a work plan for a comprehensive monitoring program that will serve the purposes of the GEMC, the institutions receiving retrofits, building researchers and others involved in LoanSTAR. Chapter 2 describes the purpose, objectives and benefits of the monitoring and analysis program. Chapter 3 discusses organization, with a brief overview of each major task. Chapter 4 discusses the major monitoring and analysis tasks in more detail, including specific sub-tasks. This plan emphasizes the first year of the monitoring program.

Chapter 2

Objectives of the Monitoring Program

The monitoring program is an innovative and essential feature of LoanSTAR that will serve the different needs of many interested parties. The monitoring program has four primary purposes:

1. Verify energy and dollar savings of the retrofits.

2. Reduce energy costs by identifying operational and maintenance improvements at facilities receiving retrofits.

3. Improve retrofit selection in future rounds of the LoanSTAR Program.

4. Provide a detailed data base of energy use in commercial buildings located in Texas.**

Money for each retrofit financed by LoanSTAR must be repayed to the GEMC on the basis of energy savings estimated during energy audits of the building. Thus, the monitoring program's first purpose is to determine whether retrofits save as much as estimated in audits. A monitoring plan must be developed for each retrofitted facility to verify savings. Verification of savings will include measurement of consumption data before and after the retrofit, and analysis of the data to account for weather, changes in operation of the building, etc. This is a quality assurance method to ensure that agencies purchasing retrofits receive real savings from the LoanSTAR Program.

The second objective of monitoring is to reduce the energy costs of a building by studying its energy-using characteristics. Experience at the University of Colorado, Princeton University and the U.S. Department of Energy has demonstrated how monitoring identifies specific energy use patterns of equipment (lights, HVAC, etc.) and changes in operation that can substantially reduce the energy use of a building. Monitoring specific equipment can provide a precise breakdown of how much energy is used for cooling, lighting, heating and other. These data enable identification of retrofits that are not performing as expected and why, so "non-performers" can be dropped from future phases of the program. The data (with

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*"Commercial" building as used in this document refers to any state-owned building, school or local government building included in the Loan STAR Program. No distinction is made between "institutional" buildings and other "commercial" buildings.

interpretation) also will be made available to the building operator to help identify ways to improve daily operation of the facility. In addition, data from monitoring can also show how changes in occupancy, weather, equipment, etc. have affected the energy use of a building. The savings realized from this activity may pay for the entire monitoring program.

The data and subsequent analysis will measure the cost effectiveness of different types of retrofits in Texas buildings. Some retrofits will prove more effective and others less effective than expected. This knowledge will enable engineers who perform future audits to make more cost-effective recommendations. Hence the third objective is to increase the cost-effectiveness of future rounds of the LoanSTAR Program by reducing the number of ineffective retrofits installed.

The final major objective of monitoring is the establishment of a detailed, commercial building, end-use data base for buildings in Texas. Several large data collection programs in the U.S., including one at the Pacific Northwest Laboratory and another at the Lawrence Berkeley Laboratory, provide building scientists with data bases for analysis of building energy use and development of better analytical tools for predicting energy use. None include a large number of buildings in hot and humid climates, and none have been established for evaluation of the effectiveness of retrofits. Thus, the data base for the LoanSTAR Program will be unique and provide building scientists with invaluable data for future analyses.

Chapter 3

Organization

The Monitoring and Analysis Program (LoanSTAR MAP) will be conducted by the Energy Systems Laboratory (ESL) at Texas A&M University, which will act as the Monitoring and Analysis Contractor (MAC), and by Data Acquisition System Subcontractors (DASS) and a Monitoring Advisory and Review Committee (MARC), with other subcontractors as needed. The MAC will oversee monitoring, design the data base and write software, conduct analyses, interface with building operators and conduct educational programs for building operators. The MAC drafted this comprehensive plan to achieve the objectives described in Chapter 2. The plan will be refined with input from the Governor's Energy Management Center (GEMC) and the MARC. The MARC also will provide ongoing contact with other monitoring and analysis efforts to ensure incorporation of applicable techniques and results from those efforts. The data acquisition system subcontractors will install and maintain the monitoring equipment under the supervision of the MAC. Other subcontracts with Battelle Pacific Northwest Laboratory, Lawrence Berkeley Laboratory, Massachusetts Institute of Technology and Princeton University are planned to supplement the expertise of the MAC.

Monitoring and Analysis Contractor

The monitoring and analysis contractor is responsible for carrying out the overall monitoring and analysis program. Major duties include:

- preparing this draft plan for the metering and analysis needed to achieve program objectives.
- selecting and supervising performance of the data acquisition system subcontractors.
- preparing a list of approved hardware (after testing for compatibility), including updates.
- designing and implementing a system to archive the data collected.
- analyzing data to determine savings realized by retrofits.
- Reporting results to the GEMC and building owners.
- assigning audits to audit contractors.

- reviewing audit reports.

- Developing a facility for calibration of sensors and instrumentation.

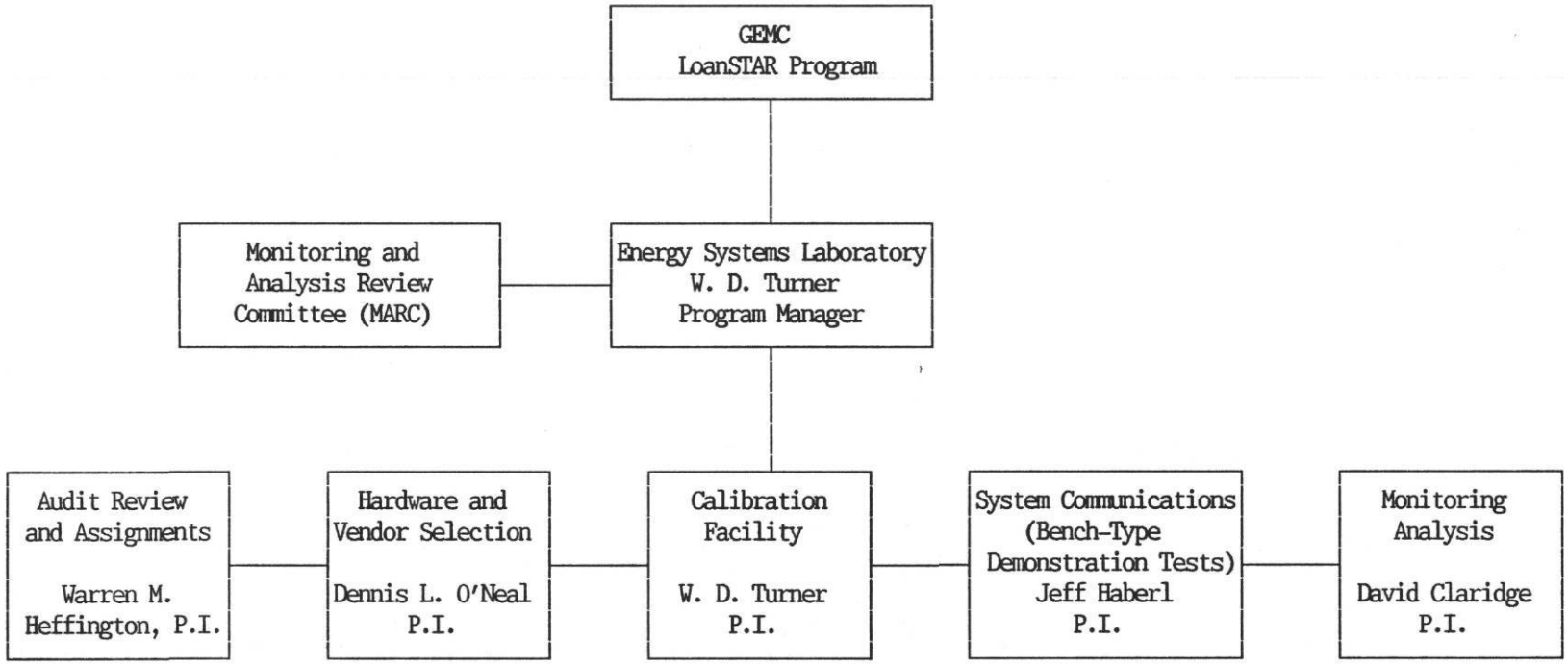
- developing an energy end-use data base for LoanSTAR Buildings.

- analyzing data and examining facilities to determine whether further retrofits and operational savings are practical.

- training facility operators to implement operational procedures that improve efficiency of building operation.

The duties of the MAC have been divided into five major tasks as shown in Figure 1. The tasks are described below.

Figure 1. Metering and Monitoring Analysis Subcontractor - Tasks and Principal Investigators



Task 1. Audit Review and Assignments: provide independent engineering review of all audits submitted to the GEMC; assign buildings to the consulting engineering teams selected to conduct audits for the LoanSTAR Program.

Task 2. Monitoring Systems Selection and Installation: ensure collection of adequate and reliable data by determining metering requirements, selecting data acquisition systems, and selecting and supervising the DASS who will install and maintain monitoring equipment.

Task 3. Calibration Laboratory: maintain NIST-traceable instrumentation to bench-test and prequalify different types of sensors and other hardware for use in the MAP; also calibrate portable instrumentation used to check field installations.

Task 4 - Systems Communications Testing and Development: bench-test hardware systems types before they are accepted for use in the MAP and develop software for use in polling and archiving data.

Task 5- Monitoring Plans, Analysis and Reports: analyze monitored data from LoanSTAR buildings and report the savings and O&M measures identified to the GEMC and agencies that own or operate individual buildings.

Data Acquisition System Subcontractors

Data acquisition system subcontractors are required to install and maintain data acquisition equipment in the buildings monitored. The DASS will prepare the metering installation plan for each building, with the cooperation of and subject to approval of the MAC (and the agency); select hardware from the approved list; and install the system. The DASS will also calibrate the system (including periodic recalibration) and provide maintenance as necessary to ensure that at least 90 percent of the data collected is usable. Calibration procedures must be approved by the MAC.

Monitoring Advisory and Review Committee

The monitoring advisory and review committee is composed of representatives from eight organizations with experience in monitoring and analyzing data from buildings. The MARC will meet initially to develop recommendations for the comprehensive monitoring and analysis plan, using the MAC draft plan as a "straw-man" document. The committee will meet thereafter at six- to twelve-month intervals to review progress of the program, ensure that the monitoring and analysis fully integrate appropriate input from other

monitoring projects and recommend future directions of the program. Members of the MARC come from national laboratories, universities, a federal agency and a utility research organization.

Chapter 4

Task Plans

The previous chapters have described the purposes and organization of the monitoring and analysis program in broad outline. This chapter provides detailed descriptions of the tasks of the monitoring advisory and review committee and the monitoring and analysis contractor.

Monitoring Advisory and Review Committee

The first meeting of this committee will be held December 14-15, 1989 in Austin, Texas to modify and refine this draft of the Comprehensive Monitoring and Analysis Plan. This mechanism will enable the MAC to utilize the experience of other major monitoring programs to minimize problems and avoid duplication of effort. Historically, large-scale monitoring programs have taken two- to- five years from inception until significant data was acquired. One of the goals of the LoanSTAR Program is to reduce this costly front-end requirement. Initial retrofits in the LoanSTAR Program are planned within a few months, so the MAP must be implemented quickly.

The two-day workshop will be structured to use the draft plan as a starting point -- not as a definitive statement of how the program will be conducted. The workshop will produce a refined and detailed outline of changes needed in the plan, to be implemented by the MAC immediately following the workshop.

Work Plan

Date	Action
Year 1:	
December 1989	Planning Workshop
Late Spring 1990	Review Meeting
Year 2:	
Late Autumn 1990	Review Meeting
Late Spring 1991	Review Meeting
Successive Years:	
Late Autumn	Review Meeting
Late Spring	Review Meeting

Monitoring and Analysis Contractor

Task 1. Audit Review and Assignments

Purpose

This task requires an independent review of all energy audit reports submitted by the eight consulting engineering firms under contract to the GEMC. Reports will be reviewed for use of appropriate technology, conceptual correctness, adequacy of implementation cost data, numerical accuracy and compliance with program guidelines.

Another purpose is to assign audits at a pace that keeps approximately fifteen engineering teams reasonably busy and on schedule completing the audits.[1] These audit assignments likely will be made by personnel of the GEMC, including a Texas A&M engineer officed in the GEMC. This task advertising, interviewing and hiring for the engineering position.

Functions

Conduct desk-top audit reviews for consulting engineers' reports. All reports in the draft stage will be reviewed to assure they are accurate, propose the use of suitable retrofit technologies, are conceptually correct, have adequate implementation data, are numerically correct and are in compliance with guideline and format requirements. This task involves final approval of the audit reports, which triggers certain payments to the firms. It is the primary function of Task 1.

Assign audits.* Agencies desiring audits apply to the GEMC. The audit requests must be reviewed and assigned to the consulting engineering firms in a timely manner.

Review preliminary on-site screening reports (POSSR).* Facilities are screened by an assigned engineering firm to identify projects and eliminate poor audit candidates at an early stage. The screening results in a tentative list of projects and a proposed audit cost by Energy Cost Reduction Measure (ECRM) that must be reviewed and approved.

Conduct meetings of the consulting firms, agency and GEMC.* In conjunction with the POSSR review, a meeting between representatives of the consulting firm, agency and GEMC must be conducted to finalize the tentative ECRM projects in the POSSR.

Negotiate audit prices.* Audit prices proposed by the contractors are given close scrutiny and are subject to

negotiation when it is in the interest of the State to do so.

Participate in audit format training workshop.* TAMU has already participated in a one-day workshop to train auditors on the audit guidelines and format, and will do so on an as-needed basis.*

Work Plan

Date	Action
Year 1	Employ engineer to be officed in the GEMC to: assign audits; review POSSRs; conduct meetings of the consulting firms, agency and GEMC; and negotiate audit prices.
December 1, 1989	Participate in audit format training workshop.
Year 1 - Year 4	Conduct desk-top audit reviews of consulting engineers' reports. This has been ongoing since contract initiation and will continue until approximately four to six months after the last audit. The review procedure used is described below

Audit Report Review Procedure

The following procedures are followed in the detailed desk-top audit review process at Texas A&M University. Audit report drafts are sent to the GEMC, the agency, and Texas A&M. When a draft is received at Texas A&M, it is logged in and comments are solicited from the agency energy manager. The draft is routed to a review assistant (graduate student) who reviews it in detail for numerical correctness and agreement with the POSSR, format and guidelines. Insofar as possible, the review assistant comments on the concepts employed and the technology recommended. A copy also is sent to the cost analyst (a professional cost estimator from the Department of Construction Science) who reviews the implementation cost data.

The draft then proceeds to a professional engineer in the Mechanical Engineering Department who discusses identified problems with the review assistant or cost analyst; reviews unusual aspects of the report, including new ECRMs and questionable procedures; and independently reviews the report for overlooked problems. The engineer then merges the comments of the agency energy manager, GEMC and Texas A&M reviewers. Two annotated review copies are prepared and one is returned to the consulting engineering firm for

action. The other is kept as a record copy at Texas A&M. Occasionally, the draft procedure is repeated. When the final report is received at Texas A&M, it is compared to the record copy and any problems are reconciled prior to acceptance.

Task 2. Monitoring Systems Selection and Installation

Purpose

This task ensures that adequate and reliable data are collected to monitor energy use of the buildings participating in the LoanSTAR program. Data collected from the buildings will serve as the basis for determining the cost- effectiveness of different retrofits as well as providing indices of how well an individual building is performing. Thus, it is critical that the data are the best that can be collected given economic constraints.

Functions

The major functions in this task include: determination of metering requirements, data acquisition system subcontractor qualification, data acquisition systems subcontractor selection, and installation and maintenance of systems.

Determination of Metering Requirements

The monitoring program is intended to verify savings, ensure that retrofits operate properly and identify additional measures to reduce energy costs. Sufficient data must be collected to achieve these objectives, but monitoring and analysis expense must not undermine the cost-effectiveness of the LoanSTAR Program.

Evidence from LBL, Princeton, the U.S. DOE, the University of Colorado and elsewhere shows the cost- effectiveness of sub-metering large buildings with major retrofits. However, savings achieved in smaller buildings do not generally justify the expense of sub-metering. Such buildings will have whole-building energy consumption analyzed, sometimes with monthly data and sometimes with 15-minute or hourly demand data.

Four levels of systems have been developed for the monitoring program. These accommodate the necessary data requirements with the money available for monitoring retrofitted buildings. The levels also are compatible with different hardware available on the market. As the project progresses beyond the prototype year, the definition of the levels and associated hardware requirements is expected to change.

Level 0. Facility/whole building(s) utility data: These data will vary from monthly consumption data, based on utility bills, to weekly or daily data collected by utility meters. It is useful for separating consumption into heating, cooling, water heating and other non-weather related consumption. A substantial portion of retrofits in the schools and local governments are expected to fall within this category.

Level 1. Whole-building and limited sub-metered hourly data: Ongoing work at Texas A&M, Princeton and LBL shows that use of hourly data permits a more detailed analysis of end-use patterns and identification of major individual operating parameters within buildings than does the use of monthly or daily data; for example, whether lights or air conditioners are being turned off as scheduled. This level will utilize one to four channel data acquisition systems and is also a viable option for buildings of intermediate size. Portable meters will sometimes be used to collect such data for a one- to two-month period.

Level 2. Moderate sub-metered hourly data: This level has all the capabilities of the first two levels and also enables more detailed analysis for identifying the savings from specific retrofits and pinpointing building operational problems. Moderate sub-metered data acquisition systems will be simple four to twenty channel systems. Sub-metering in some smaller all-electric buildings can be accomplished with smaller systems to obtain adequate data at minimum cost.

Level 3. *Detailed sub-metered hourly data*: These systems typically include at least 20 channels of data. Given current costs for these systems, they are expected to be cost-effective only in large buildings and groups of smaller buildings with retrofits valued at more than $500,000. Large buildings constitute about half of the expenditures expected in Phase I of the LoanSTAR Program. These systems also will be required in selected smaller installations (such as schools and local government buildings) to "calibrate" the simpler levels (i.e., daily or monthly manual watt-hour readings) of monitoring for different building types in Texas. Portable systems will be used for one- to two-month periods in some of these buildings as well.

The feasibility of using an agency's existing energy management control system (EMCS) to gather some or all of the required data will be explored during this first year. Cost reductions are possible if it is feasible to use EMCS systems for data acquisition.

Data Acquisition System Subcontractor Qualification.

Subcontractors will be required to install and maintain data acquisition equipment in monitored buildings. The DASS will prepare a metering installation plan for each monitored building, with the cooperation and approval of the MAC (and the agency). Then the DASS will select hardware from the approved list and install the system. The DASS also will calibrate the system (including periodic recalibration) and provide maintenance as necessary to ensure that data collected during the monitoring period are usable.

The MAC will qualify three to six engineering firms to work as subcontractors during this first year. The number of qualified DASS may be changed if problems arise concerning installation quality or project scheduling.

Data Acquisition System Subcontractor Selection.

DASS selection will be based on guidelines in the Request for Qualifications (RFQ) that was sent to interested subcontractors in September 1989. The selection committee consisted of several staff and principal investigators of the MAC and GEMC. Committee members were given copies of each respondent's RFQ and evaluated the RFQ according to the following criteria:

general knowledge of data acquisition systems	(15%)
knowledge of hardware and software	(15%)
knowledge of calibration requirements	(15%)
ability to staff project	(15%)
quality of prior work	(25%)
geographical location(s) in the state	(15%)

The committee's evaluations were collated and the final list of subcontractors forwarded to the GEMC for approval.

Data Acquisition Systems Selection

Data acquisition systems include both the data-logging hardware and transducers which measure electrical power, temperature, pressure, etc. The selection process will continue throughout the duration of the project. As new hardware is qualified, it will be included on an approved hardware list from which the DASS may make purchases.

A list of data logging equipment appropriate for each level of monitoring has been developed by the MAC (Table 1). The equipment must have an open communications protocol so the MAC can incorporate it into the LoanSTAR MAP Network (MAP NET). A sample of each of the vendors' systems is undergoing evaluation by the MAC to ensure compatibility with data transmission protocols and any other equipment it must interface with before being listed.

Table 1 - Data logging hardware being evaluated by the MAC.

Level	Manufacturer
1	Sangamo
2	Campbell/Synergistics Controls
3	Synergistics Controls

The MAC also is discussing quantity discounts with these manufacturers. It may be possible to reduce the purchase price of data loggers and some transducers by 10 to 25% of retail prices.

Estimating the savings due to a retrofit will require accurate estimates of end-use energy in many of the buildings. End-use measurements require a variety of transducers. Listed below are the transducers that are anticipated:

1. electrical sensors
   - current transformers
   - wattmeters
   - voltage transformers
2. temperature sensors
   - RTD
   - thermocouple
   - thermometer
   - IC
3. humidity sensors
   - relative humidity
   - dew point
4. airflow meters
   - hot wire
   - pitot-static
   - turbine
5. waterflow meters
   - turbine
   - venturi
6. pressure transducers
   - differential
   - total
7. anemometers
8. Btu meters
9. pyranometers

Installation and Maintenance of Systems

The installation of a monitoring system at a site will require several steps:

1. review of audit report and loan application.
2. assignment of DASS.
3. installation of whole building meter.
4. development of a site metering and analysis plan (SiteMAP).
5. purchase and installation of monitoring system by DASS.
6. system verification.
7. maintenance and calibration of monitoring system.

Review of audit report and loan application:

To consider installation of a monitoring system in a building, the MAC first will review the audit report for the building as well as the loan application. This review determines what level of metering system to install at the site and provides a preliminary contact between the MAC and the agency. The audit reports provide useful data on building size, monitoring equipment, current potential difficulties in end-use monitoring, etc. The loan application contains information about the retrofit that will be installed in the building.

Assignment of DASS:

The MAC will assign a DASS to a site based on the site's monitoring requirements and geographical location. The DASS will be chosen from the list previously approved by the MAC and the GEMC. During the prototype year, the MAC may have more than one DASS visit the same site to aid in developing site plans and identifying potential field installation problems.

Installation of whole building meter:

For all levels of monitoring, the priority will be to obtain whole building electrical and gas metering (Level 1) as soon as feasible. Initiation of Level 1 data collection at Level 2 and 3 sites will provide the MAC with data several weeks to months before the complete Level 2 or 3 system is operational. Level 1 metering could be included as a part of the DASS's initial visit to the site. The feasibility of this approach will be tested in the pilot year.

Development of a site metering and analysis plan:

When the agency loan is approved by the GEMC, the MAC will conduct a preliminary survey to determine information such as building description, utility billing history, existing metering, EMCS system information, type of retrofit, estimated savings, local climatological data and photographic record. Some of this information will come from the audit report and loan application. With these data, the MAC will develop a Conceptual Monitoring and Analysis Plan (CONMAP) with an initial estimate of the metering level required for the facility.

The MAC will then contract a DASS to conduct a one- to two-day site visit to develop a Preliminary Site Monitoring and Analysis Plan (PREMAP) analogous to the preliminary on-site screening report of the audit program. The PREMAP will

include options for hardware (specified by brand name), equipment locations, data to be provided, data format, as well as estimates of hardware and installation costs. The MAC will be responsible for developing procedures that the DASS must follow in completing the PREMAP.

This PREMAP and CONMAP will then be used by the MAC to develop a site monitoring and analysis plan (SiteMAP) that contains final recommendations for the type of monitoring system to install, locations, etc. Agency concurrence on the SiteMAP is important to ensure that the proposed installation does not interfere with an existing system and is installed in an accessible and safe location. The agency's concurrence also is important because the money for the monitoring system is paid by the agency out of its retrofit loan. The GEMC will have final approval on each site metering plan.

Purchase and installation of monitoring equipment:

Once a SiteMAP is approved, monitoring equipment can be purchased and installed. Only models certified by the MAC calibration facility can be specified for installation. The DASS contract will include hardware purchase, installation, calibration and maintenance. All installations will be calibrated in the field using portable equipment which is periodically recalibrated at the ESL. The MAC resident engineer will oversee installation, verifying that equipment works to specifications and that the data being collected is in proper format and passes a specified battery of data quality control tests.

Afterward, the DASS will provide periodic inspections, recalibrations and verification of data accuracy according to a prescribed schedule.

System Verification:

Data verification is performed immediately after the monitoring equipment is installed. The data will be compared with past utility data, auditor estimates of consumption and any other information available to verify that the data acquisition system and sensors are providing reasonable values. This is followed by independent checks of most sensor outputs using portable instrumentation. Such checks must be performed periodically for data quality assurance.

Maintenance of monitoring system:

The contract documents and specifications cover warranty items, routine maintenance and unscheduled or emergency repairs to the data acquisition system. Continuing maintenance of the equipment must be provided in a timely

manner to assure that usable data is delivered to the MAC at least 90 percent of the time.

Work Plan

Date	Action
Sept-Oct 89	Initial selection of pilot year data logging systems.
Sept-16-89	RFQs sent out to potential contractors.
Oct-16-89	RFQ deadline for submission.
Nov 89	Final approved list of DASS distributed.
Dec 89	DASS visits to pre-selected site to develop site plan methodology.
Jan 90	Initial list of approved LoanSTAR sites assigned to DASS.
Jan-Aug 90	Continue DASS site assignments and follow-up on completed installations.

Task 3. Calibration Laboratory

Purpose

The purposes of the Calibration Laboratory are:

1. Construct an NIST-traceable facility which can be used to test sensors and verify their compatibility with selected monitoring systems.

2. Establish a facility to troubleshoot faulty sensors found in the field.

3. To verify portable instrumentation which can be used for field testing and validation.

4. Have a facility to bench-test and pre-qualify proposed hardware systems prior to installation in the field, which means close interaction with Task 4, Systems Communications.

The calibration laboratory will be located at the Energy Systems Laboratory on the Texas A&M Riverside Campus. An expansion of these purpose statements follows:

1. The philosophy behind establishing the calibration laboratory is to be able to verify both sensor accuracy and compatibility with the monitoring systems before field installation. In too many cases, the field installation is the first check of system compatibility. For example, a recent installation at a Texas state facility took months before the system was operational.

2. Field installation problems likely will arise with faulty sensors or a faulty class of sensor. Since the DASS are required to maintain and verify periodic calibration of their systems in the field, the ESL calibration facility can be used to determine sensor problems and also resolve potential conflicts about incorrect sensor readings.

3. Calibrated portable instrumentation also will be developed for spot checks on the DASS installation. The DASS is responsible for installing the system and certifying proper operation, but a portable field unit will enable the MAC to verify proper system operation on-site. The unit also can be used for trouble-shooting older installations when problems arise.

4. The accuracy of sensor calibration is key to the whole monitoring project. Data obtained from the DAS has to be accurate to maintain confidence in the project. To verify the accuracy of sensors and to have a facility that the DASS will have confidence in, NIST-traceable calibration is

absolutely necessary. The ESL will make NIST- traceable services available to potential hardware suppliers, and will maintain an NIST-traceable facility for all the common quantities (i.e., temperature, velocity, flow, rpm, etc.) that will be encountered in this program. It is also anticipated that field sensors and systems will be rechecked periodically to verify their continued calibration.

Functions to be Performed

The calibration facility will include the capability to measure electrical energy, power factor, electric demand, temperature, air and liquid flow rates, humidity, pressure, light levels, air velocity and rpm. Services available from local utilities for a nominal fee will be used for calibration of electrical meters and gas meters. It is not cost effective to perform independent calibration with less than 100 sites per year.

The Energy Systems Laboratory will use National Institute of Standards and Technology (NIST) certified instrumentation where practical, but as a minimum, will maintain NIST-traceable instrumentation. Periodic calibration will be maintained for both the primary-and secondary-standard hardware.

Work Plan

The calibration laboratory will be constructed at the Energy Systems Laboratory, a test laboratory certified by the Home Ventilating Institute for air flow testing of fans. When a performance curve is run on a fan, quantities such as rpm, power and flow rates normally are measured. Thus, some of the facilities and instrumentation necessary for air flow and power measurements already exist. Where possible, existing test facilities will be used or modified to meet the needs of the calibration laboratory.
The facility is scheduled for completion in March 1990. Testing will be conducted as needed thereafter.

The following briefly describes facilities needed to calibrate temperature, humidity, liquid flow, air velocity and lighting level sensors. The range of calibration, types of sensors calibrated, accuracy of calibration and applicable standards are specified.

Objective:

Develop and maintain the capability to calibrate and test liquid-in-glass thermometers and electronic temperature measuring systems to an accuracy of $\pm$0.2|F (0.1|C) over a

range of -40|F to 500|F (-40|C to 250|C) and have traceability to NIST.

Capacities:

1. range of calibration: -40|F to 500|F (-40|C to 250|C)
2. accuracy: ±0.2|F (±0.1|C); traceable to NIST
3. type of devices that can be calibrated:

   a. liquid-in-glass thermometers
      - total immersion
      - partial immersion

   b. electronic temperature measuring systems
      - thermocouples
      - thermistors
      - RTD
      - integrated circuit sensors
      - temperature portion of relative humidity sensor

Standards:

1. International Practical Temperature Scale of 1968
2. ASHRAE Standard 41.1-86, Standard, Method of Temperature Measurement
3. ASTM Standard E220-86, Standard, Method of Calibration of Thermocouples by Comparison Techniques
4. ASTM Standard E64-86, Standard, Method for Testing Industrial Resistance Thermometer
5. ASTM Standard E77-84, Method of Verification and Calibration at Liquid-in-Glass Thermometers
6. ASME Standard PTC 19.3-74 Part 3, Temperature Measurement Instruments and Applications

Equipment

- thermometer storage rack
- microscope (15-20-X power)
- ice bath with necessary accessories
- constant temperature bath (-40|F to 500|F)
- distilled water storage container (20 gallons)
- ice shaver
- ice maker/storage
- primary set of ASTM thermometers (NIST certified)
- 3 Pt thermistors (NIST certified) with digital readouts (0.001|F)
- 10X power reading telescope

Simplified Testing Procedure

1. physical examination of temperature measuring device for flaws under microscope.
2. measurement in a prepared ice bath against primary thermometer and the platinum thermometer.

3. measurements in prepared constant temperature bath (three tests with a minimum of 10 points each).
4. measurement in a thermocouple well or duct, as required.
5. generation of test report including graph.

Humidity

Objective

Develop and maintain a laboratory for calibrating relative humidity sensors and dewpoint sensors to an accuracy of ±1.5 percent over a range of 5 - 99 percent R.H. and have traceability to NIST.

Capacities

1. range at calibration: 5 - 99 percent
2. accuracy = ±1.5% R.H., traceable to NIST
3. type of devices that can be calibrated:
   a. psychrometer
   b. dewpoint meters
   c. dimensional change devices

Standards

1. ASHRAE Standard, 41.1-86, Standard Method for Measurement of Moist Air Properties
2. ASTM Standard E337-62, Standard Method for Determining Relative Humidity by Wet and Dry Bulb Psychrometer
3. ASME Standard PTC 19.3-74 Part 3, Temperature Measurement, Instruments and Apparatus, Revised 1985

Equipment

- 3 precision dew point sensors
- 3 vacuum pumps
- 3 flow meters - cubic feet of air per hour
- temperature/humidity chamber (obtained from a DOE Program)
- 2 salt bath solutions - one at 11 percent R.H. and one at 95 percent R.H.

Simplified Testing Procedure

1. physical examination of humidity sensor
2. installation of humidity sensor in low R.H. salt bath
3. installation of humidity sensor in temperature humidity chamber and run three times with a minimum of 9 points each time
4. installation of humidity sensor in high R.H. salt bath
5. generation of test report including graph

Hydraulic Pressure

Objective

Develop and maintain a laboratory for calibrating absolute, differential and gauge pressure transducers to an accuracy

of ±0.5 percent over a range of 0 - 500 psi and have traceability to NIST.

Capacities

1. range of calibration: 0 - 500 psi
2. accuracy: ±0.5 percent, traceable to NIST
3. types of devices that can be calibrated:
   a. Pressure transducers
   b. Pressure gauges

Standards

1. ASME Standard PTC 19.3-87, Part 2 Pressure Measurement Instruments and Apparatus
2. ISA Standard 537.6-7.6 Potentiometric Pressure Transducer, Spec and Test of (Revised 1982)
3. ANSI B-40.1, American Standard for Indicating Pressure and Vacuum Gauges; Round Dial Type with Elastic Pressure Chamber, 1939

Equipment

1 dead weight tester with digital readout

Simplified Testing Procedures

1. physical examination of test pressure sensor.
2. install test pressure sensor on test stand and perform three tests with a minimum of 10 points each starting at lowest pressure to rated pressure.
3. generate test report including a graph.

Air Pressure

Objective

Develop and maintain a laboratory for calibration of manometer, air pressure and draft gauges to an accuracy of ±0.01 inch W.G. over a range of 0 - 24 inches W.G. and have traceability to NIST.

Capacities

1. range of calibration: 0 - 24 inches W.G.
2. accuracy: ±0.01 inch W.G.
3. types of devices that can be calibrated:
   a. manometers
      - inclined
      - micro manometer
      - regular
      - U tube
   b. pressure gauge

Standards

1. ASME, Standard PTC 19.2-37, Part 2, Pressure Measurements-Instruments and Apparatus
2. ISA Standard RP2.1-62 Manometer Tables Recommended Practices

Equipment

- hook gauge
- 2 Merian micro manometers
- precision barometer
- quick test vacuum pump

Simplified Testing Procedure

1. physical examination of test equipment.
2. calibration of micro manometer against Hook gauge.
3. installation of test equipment against micro manometer with three tests with a minimum of 10 points each starting at lowest point up to the rated pressure.
4. generation of test report including graph.

Liquid Flow

Objective

Develop and maintain a laboratory for calibrating liquid flow meters to an accuracy of ±0.5 percent of rated flow over a range of 1 - 650 gpm, meter from 1/2 - 4 inches in size and have traceability to NIST. Flow in excess of 650 gpm will be calibrated under subcontract.

Capacities

1. range of calibration: 1.0 - 650 gpm
2. Accuracy ±0.5 percent of rated flow
3. type of devices that can be calibrated:
   a. orifice
   b. wedge
   c. venturi tube
   d. flow nozzle
   e. positive displacement
   f. turbine
   g. vortex
   h. electro magnetic
   i. ultrasonic
   j. mass - cariolis
   k. mass - thermal

Standards

1. ASHRAE, Standard 41.8-78, Standard Method of Measurement of Flow of Fluid - Liquids
2. ASME, Standard PTC 19.5-72, Application Part III of Fluid Flowmeter

Equipment

- 3 liquid manometers
- 10,000 gallon storage tank
- piping and valving
- 6,000 gallon receiving storage tank
- screening material
- P & T ports
- flow pumps: 500 gpm, 150 gpm and 50 gpm

Simplified Testing Procedure

1. physical examination of flowmeter.
2. installation of flowmeter in appropriate flow test stand and run test points (10 points) from highest to lowest points
3. generate test report including graph.

Air Velocity

Objective

Develop and maintain a laboratory for calibrating pitot tube, hot wire thermoanemometer and rotary devices to an accuracy of ±0.01 inch W.G. or ±10 fpm over a range of 10 - 8,000 fpm and have traceability to NIST.

Capacities

1. range of calibration: 0.0 - 10.0 inches W.G.
   0 - 8,000 fpm I10 fpm
2. accuracy: ±0.01 inch W.G.
3. type of devices that can be calibrated:
   a. pitot tube
   b. hot wire thermoanemometer
   c. rotary devices

Standards

1. ASHRAE, Standard 41.7-84, Standard Method of Measurement of Flow of Gas
2. ASTM; Standard D3796-79, Practice for Calibration of Type S. Pitot Tube.
3. ASME, Standard PTC 19.2-87, Part 2 Pressure Measurement -Instruments and Apparatus
4. ISA RP2.1-62 Manometers Tables, Recommended Practices

Equipment

- 1-D Hot wire thermoanemometer with digital readout
- acrylic tubing
- inlet bell
- swedgelock fittings

Simplified Testing Procedure

1. physical examination of sensor.
2. install sensor in test chamber and run 3 tests with a minimum of 10 points each starting from the lowest point up to the rated point.
3. generate test report including graph.

Electric (KW and KWH) and Gas Utility Meters (MCF)

Calibration to be conducted under subcontract to local electric and gas utilities.

Light Levels

Portable, light meters will be compared to an existing NIST-traceable light meter at the Energy Systems Laboratory.

Task 4. System Communication Testing

Purpose

The purpose of this task is to conduct bench-mark communications testing of all field data acquisition systems for the LoanSTAR MAP. This includes testing the compatibility of sensors, DAS and the host computer. Public domain software, using open communications protocol, will be developed by the ESL for each system. DAS types that adequately satisfy ESL testing will then be accepted (certified) for use in the LoanSTAR MAP.

Functions

The primary functions of system communications testing are: 1) communications benchtest, and 2) software design.

Communications Benchtest

The communications benchtest facility will ensure that the local area network polling computers have access through open communications protocols to the instrumentation installed in each building. Each type of data acquisition system selected for a LoanSTAR building must be tested and certified for compatibility with MAP software. This testing will be conducted at a communications benchtest facility to be built at the ESL on the TAMU Riverside Campus. The facility will connect to the LoanSTAR MAP Network via a T1 fiber optic connection between the main campus and the Riverside Campus.

The LoanSTAR MAP Net will communicate with the benchtest facility over this T1 link and by modem to facilitate side-by-side testing with ESL benchtest equipment. MAC will establish a battery of tests, including: public domain modem function under automatic answering/automatic dialing (AA/AD), hardware/software implementations, catastrophic loss of power/power-up cycles, bit error detection and remediation, redial on busy or loss of connnections, password sign-on/sign-off, recording interval set/reset, clock set/reset, status check/reset, bit stream protocol for handshaking identification, initialization, audit trail capabilities and emergency operating procedures. The open protocol requirement is essential.

MAC can and will require source code in order to establish communication protocols and procedures. In such cases, non-disclosure agreements will be signed in order to obtain those portions of the code that contain vital information. MAC must have ready access to address codes and bit stream password construction of all field installations. These

protocol requirements will reside encrypted on the database, linked to each respective installation.

Software Design

A necessary subtask of the system communication testing and development is the development of software to poll, archive, analyze and report the energy savings of agencies participating in the Texas LoanSTAR. Important aspects of the software development process include the database design approach and the functional tasks of the LoanSTAR MAP database. A description of a typical data path for a Texas LoanSTAR agency or building also is provided.

Database design approach

The software engineering approach will include: 1) system engineering and analysis, 2) software requirements analysis, 3) design, coding and testing of software, and 4) Maintenance and upgrades.

1. System engineering and analysis (Product: software plan). This task will identify user requirements; define the analysis to be performed and specify products to be produced; survey other organizations to see what systems are currently being used; identify proprietary software packages that may or may not be performing similar tasks; and perform a formal literature search concerning work performed in this area.

2. Software requirements analysis (Product: software requirements specification). Once the software plan has been established, the next task is to develop the software requirements specification. This document will define data files, database structure, paths for data flow, data inputs/outputs, and software packages/languages to use during the codification process. Specialty proprietary statistical, database and graphing packages also will be evaluated for inclusion in the software design.

3. Design, coding and testing (Product: preliminary and detailed design, coding and testing). This task comprises the formal development, coding and testing of software modules. It includes proper documentation and insertion of completed code into the system architecture. Available public domain software will be used (when appropriate) to reduce coding requirements.

4. Maintenance and upgrades. This task entails the maintenance and upgrades of software produced in the previous three tasks. Maintenance and upgrades are important functions for any software project. Unlike hardware, computer software requires continual upgrading and maintenance to assure that problems (or "bugs") are resolved

and new features incorporated into the system as rapidly as possible.

Functional Tasks for the LoanSTAR MAP DataBase

Primary functions of the LoanSTAR MAP include: 1) data entry, retrieval, polling and editing, 2) Database structure and relationship, 3) data retrieval, reports, graphs, browsing, and transfer, and 4) database documentation, help and training.

1. Data entry/retrieval/polling/edit. Data will enter the MAP database from one of several paths: by entry into pre-formatted screens, retrieval from archive files, and from polling of field units. All data will be systematically checked for errors, stored in the appropriate archive format and loaded into the relational file for on-line access.

2. Data Structure/Relationships. An important aspect to develop is the database structure and relationship to other data records in the database. This task involves development of database formats that will hold the diverse data needed for analysis of energy consumption data. An outline of anticipated database information requirements is shown in Figure 1. For example, the information required for a typical building easily could include: hourly consumption data and analog inputs, daily data, monthly data, annual data, site description information, schedule information, engineering information, log notes from site visits and interviews, weather information, predicted or simulated consumption, utility billing data and utility rate information. Such information then will be properly cataloged and maintained by the database management system.

3. Data retrieval, graphs, reports, browsing and transfer files. The primary product of the LoanSTAR MAP Network will consist of reports and graphs that document energy savings for the GEMC. Transfer files containing detailed information will allow for export/import of the data product for comparative study.

4. System documentation/help/training. System documentation and help and training manuals also will be developed to assure transferability of the information and institutional memory of the coding source code.

Typical Data Path for Texas LoanSTAR Agency

Data entering the LoanSTAR MAP can originate from three primary sources: 1) electronically polled data, 2) manually entered data, and 3) data transferred from existing databases. The paths for the different data are listed below.

1. Electronically polled data.

a. Poll site, check for transmission errors, test for dead telephone line, no answer,etc. -- archive raw data.
b. Translate to common data format, conduct additional error checking, archive translated data.
c. Prepare data for insertion into on-line relational data-base.
d. Use multi-generation archive of on-line relational data-base.
e. Analyze data and prepare reports and graphs.

2. Utility-type manual data.

a. Transcribe data using data entry screens, archive raw data.
b. Prepare data for insertion into on-line relational data base.
c. Use multi-generation backup of on-line relational data-base.
d. Analyze data and prepare reports and graphs.

3. Data transferred from existing records.

a. Transfer data using appropriate transfer routines.
b. Prepare data for insertion into on-line relational data-base.
c. Use multi-generation backup of on-line relational data-base.
d. Analyze data and prepare reports and graphs.

Work Plan

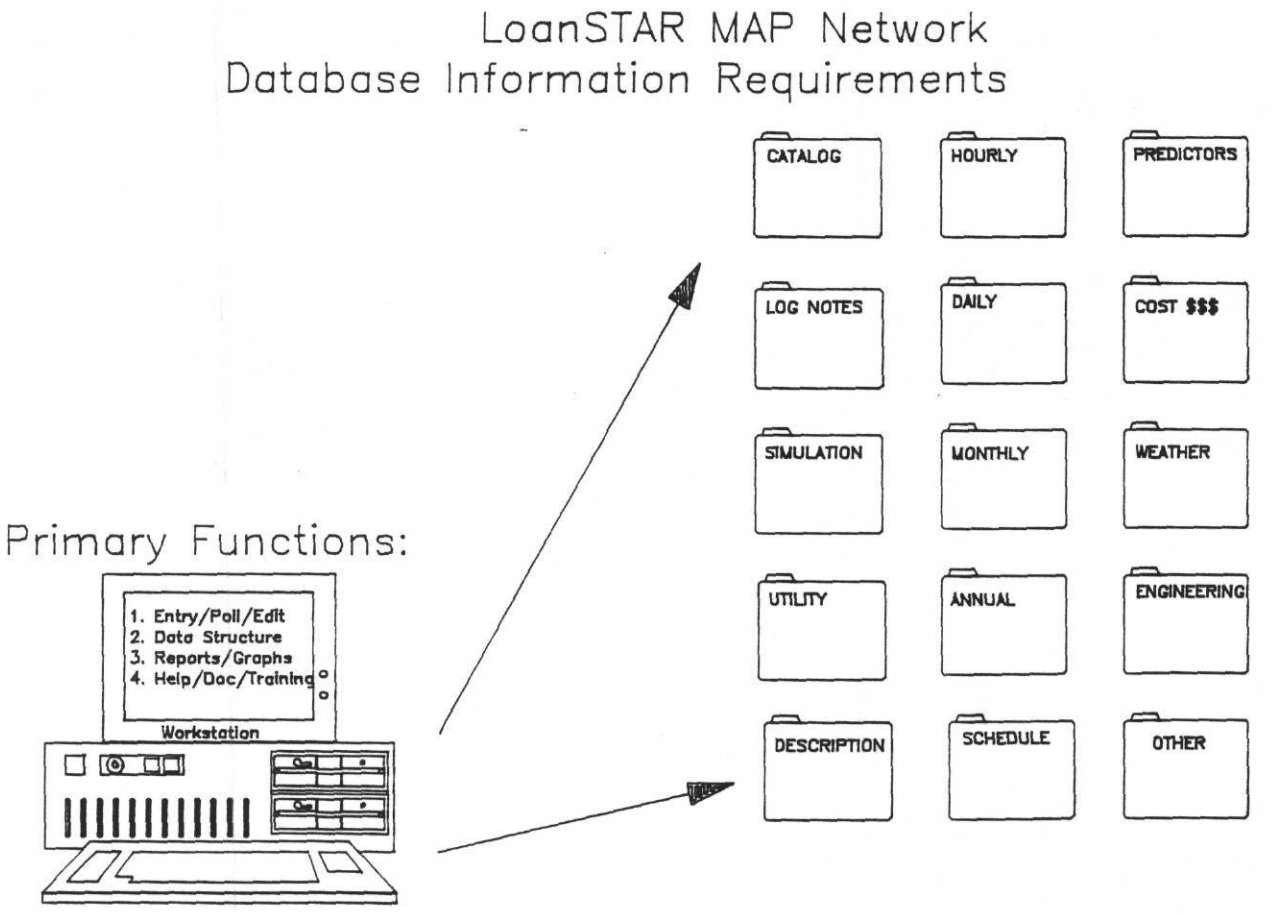
The following tentative schedule has been set for delivery of Task 4 sub-tasks.

Date	Action
December 1989	System engineering and analysis Deliverable: Software Plan
January 1989	Software requirements analysis Deliverable: Software Requirements Specs
Jan.-Mar. 1989	Design, coding and testing Deliverable: Preliminary & Detailed Design
Continuous	Maintenance and upgrades

Figure 2

Texas LoanSTAR Map Database Information Requirements

This figure shows the information requirements for the LoanSTAR MAP database. The four primary functions of the database are shown in the screen of the workstation. A set of typical files is shown to illustrate the complexity of the different types of information needed to make decisions about energy consumption usage.



Task 5. Monitoring Plans, Analysis and Reporting

Purpose

This monitoring and analysis task is responsible for analyzing collected data to:

1. determine the energy and dollar savings of the retrofits.
2. reduce energy costs by identifying operational and maintenance improvements at retrofitted facilities. Operator interviews are part of this subtask, as well as communication of needed changes to appropriate agency and operating personnel.
3. identify the savings of individual retrofits to help improve retrofit selection in future rounds of the LoanSTAR Program.
4. develop an end-use database of energy use for commercial/institutional buildings located in Texas.

Functions

This task will be conducted in two major phases: the pilot year and subsequent analysis with refinements added. During the pilot year, a local area network of computers, named the LoanSTAR MAP Net,will be assembled to archive data and conduct analysis. Data analyses will be performed in several phases for each monitored site. These include:

- verification/modification of audit assumptions
- pre-retrofit analysis
- preliminary post-retrofit analysis
- detailed post-retrofit analysis
- interaction and feedback to agencies and operators
- reports

The pilot year will be devoted to developing and testing a set of procedures and analysis techniques needed to implement these activities for each site. Refinements to the procedures will be added throughout the program. Subsequent analysis will streamline and automate such procedures to enable analysis of the increasing number of buildings in the program. During the second year and subsequent years, an end-use database for commercial and institutional buildings in Texas will be assembled and described, based on data available in the database.

MAP Net Hardware Design

The MAP Net will receive data from field instrumentation, analyze the data and produce reports from the analysis. This network is being configured to archive raw data on

optical WORM discs, process working data files on a large server disc, automatically back up all data transactions on cassette tape, and produce hard copy on a server printer. The network includes multiple work stations for engineering analysis, software development and secretarial duties. Data received from buildings is linked to a number of parametric files that contain information about building design, operational characteristics, weather, engineering constants and relationships, reports and recommendations, etc. All of these linkages will be encrypted on the database, so those with a valid need to know may access readily, through proper password protocol, the data necessary for their work. The hardware configuration of the LoanSTAR MAP Net is represented in Figure 3.

Information from field installations is received on the file server via modem communications controlled by XT class PCs. For interested users outside the MAP Net, there is a modem controlled by another XT class PC that will assess validity of the need-to-know. For example, a vendor may wish to monitor his LoanSTAR installations on occasion. As a qualified DASS, he has a legitimate need-to-know and will be given access clearance, only to query his own installations. All queries to this computer will be recorded in their own database for relational processing and audit trailing. A portable XT class PC will be deployed as needed to spot-check instrumentation function and integrity.

The file server is a dedicated 80386-based Ethernet processor. As such, it contains relevant hardware and software to amass the data coming from field instrumentation; to insure protection of the data system against invasion by computer virus, worms and trojan horses; and to back up automatically all data on a frequent schedule. Besides network workstations, the file server maintains an optical WORM disc for archiving, a working disc for software residence and file manipulation, an automatic cassette tape backup and a laser printer. There are three kinds of workstations on the network: 80286 clones, 80386 clones and Apple Macintosh class PCs. These machines are distributed across three primary uses: secretarial workstations, engineering workstations and staff workstations. Each of these classes will have its own password-protected area of access to the database. The LoanSTAR MAP Net will reside on the TAMU Ethernet backbone. This connectivity ensures LAN access to the IBM and Amdahl mainframes, the VAX clusters and the Cray YMP supercomputer on campus. This connectivity also puts the LAN on national networks such as BitNet, etc.

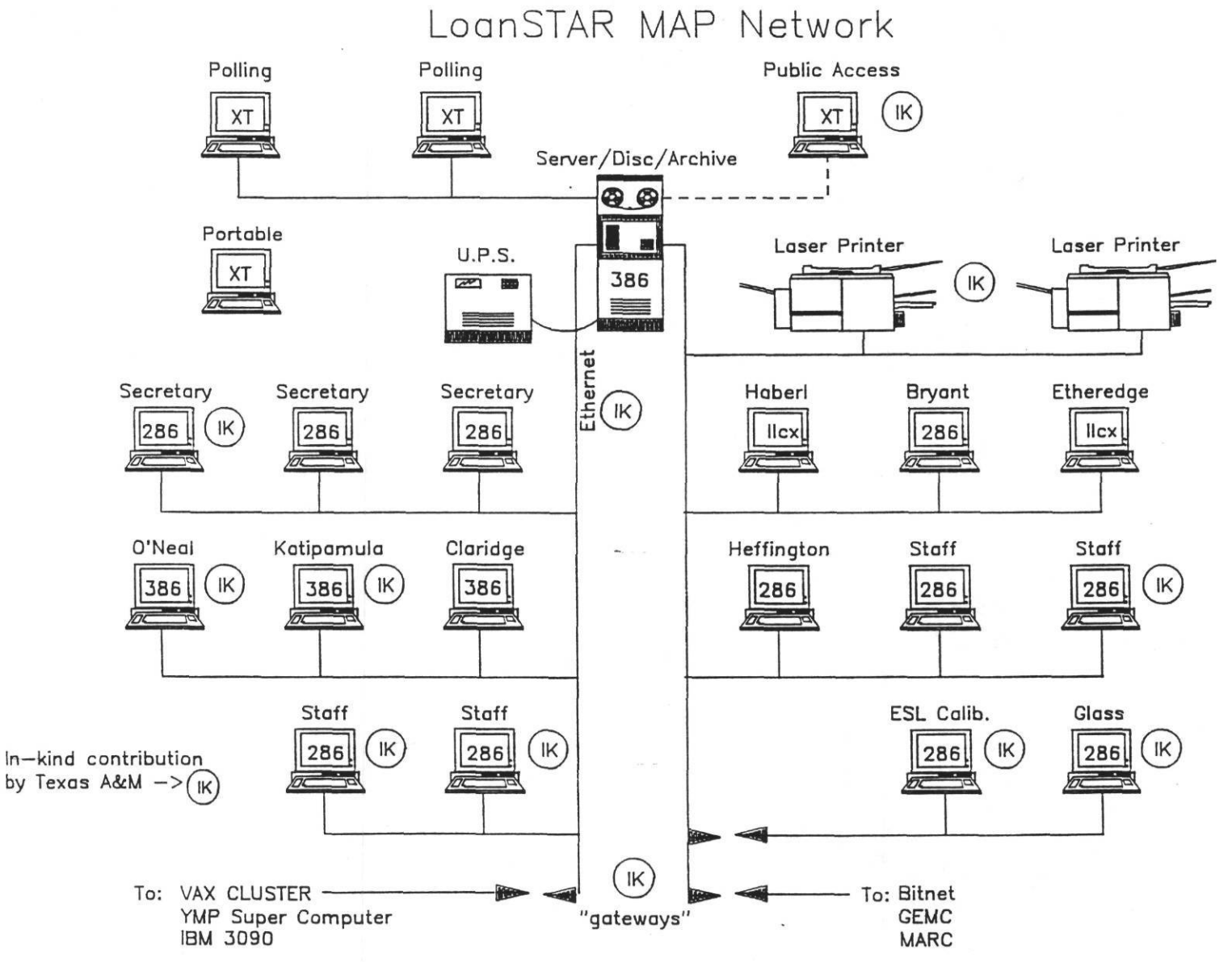


Figure 3. Texas LoanSTAR MAP Network. This figure shows the Texas LoanSTAR MAP NET to be configured at Texas A&M. The MAP NET will utilize a 386 class LAN server and 17 workstations connected with an existing Ethernet.

System Operation

The primary function of the LoanSTAR MAP Net is to acquire and archive data, analyze data and report the results to the project monitor and others. The hardware discussion above outlines the physical configuration of the network. This section briefly develops the network functions for each of several groups of people associated with various kinds of data in the database, and the relevant processing by each group. The methods by which data acquisition, archival, analysis and reporting are accomplished are not task independent. The primary function of data acquisition and archival is augmented by data processing all along the task alignment of the program. The operation of the LoanSTAR MAP Net will proceed according to task assignment as previously diagrammed, and summarized below.

The approved audit reports and recommendations from Task 1 will reside on the database with an identifier for each report. The identifier will indicate the level of monitoring this site receives, and linkages to the data that come from this site. The DASS for each approved site under Task 2 will enter the database with an identifier that links his instrumentation to the field site.

Information transmitted to the file server via polling computers from each field installation will enter the database with an appropriate identifier. Pertinent to each field site is other information relating building population and use parameters, operations and maintenance practices, architectural parameters and meteorological parameters. Each of these classes of data will enter the database with an identifier to link it to the polled information. The information in the database subsequently is processed at the engineering and staff workstations. The result and reports thus produced will reside on the database with an identifier that links all the raw and processed data files.

Verification/Modification of Audit Assumptions

The engineering savings estimates for the LoanSTAR retrofit measures rely on numerous assumptions made by the auditors. Some of the most crucial estimates are the electrical gains, building schedules, lighting schedules, etc. Data obtained from initial monitoring of buildings will be used (when practical) to check audit assumptions. In some cases this may lead to recalculated savings estimates. A procedure will be developed for "calibrating" the inputs used by energy calculation tools for use in these checks. Such a procedure is currently being developed for use with the DOE-2 building simulation program. Since this program is large and time-consuming to use, it must be restricted to certain very large installations. Similar "calibration" procedures

for less detailed programs, such as ASEAM, also will be investigated.

Pre-retrofit Analysis

Pre-retrofit analysis will utilize energy-use data collected from the building before retrofit measures are installed. This analysis will develop a preliminary model of energy use in the building that will be used to determine energy savings and cost savings due to the retrofit. The quality of such models depends on the amount and type of data available. In some cases, only a few months of monthly whole-building data will be available, but generally it is expected that at least two or three months of daily whole building data will be available. In some cases, a significant sequence of hourly data will be available. Additional information that will be used includes the audit reports and data, the DASS site plans and finalized measurement site plans, supplemented in some cases by interviews with building operators.

During the pilot year, procedures will be developed for using this pre-retrofit data to develop a suitable empirically-based model (with physically meaningful parameters) for predicting energy use. Different levels of model complexity will be used for different levels of data, e.g. a sequence of monthly data likely will permit use only of temperature (using PRISM) as a predictive variable. Daily data would permit incorporation of additional predictive parameters (e.g. scheduling, solar radiation, etc.) in models of slightly greater complexity. Hourly data on energy use, weather, occupancy, etc. will make possible evaluation of models which incorporate hourly schedules, weather data, etc.

Pre-retrofit data also will be examined to determine whether submetering installations accurately measure the response of the building and particular end-uses to the planned retrofits. In some cases, the analysis might indicate a need for changes in the monitoring systems installed.

The procedures developed during the pilot year will be evaluated and updated in later years to incorporate refinements based on experience gained with the Texas LoanSTAR buildings.

Preliminary Post-Retrofit Analysis

Preliminary post-retrofit analysis will be conducted to provide initial savings estimates based on measured data and to compare these estimates with the audit savings estimates. This analysis may lead to corrective measures if the retrofits are not performing as planned.

Measured consumption following the retrofit will be compared with the consumption predicted by the model developed in the pre-retrofit analysis. This will indicate whether the retrofit measures are performing as planned. If retrofit measures do not perform to design expectations, further analysis (sometimes in conjunction with site visits) will attempt to determine whether there is a modeling problem, an installation error or an incorrect audit estimate of savings. These findings will be used to correct or update the model or audit estimate of savings when necessary.

When installation errors are detected, the retrofit contractor will be contacted and asked to correct the installation. Correction of such problems will increase savings from the retrofit and may prove to be a significant benefit of the monitoring and analysis program. Anticipation of such cases necessitates development of a procedure to resolve conflicts between retrofit contractors and Texas A&M as the monitoring and analysis contractor.

Detailed Analyses

Following pre-retrofit analysis and preliminary post-retrofit analysis, the building models will be refined as additional energy-use and other data are collected. Thus, as information is obtained about building schedules, system operating parameters, etc., it often will be possible to update the pre-retrofit models by using the new information as inputs with the pre-retrofit energy-use data. The refined "pre-retrofit models" will be used then to provide better estimates of retrofit savings.

In some installations, "on-off" testing will be used to determine the impact of retrofits such as lighting. This will be particularly valuable if pre-retrofit data is inadequate.

While all three phases of the analysis effort will seek operational improvements to produce additional energy or cost savings, it is expected that the majority of that effort will occur during this phase. Identification of O&M measures typically will require significant interaction with building operators. This activity is experimental; it has been applied in a couple dozen individual buildings, but it has never been applied before to a large number of buildings. So significant effort will be required to develop an efficient approach to finding, communicating and measuring the impact of these O&M measures.

This portion of the analysis effort also will identify the savings attributable to specific retrofit measures when practical. This information will go to the GEMC to improve the measures selected for future loans.

Feedback to Building Owners and Operators

The MAP will differ from all previous large-scale monitoring programs by its emphasis on interaction with building operators so they will better understand operating practices and provide subsequent suggestions for improving operating practices. Evaluation of current operating practices will be based on an examination of whole-building and submetered consumption data as well as discussions with building operators. The experience of earlier research projects suggests that an interactive process will be most effective. Some features of the operation are obvious from the consumption data, but others require observation of the data and discussion with building operators. However, an important part of this task is attention to the behavioral aspects of communicating with the operators so they will feel they are an important part of the team, and hence want to see the O&M measures implemented and succeed.

An initial meeting with the building operators will review the preliminary data collected, familiarize them with system capabilities and solicit their input on specific operating problems which may be apparent in the data. The emphasis will be on benefits to both MAC personnel and the operators. The program will make them look better as operating personnel and enable them to learn more about their buildings. Subsequent meetings will be held when analysis shows a need for operator input or leads to recommendations for operational changes. Written recommendations will be sent to the agency and research will be devoted to determining the most effective written, verbal and graphical communication formats.

The successful implementation of operating improvements will be enhanced greatly if the GEMC and the agencies can provide significant financial (or other) incentives for key operating personnel in buildings that have or achieve highly efficient operation.

Reporting

The findings from this program will be reported in four ways:

- regular written summaries.
- technology transfer workshops.
- feedback (written and oral) to building owners and operators.
- public domain polling, archive and analysis procedures.

Regular Written Summaries

Regular summaries from this program will take several forms. For the GEMC and the agency involved, both of which are interested in monitoring the success of a retrofit, summaries will be provided quarterly. These summaries will include details of energy use and dollar savings by end-use (when monitored). Additional reports will be provided for buildings/facilities which perform below expectations. The fourth quarter report will be an annual report that summarizes major advances in analysis techniques, methods for identifying O&M measures and effective ways of communicating and implementing findings. The reports for this task normally will be incorporated within the overall report for the project, though topical reports and papers will be produced.

Technology Transfer Workshops

As the data from this program are analyzed and new techniques developed for estimating retrofit energy savings, the MAC will organize workshops to transfer this technology to engineering auditing firms, building operators, etc. The first workshop is planned for the second year of the MAP. Some of these workshops will be incorporated into the annual building symposium that is hosted by TEES and sponsored by the GEMC.

End-Use DataBase

An energy end-use database for the buildings in the LoanSTAR Program will be assembled and described based on the data archived. This database will be useful to state agencies for defining appropriate energy-use indices, planning and budgeting for energy costs of new construction, etc. It also will be useful to utility companies within the state. Support from utilities will be sought to broaden and enhance the value of this database. A more detailed plan for this database will be provided in the plan for Year 2.

Subcontracts

Four subcontracts will be negotiated under this task to provide support to the entire project. They are:

1. Lawrence Berkeley Laboratory: consultation on the metering, monitoring and analysis tasks and work with the EMCS system on a specific building to investigate the necessary system communication protocols and incorporate

edata from the EMCS system into the remote monitoring program;
2. Massachusetts Institute of Technology: consultation on development of calibration procedures, data acquisition hardware and software support; and advice on the metering, monitoring and analysis tasks.
3. Pacific Northwest Laboratory: to provide consultation on monitoring hardware, building monitoring, software, analysis and handling of the data.
4. Princeton University: to provide PRISM and behavioral support work, and consultation on the metering, monitoring and analysis tasks.

Work Plan

During the first year of the project, this task will emphasize development of procedures while carrying out analysis on the buildings for which retrofits are planned. This will result in application of less refined analysis tools and methods to some buildings than will be used later. During the following years, implementation of the procedures will proceed on larger numbers of buildings with research effort aimed at refining and improving the techniques used.

Listed below is a set of subtasks that will be implemented.

Year 1

- Analyze data and develop model for prototype building with Level 3 system (Zachry Engineering Center, TAMU).

- Collect and analyze data and develop model for prototype building with Level 2 system (Harrington Tower, TAMU).

- Collect and analyze data and develop model for prototype building with Level 1 system (A&M Consolidated High School, College Station).

- Calibrate DOE-2 model of Zachry Engineering Center and evaluate planned retrofits.

- Develop calibration procedure for use of DOE-2.

- Calibrate ASEAM to A&M Consolidated High School.

- Develop calibration procedure for use with ASEAM.

- Analyze data from Zachry Engineering Center and attempt to identify O&M changes.

- Analyze data from Harrington Tower and attempt to identify O&M changes.

- Analyze data from A&M Consolidated High School and attempt to identify O&M changes.

- Collect and analyze data from buildings approved for retrofit during first year of LoanSTAR Program.

Year 2

- Collect and analyze data from buildings retrofitted during year 1 of LoanSTAR.

- Collect and analyze data from buildings retrofit during year 2 of LoanSTAR.

- Develop preliminary methodology for identifying O&M measures using measured data and operator interviews.

- Refine models developed during Year 1 and apply to buildings for years 1 and 2.

Year 3

- Refine procedures developed during years 1 and 2.

- Collect and analyze data from all appropriate buildings.

- Additional tasks to be defined.

Year 4

- Same as year 3 with additional buildings on line.