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REMOTE TERMINAL SYSTEM EVALUATION

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Laboratory for Applications of Remote Sensing
Purdue University

The Laboratory for Applications of Remote Sensing at Purdue University has developed an earth resources data processing system which is being used by both LARS personnel and remote terminal users in part to determine the value of the system for training, technology transfer, and data processing. The results of Purdue's participation in this project are documented in this report. The facility has been used at seven separate sites and demonstrated to be a cost effective system for training personnel and technology transfer as well as meeting many data processing needs.

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I. INTRODUCTION

The Laboratory for Applications of Remote Sensing (LARS) at Purdue University has developed an Earth Resources Data Processing System which is being used by both LARS personnel and remote terminal users to evaluate the system for training, technology transfer, and data processing. This evaluation activity was organized through the Earth Observation Division of NASA at the Johnson Space Center in Houston, Texas, and included participants at five terminal sites and Purdue University. In addition to the five sites included in this project two other sites were connected to the system under separate agreements. The experience of these two sites are included in this report. The results of the remote terminal project are documented in seven reports: one from each of the five project sites, Purdue University, and an overview report summarizing the other six reports. This report contains the results of Purdue's participation in this project.

The purpose of a remote terminal to the LARS system is to provide an earth resources data processing capability to any group for training, technology transfer, and data processing. The technology for digital processing of remotely sensed data is relatively new. Since the use of this technology depends on knowledge of the technology by individuals at the site where processing might take place, one of the emphases of the remote terminal project was to determine appropriate training requirements and provide materials for training individuals at the remote site.

Technology transfer was another major interest of the remote terminal project. Trained individuals at a remote site does not in itself imply that a capability to process earth resources data exists there. A more complete understanding of the technology - including familiarity with specific implementations of processing techniques, knowledge of data sources, interdisciplinary approaches to information problems, etc. - is required before the capability to process data has truly been transferred from a group possessing these skills to a group desiring this capability. The term "technology transfer" is used in this report to denote this broader activity.

A secondary interest of the remote terminal project was determining the extent to which data processing tasks could be carried out effectively at a remote site. Once the capability to process data has been transferred to the remote terminal site, many options are available to the site organization for implementation of a hardware/software capability to meet their data processing needs. One such option is the continued use of the remote terminal. An evaluation of this use has been part of the remote terminal project as was the formulation of recommendations for future terminal configurations.

This report documents the details of Purdue's participation in this project. Chapter II describes the history of the development of the technology leading to the remote terminal concept and the remote terminal project. The objectives of the remote terminal project and Purdue's participation are also included in Chapter II. A discussion of Purdue's activities relating to the remote terminal project is included in Chapter III, organized around the Purdue objectives in the project. Much objective and subjective data relative to a remote terminal system is contained in this chapter. Chapters IV, V, and VI then summarize the significant accomplishments, conclusions and recommendations resulting from Purdue's participation in the project.

II. PROJECT OVERVIEW

A. Development of LARSYS

The initial remote sensing data processing research at Purdue University began in 1966 [1, 2, 3, 4, 5]. The objectives for this research were to develop data processing techniques which would apply already-developed pattern recognition techniques to remote sensing using multispectral scanner data acquired by the Willow Run Laboratory of the University of Michigan's Institute of Science and Technology [6, 7]. The data processing techniques were (1) to provide researchers of all disciplines with access to available multispectral data; (2) to provide a mechanism by which researchers could merge data from other sources, such as ground truth, with the multispectral data; and (3) to provide researchers the capability to apply pattern recognition techniques to the multispectral data. The purpose of the development of these techniques was to establish procedures for classifying multispectral data into classes of informational value.

The results of using these procedures in a broad base of applications led to the development of an earth resources information processing system which can provide, in a timely manner, information about the earth's resources. This system is called LARSYS (the "LARS System"). Researchers from Purdue, NASA, USDA, USDI, the University of Michigan, the University of California, and other agencies tested LARSYS on many varied applications of remote sensing. The use of this system for many applications by these agencies was of critical importance to showing the feasibility of using machine processing techniques for remote sensing.

By 1970 the use of LARSYS became limited in two ways. One, the system was incapable of being used by researchers unless they were physically located at Purdue. Two, the system was incapable of handling the number of users willing to physically locate themselves at Purdue. However, the fundamental concepts of an earth resources data processing system had been developed and tested extensively through LARSYS. These concepts were the development of a multispectral - multitemporal data bank, critical hardware and software components for the system, and training procedures for the use of the system.

Procedures for the creation of a multispectral - multitemporal data bank were developed for LARSYS. Data from most existing multispectral data sources have been made available to users of the LARSYS system. In addition, multitemporal data sets were successfully created via registration techniques.

This relatively rapid access to data through LARSYS was one of its most attractive features.

The concepts of hardware and software required for access to the system by researchers of many disciplines had also been developed and thoroughly tested. The primary access to the system was through a typewriter terminal, a printer, a card reader, and a card punch. The concepts of interacting with the data via a digital display had also been developed and implemented. This ease of access to all aspects of the system was another feature which attracted users.

A problem with using a system like LARSYS, which particularly faces universities and in general is shared by all other agencies, is one of personnel turnover. The need to train users of LARSYS was recognized early in its development; therefore, procedures for this training were developed along with the system. Thus, another attractive feature of LARSYS was the capability to rapidly train users of the system. Training materials and procedures for using them were well developed when negotiations began to expand the availability of LARSYS to locations remote to Purdue University.

B. Development of Terminal Concept

In 1970 when restricted access to LARSYS began to limit the research at Purdue and to limit the transfer of the technology developed at Purdue to NASA sites and other agencies, Dr. A. B. Park began negotiations with Purdue to expand the capabilities of LARSYS. The results of these negotiations, a remote terminal concept, were documented in a letter to Dr. Park by R. B. McDonald of Purdue dated February 5, 1970. The concepts included in this documentation were expected to significantly speed the development of data processing capabilities required for the support of NASA and the nation's earth resource program. The concepts presented were to tie together the activities of a number of remote sensing research groups through a common data processing and data communications system. Thus, groups from different areas around the country would be able to evaluate the techniques developed. The remote terminal system would provide each group with a common processing and analysis capability and an effective mechanism for exchange of information as it becomes available. Each user of the system would have the capability of immediate access to analysis techniques, computer programs, etc. This was felt to be particularly important with respect to the availability of data from ERTS.

The remote terminal system [8] was conceived to be a cost effective mechanism of transferring the technology developed at Purdue and rapidly exchanging new concepts between groups.

The cost effectiveness of the system arises from the centralization and sharing of the expensive portion of the processing hardware, the centralization of software maintenance, and the commonality of system data formats, the sharing of common system documentation, the commonality of training procedures, etc.

The remote terminal system began, under NASA sponsorship, with the acquisition of an IBM 360 model 67 computer system early in 1971. LARSYS was immediately implemented on this machine and the development of a remote terminal which could be installed at other sites began. Also an experiment which thoroughly tested the application of the system to a problem of national significance was initiated.

The 1971 Corn Blight Watch Experiment thoroughly tested the technology. The success of this experiment to demonstrate that remote sensing technology would solve problems of national significance and scope was an important milestone in the nation's earth resources program. The impact of using LARSYS in the Corn Blight Watch Experiment was to demonstrate its capability to be used in the near operational mode on large amounts of data. By the time ERTS was launched, LARSYS had handled ground truth data from 240 one by ten mile segments every two weeks, classified operationally 4 million data points every two weeks, processed the results of the analysis of 270 segments (more than 50 thousand agricultural fields) every two weeks, in addition to supporting the LARS research activity at Purdue. Also a terminal remote to LARS data processing facility had been developed, tested, and put into operation at Purdue in preparation for training the personnel required to support the first terminal remote from Purdue University.

C. Project Objectives

John D. Overton of the Earth Observations Division, Science and Application Directorate, Johnson Space Center, Houston, Texas was appointed chairman of the remote terminal steering committee. Under his leadership, a committee of Terry L. Phillips from Purdue University, William L. Alford of the Goddard Space Flight Center, Harold Maurer of the Wallops Station, John Cornwell of the Lockheed Electronics Corporation, and Frank Ravet of the Earth Resources Program Office at the Johnson Space Center, prepared a document entitled, "Plan for the Evaluation of Remote Terminals with Purdue University's Laboratory for Applications of Remote Sensing." This plan was finalized in February of 1973 and approved by all participants on the remote terminal steering committee.

The plan detailed the initial scope of the project and a project duration of one year starting January 1973. A project implementation plan with appropriate management reviews, reports, supporting documentation, and schedule is also included in this plan. The steering committee methods for accomplishing the project objectives are also delineated. All aspects of the remote terminal project were coordinated by the steering committee chairman through the use of a computer generated project schedule showing each project goal. The monitoring of the completion of each project goal was successful and greatly enhanced each participant's ability to accomplish the project objectives in a timely manner.

The objectives of the remote terminal project delineated in the project plan were:

1. Evaluate the current techniques and hardware/software implementation, cost estimates, and training requirements for extrapolation to a pilot remote sensing data processing and analysis system to support inter-organizational, geographically separated users.
2. Determine operational feasibility of an inter-organizational data processing/analysis system for geographically separated users of remotely sensed data.
3. Quantitatively determine critical data processing/analysis habits of diverse investigators for the purpose of establishing improved requirements for future sensors and data processing facilities.
4. Provide training in automatic data processing to a larger and more diverse set of remote sensor data users.
5. Transfer of developed remote sensor data processing technology to a more diverse set of remote sensor data users.
6. Determine requirements for follow-on activity (if any) to this project.

Appended to the project plan are the Site Evaluation Plans for each of the participants of the project.

Although the Goddard and Houston terminals were attached to the system before January 1973 and the steering committee began functioning in November 1972, the official duration of the project was specified in the project plan as calendar year 1973. By March 1973 it became evident that Wallops would not have their remote terminal during a significant portion of 1973 and the project objectives could be better met if terminals located at non-Federal agency sites could be implemented. These recommendations were made to the Earth Resources Program Office and requests for additional terminals were sent out. In June of 1973 the project duration was extended to include calendar year 1974 and a request from the State of Texas and Old Dominion University was received and recommended for approval by the remote terminal steering committee and approved by the Earth Resources Program Office.

D. Purdue Objectives

The Purdue/LARS Site Evaluation Plan was presented to the steering committee on March 20, 1973. The scope of Purdue's plan was in concert with that of the project. The Purdue evaluation plan contained procedures for performing the experiment, criteria for evaluating progress in the experiment, technical reports, and objectives. The objectives of Purdue's participation in the project were:

1. To provide a facility for the evaluation, by a wider community of users, of remote sensing data processing techniques developed at Purdue/LARS.
2. To provide a facility for training personnel in the use of advanced remote sensing data processing techniques.
3. To provide others the opportunity to evaluate the current implementation relative to their remote sensing data processing needs.
4. To provide a facility for immediate access to and knowledge of present and future techniques (transfer of technology).
5. To evaluate the current implementation of those (remote sensing data processing) techniques in the Purdue/LARS remote terminal system and associated software.

These objectives are presented in an order different than they appear in the project plan in order to better organize the discussion of the objectives. The order given here is used in section III.

III. DISCUSSION OF PROJECT OBJECTIVES

This section discusses the highlights of Purdue's activities supporting the remote terminal project. These activities are discussed using the framework of the objectives presented in section II-D of this report.

A. Establishment of a Remote Terminal Facility

Objective 1 of Purdue's participation in the remote terminal project was:

"To provide a facility for the evaluation, by a wider community of users, of remote sensing data processing techniques developed at Purdue/LARS."

To meet this objective, Purdue aided in the installation of the Goddard Terminal, the Houston Terminal, the Wallops Terminal, the Langley/Old Dominion University(ODU) Terminal, the Texas Terminal, and aided the modification of the Wallops and Goddard Terminals. In addition, Purdue helped install a terminal at Indiana State University(ISU) and the EROS Data Center(EDC). Reports on these latter two installations are included as supplementary information to the experiment even though they were not formally part of this project. In addition to the terminal installations, Purdue maintained the central processing site. Aspects of this support where they relate directly to the remote terminal project are also discussed here. A diagram of the location of these terminals is shown in figure 1.

1. Basic Considerations Relative to Terminal Installation:

a. Terminal hardware. The design of LARSYS provides for the user to access and control processing via a keyboard terminal. A line printer/card-reader/card-punch facility is also required at each site for production of output, as well as for reading input decks. For this experiment, it was necessary to use terminals supported by the operating system of the Purdue 360/67 - namely an IBM 2741 or teletype 33/35 typewriter terminal, and an IBM 2780 reader/printer/punch. Presumably, "equivalent" hardware from other manufacturers would work, but several factors mitigated against exploring the possibilities in this area, at least at the beginning of the experiment. The most important was the fact that the prepared training packages for LARSYS users assumed the use of IBM equipment. These had been prepared using a remote terminal made up of an IBM 2741 typewriter terminal and an IBM 2780 line printer/card-reader/card-punch. This terminal was already successfully in operation at a LARS site half a mile away from the

EARTH RESOURCES DATA PROCESSING NETWORK

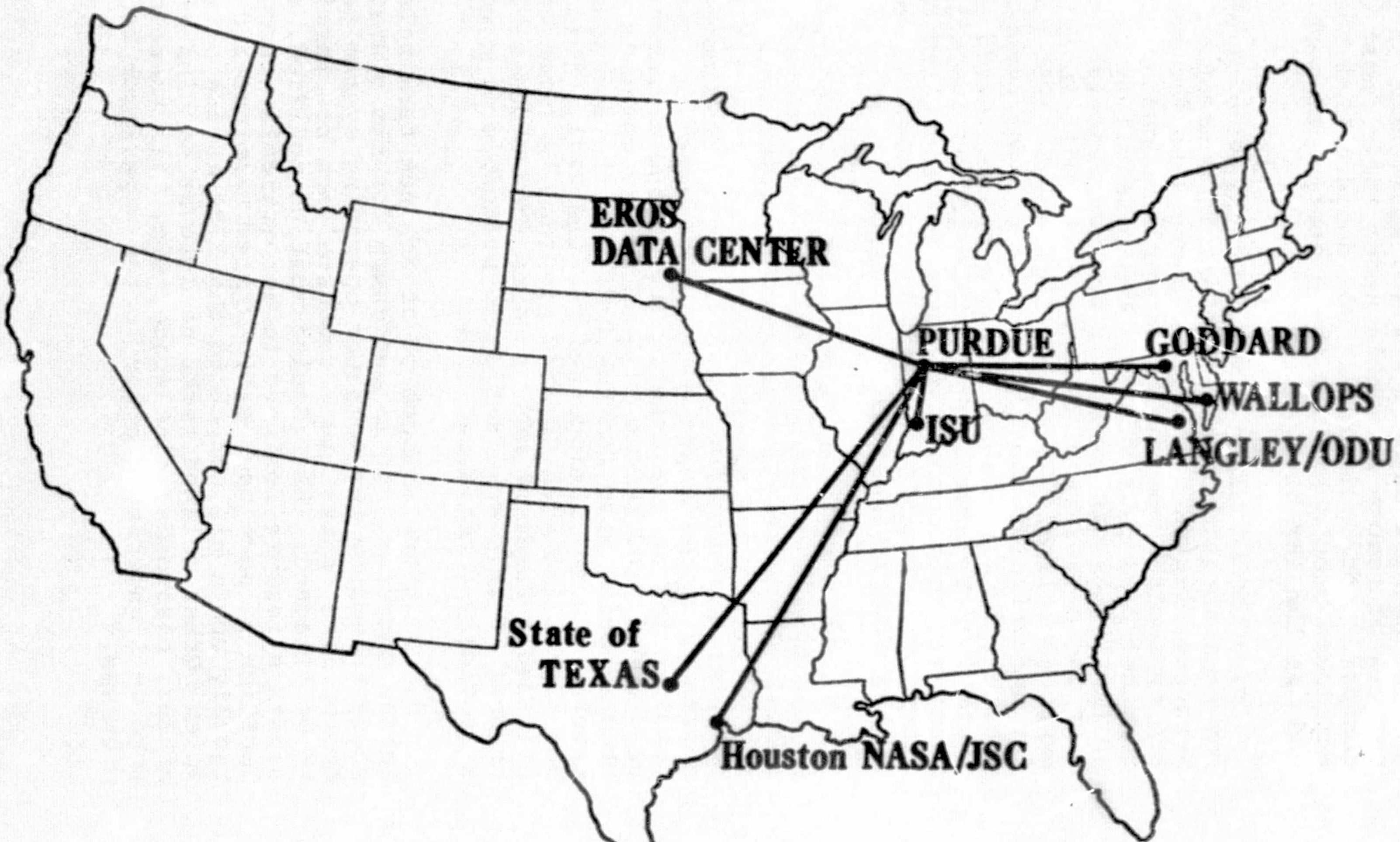

Figure 1. Location of Remote Terminals in December 1974

main computer site. Also, the IBM sales organization offered special support for and assistance in creating a network of remote terminals under their "host computer concept." Accordingly, it was decided that the initial terminals should emulate the prototype as much as possible and use the IBM hardware.

b. Communication lines. Of the several possibilities for communications, the simplest in concept is to have a separate, leased full-duplex phone line for each terminal -- the typewriter and the reader/printer/punch. The prototype terminal used this scheme. The possibility of using dial-up facilities was explored, but was rejected for this experiment for a variety of reasons - the most important being expected reliability at the high speed (4800 bps) required for operation of the 2780 reader/printer/punch. A second possibility was that of using a single leased phone line instead of two, with appropriate modems including multiplexors. This concept was used for installations after the first one. Details such as the conditioning required depend on the choice of modems - see below.

c. Modems. Details concerning modems are determined by the type of communications lines to be used, and vice versa. The initially recommended modems were the WE203 for the 2780, and use of the modems built into the terminal and computer hardware for the 2741 line. This combination requires C2 conditioning on the one phone line and no special conditioning on the other. The second arrangement to be tried used Codex 7200 modems with secondary channels - the primary channel being used for the 2780 and the secondary channel (or reverse channel) being used for the 2741. This requires just one phone line with C2 conditioning. A later arrangement utilized a Paradyne M48 or Codex 4800 modem with reverse channel -- this combination in principle does not require a specially conditioned line.

d. Software changes to attach new terminals to the Purdue computer. It is necessary for the system programming staff to modify the computer operating system to define appropriate "ports" to accomodate each new terminal that is to be attached. LARSYS also must be modified, since it includes a feature designed to automatically recognize the location of each user's typewriter terminal and to automatically route his output to the 2780 at the corresponding site. Other related tasks need to be handled -- assignment of IDs, passwords, disk space, etc. All these considerations were well understood prior to the experiment and caused no problems.

e. Data. Procedures had to be set up to allow users at remote sites to enter data into the LARS data base, and to allow tapes containing results of processing to be sent back to users at their request.

2. Goddard Terminal Installation:

The installation of the initial terminal at Goddard Space Flight Center, in August-September of 1972, did not go as smoothly as had been hoped. Initially, there were coordination problems arising from the fact that NASCOM (located at Goddard) ordered the telephone lines and modems and that Purdue/LARS ordered the terminal hardware. Delays in the installation of the former meant that the terminal hardware lay unused for a month, although it was on rent. Then after the 2780 finally could be tested online, it would not operate properly with the Purdue software system. Even after the cause of this problem was pinpointed (an analysis of data being received at Purdue showed that the 2780 was sending two bytes in the redundancy check character position instead of the proper one byte), it still took nearly a week for IBM to find the hardware cause of the problem (a miswired connection in the 2780).

Some operational problems existed from the beginning with the modem configuration used for the Goddard terminal (WE203A modems, with a home-built loopback/test facility). A newer and more modern WE208A replaced the WE203A in May 1973, and led to somewhat more trouble-free operation.

3. Houston Terminal Installation:

The installation of the second terminal, at the NASA Manned Spacecraft Center (later Johnson Space Center) in November-December 1972, was accomplished with much less trouble. This was all the more gratifying, since it included a previously untried combination of a Codex modem and multiplexor at each end of a single telephone line. This allowed the single telephone line to be used to run both the 2741 and 2780 terminals. John Cornwell at Houston did an excellent job of ordering and scheduling installation of all components -- terminals, modems, phone line. The lack of problems demonstrated the value of having a single knowledgeable coordinator at a single site throughout procurement, installation, and production usage.

A second 2741 terminal was attached, using a new circuit board in each Codex multiplexor, during July 1973. Finally, after a few preliminary experiments over the dial-up network using teletype-compatible CRT terminals, a third low speed port was added to each Codex multiplexor during the early part of 1974.

4. Wallops Terminal Installation:

The third remote terminal was installed at the NASA Wallops Island Facility in October 1973. This event was significant in that a Data 100 Model 70-2 terminal was used in place of the IBM 2780 in the "standard" remote terminal configuration. This terminal had been successfully demonstrated at Goddard in June 1973. It was also of interest because instead of having phone lines installed between Wallops and Purdue, NASCOM installed lines between Wallops and Goddard. The lines between Goddard and Purdue were shared -- during some periods they would be used for the Goddard terminal, and at other times they would be used to "extend" the Wallops lines. While one site was operational, the other site would be "off-the-air."

This arrangement caused many operational problems since it seemed to take a long time for the Goddard and Wallops personnel to appreciate all the ramifications. Considerable confusion arose when, for example, output files belonging to Wallops were printed on the Goddard terminal after the phone lines were switched in the middle of the day. It also took a long time for the terminal users at Wallops and Goddard to coordinate their schedules with the NASCOM personnel who did the actual switching and they tended to expect the Purdue operations people to do the coordinating.

The substitution of the "plug-compatible" Data 100 terminal for the IBM 2780 terminal in the Wallops configuration produced an interesting example of a "never should happen -- but will" kind of problem. The card punch would not work at all, which turned out to be due to the fact that the Data 100 card punch (which is slower than the 2780 punch) was too slow to keep pace with the rate at which the Purdue software would send data to be punched. Then, the Purdue software (in violation of the IBM bi-sync protocol) would re-transmit the as-yet unacknowledged buffer instead of sending an inquiry about it.

The problem was circumvented by modifying the Purdue software to make it transmit blocks short enough to allow even a Data 100 to get a block punched and acknowledged before the next one arrives.

5. Langley Terminal Installation:

The notable feature about the installation of the fourth remote terminal at the NASA Langley Research Center in Hampton, Virginia, was that it marked the introduction of yet another modem vendor - Paradyne - and yet another communications carrier -- Western Union. This installation was easily the most troublesome of all.

The installation was scheduled for January 1974. The initial combination of Paradyne modem and Western Union telephone line (also ordered by NASCOM) worked so poorly that a decision was made to replace the line with a C2 conditioned line from ATT, which was installed in April 1974. Another problem existed in interfacing the Paradyne modem to the IBM 3705 Communications Controller -- resulting from the fact that IBM was not adhering to the RS-232 standard. The 3705 would place extraneous signals on lead 14 of the interface, which interfered with the operation of the 2741 terminal on the secondary channel. This problem was permanently resolved by obtaining a fix for the 3705 software from IBM. Finally, in May, 1974, Paradyne discovered the clocking pulse was fading out and disappearing every so often, and the modem at Langley was replaced.

Towards the middle of June, the IBM 2780 terminal developed problems which took IBM a full week to find and fix. Then, at the end of July, the 2780 would heat up and not operate properly.

Only since the beginning of September 1974 (after the terminals were moved to a new room), has the Langley terminal been able to operate in a relatively trouble-free mode.

6. Texas Terminal Installation:

The installation of the fifth remote terminal was at the state offices in Austin, Texas. This was a notable milestone in that this was the first terminal located at a non-NASA site. The installation date was also scheduled for January, 1974. However, there was a delay in installation, due mainly to difficulties encountered in negotiating a contract between Purdue and Texas. Delivery of the Codex 7200 modems was also a month later than requested. No previously untried pieces of equipment were ordered for the Texas terminal; two Codex 7200 modems, AT&T lines and the IBM 2741 and 2780 terminals were used, but this was the first installation for which LARS was responsible for ordering all the equipment. When the actual installation took place in mid-March 1974, few problems were encountered. The phone cable supplied with the modem had to be altered slightly, since the active pins were displaced one position, and the printer on the IBM 2780 terminal had to be repaired by IBM.

Since LARSYS requires control card and data card input, LARS was also asked to order an IBM 029 keypunch for Texas. This should be kept in mind when future proposals are written to install new remote terminals, as many places will not already have EBCDIC keypunches available for use.

7. Wallops-Goddard Terminal Modifications:

In spite of the multitude of difficulties encountered with the installation and performance of the Paradyne modem system for the Langley terminal, it was decided by NASCOM at Goddard (responsible for the Goddard, Wallops, and Langley communications links) to proceed with a plan to reconfigure the communications links for the Goddard and Wallops terminals. This plan called for using one of the existing Purdue/Goddard phone lines coupled to one of the existing Goddard/Wallops lines, together with a set of Paradyne modems to give Wallops their own private link to the Purdue system. The remaining Purdue/Goddard line was to be used with yet another pair of Paradynes to serve the Goddard terminal (while the second Goddard/Wallops line was released).

In order to do this, it was also necessary to coordinate the removal (by IBM) of one special feature and the installation of a different feature on both the Goddard and Wallops 2741's, the installation (hardware and software) of corresponding features on the 3705 at Purdue, and the removal of the WE208 modems in use up to that time. All this was done in May-June 1974.

8. Indiana State University Terminal Installation:

After a two and a half week delay in the shipment of the Codex modems, a terminal was installed at Indiana State University, Terre Haute, Indiana in September 1974. Both Codex and IBM had to be called in to service their equipment, and the terminal was completely operational by the end of September, three weeks after the scheduled date of operation. This is the first time the Codex 4800 modems have been used, and except for the fact that the use of a small connector cable (delivered with the modem) between the 2780 and the modem was not documented anywhere in our manuals, their operation has been completely satisfactory for operating an IBM 2780 and one IBM 2741 terminal, at a lesser monthly lease rate than the Codex 7200 modems.

9. EROS Data Center Terminal Installation:

The most recent terminal, scheduled to be operational on October 8, 1974 at the EROS Data Center, Sioux Falls, South Dakota, was completely operational by November 1, 1974. This site has the same set-up as the Texas remote terminal - Codex 7200 modems, AT&T lines, and IBM 2741 and 2780 terminals. A slight complicating factor was the need to deal with two local telephone companies in addition to AT&T - General Telephone in Lafayette, and a local phone company at Garretsen, South Dakota (just outside Sioux Falls).

The IBM terminals arrived several days later than planned due to the distance they had to travel from North Carolina. Then a difficult-to-diagnose problem, first blamed on the phone company, was worked on by Codex for about two and a half weeks and was finally solved with the replacement of several boards in both modems. During the same period IBM found and corrected several problems in the 2741 terminal.

10. Central Processing Site Modifications:

In the initial phases of the remote terminal experiment, the Purdue system had only seven IBM 2400 tape drives. This had significant implications related to scheduling users, and equitably sharing the scarce resource among users at Purdue and at the new remote sites. An initial guideline allowed only one remote terminal user to be active on the system at a given time, and guidelines relative to reserving time on tape drives were also in use. By January 1973, these drives were replaced by seven improved IBM 3420 drives. Splitting these between two control units at that time also helped significantly. Finally, in February 1973, three additional drives were added, significantly reducing scheduling and availability difficulties.

In April and May of 1973, an IBM 3705 Communications Controller was added to the Purdue computer, replacing the 2703 Transmission Control Unit. In each case, this is the part of the computer that attaches directly to the modems and phone lines for all terminals. Although there was some deterioration of service during the conversion, this was compensated for by the fact that with the advent of the 3705 it was readily possible and convenient to use its dials and switches to monitor activity (or lack of activity) on any given port, to tell if data is being sent or received, what operation has been issued to the line, what the modem status is, etc. This information was found to be useful in diagnosing problems.

The release of LARSYS Version 3, supplementing Version 2, occurred in July 1973. This is discussed in more detail in another section of this report. It has a beneficial effect on the problem of tape drive scarcity, since Version 3 makes it less easy for any user to keep a tape drive unnecessarily long.

11. Terminal Installation Costs:

The experience of coordinating the installation of seven remote terminals has allowed the Purdue staff to estimate the cost of terminal installation. This estimate is shown in Table 1. The costs shown in this table are based on an objective analysis for the Purdue staff, observation for the terminal staff, and specific costs. Although the costs of installing any one of the seven terminals usually varies from the estimate shown in Table 1, it is believed that $15,000 is a good estimate for the average installation. Each of the parts of this estimate, explained below, also has a relatively high variance. However, if a terminal is installed as recommended by Phillips and Schwingendorf [9], the estimate shown in Table 1 should be quite adequate.

The terminal installation costs shown in Table 1 include administrative staff from both Purdue and the terminal organization. This administrative staff is expected to negotiate the boundary conditions around which the terminal will be installed. The Purdue system specialists and the terminal system specialists then combine their efforts to prepare the location for the terminal, prepare the Purdue system for the terminal, order the necessary equipment, and coordinate the installation. The Purdue techniques specialist is responsible for the training of the terminal system specialist and terminal techniques specialist. This is usually done by the terminal specialists coming to Purdue and participating in a training program of two weeks duration. The terminal techniques specialist then is expected to train the users of the terminal through the media of the LARSYS Education Package and the expertise derived from taking the Purdue Training Course. The Purdue service staff and the terminal service staff are supportive of the above effort with the clerical services, electrical installation services, etc. The 30 computer tapes are located at the central processing site for all users of the given terminal. The shipping charges on equipment are for shipping the equipment unique to this terminal from the factory and return. The installation charges include electrical equipment, phone line installation, etc. The telephone and supplies cover other incidental installation, communication, and supplies expenses. The travel is assumed to be two trips by the terminal system specialist and technique specialist of about 1,000 miles to Purdue and one other trip between the site and Purdue, probably by the Purdue system specialist to check out the terminal site.

The terminal installation costs include only those expenses associated with installing the system. They do not include any costs for using or maintaining the system.

Table 1. Terminal Installation Costs

Purdue Administrative Staff	.5 mm @ $2,400/mm	$1,200
Purdue System Specialist	1.0 mm @ $1,800/mm	1,800
Purdue Techniques Specialist	1.0 mm @ $1,800/mm	1,800
Purdue Service Staff	.5 mm @ $1,000/mm	500
Terminal Administrative Staff	.5 mm @ $2,400/mm	1,200
Terminal System Specialist	1.0 mm @ $1,800/mm	1,800
Terminal Techniques Specialist	1.0 mm @ $1,800/mm	1,800
Terminal Service Staff	.5 mm @ $1,000/mm	500
LARSYS Educational Package	@ $925 each	925
Computer Tapes	30 @ $12.00 each	360
Shipping charges and equipment		500
Installation charges		600
Telephone, supplies		800
Travel	3 trips @ $200/trip	600
		$14,385

The monthly terminal maintenance costs will be discussed in a later subsection. The terminal installation costs can be compared to the costs of installing other systems of this type such as installing software on a general purpose computer, installing a specific hardware/software system, etc.

12. Final System Configuration

Figure 2 shows the final LARS Computer configuration at the end of the remote terminal project in December 1974. This configuration consisted of the central processing unit and 768k bytes of core; and peripheral equipment including a 2314 disk system, the 4507 digital display system, a drum system, a tape system, and assorted card readers, card punchers, printers and terminals.

Figure 3 shows the LARS Computer configuration of December 1974 for the remote terminal hardware. All of the equipment located at the central site as well as at each of the remote sites is shown in this figure.

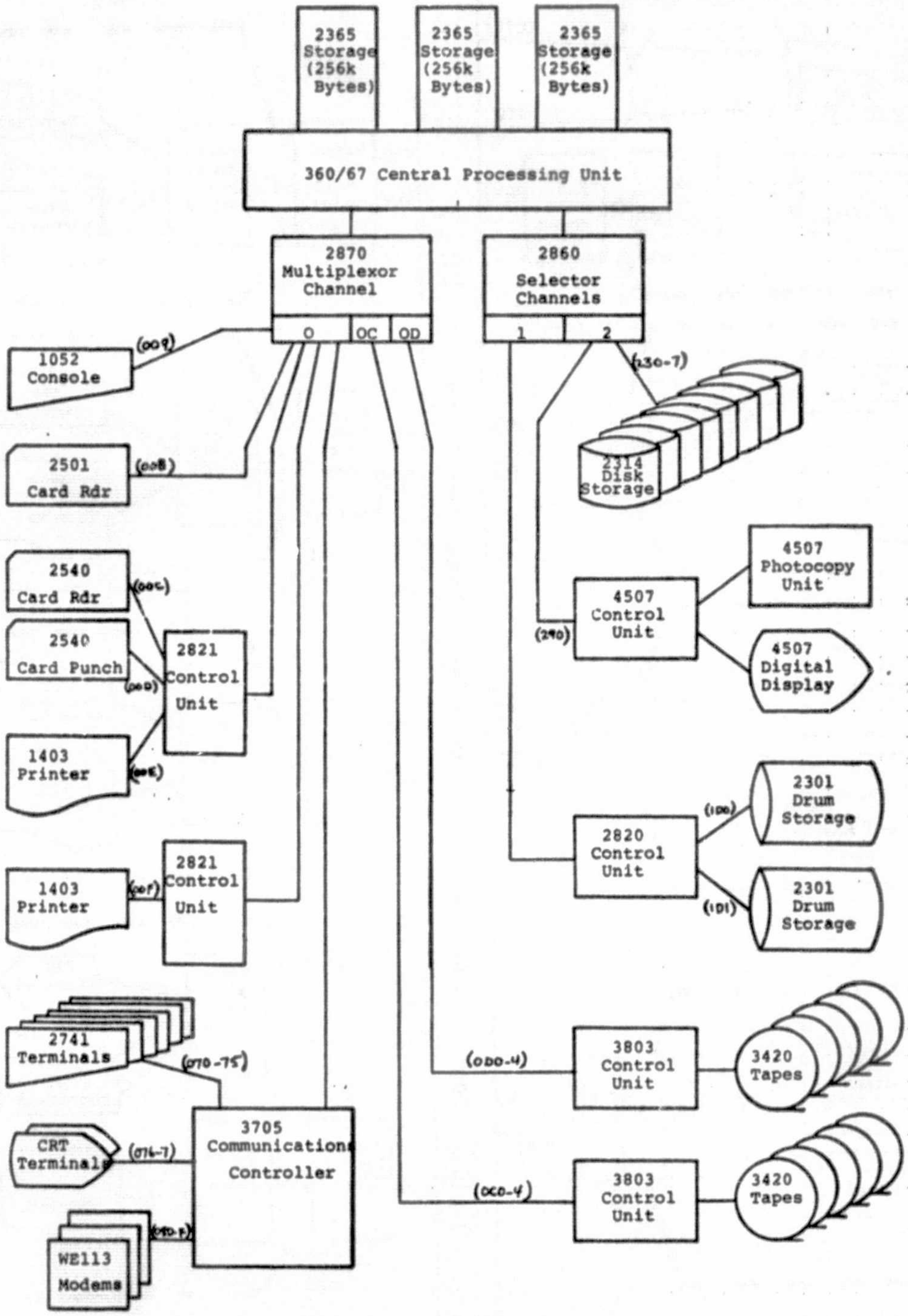

Figure 2. LARS Computer Configuration - December 1974
Central Site Hardware

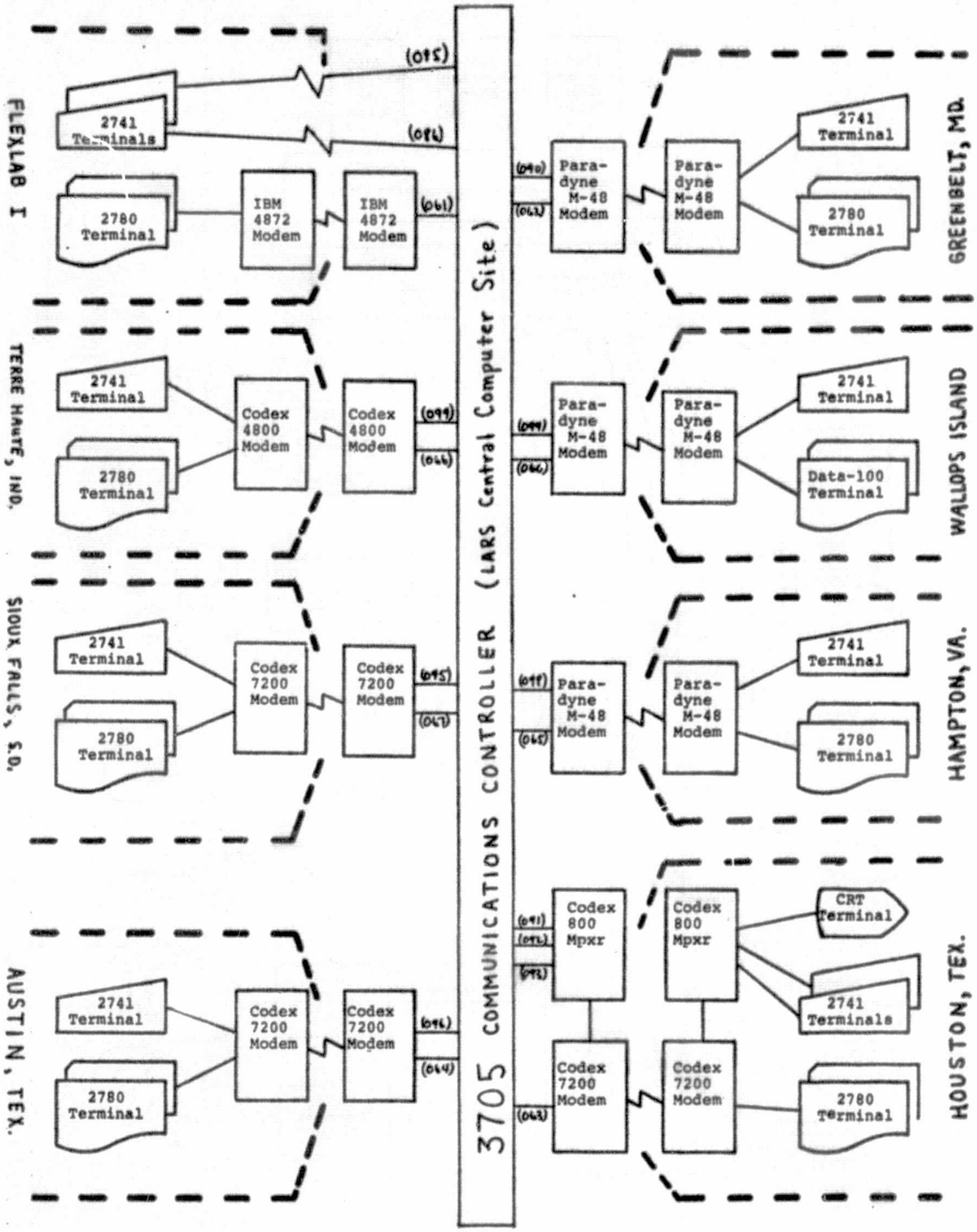

Figure 3. LARS Computer Configuration - December 1974
Remote Terminal Hardware

B. Personnel Training

Objective 2 of Purdue's participation in the remote terminal project was:

"To provide a facility for training personnel in the use of advanced remote sensing data processing techniques."

There are four important components which make up the remote terminal network - data, hardware, software and training. These components compliment one another to bring about the successful transfer of the remote sensing technology. The facility developed to train personnel in the use of advanced remote sensing data processing techniques is composed of two types of resources - human resources and training materials resources. The human resources consist of the techniques specialist and systems specialist site experts. Site experts are personnel employed by and located at the organization contracting for a remote terminal. These individuals provide the important human interface required for a successful training program. The training materials resources include the LARSYS Education Package, the LARSYS User's Manual, other LARSYS documentation, the Purdue/LARS instructors and consultants.

1. The LARSYS Education Package:

In designing the LARSYS Education Package a high priority was placed on making the materials suitable for individual study as it was felt that organizations just getting started in the analysis of multispectral data would begin by training two or three individuals and that because of differing backgrounds and other duties might be expected to progress at different rates.

The LARSYS Educational Package consists of a series of six minicourses, each designed to take a student from an initial point, defined by the prerequisites of the minicourse, to an end point defined by its instructional objectives. The student progresses in a linear manner through all six minicourses, each of which provides a mechanism for information transfer, an opportunity for the student to practice or study the skills or ideas presented, and a problem or test situation where he can determine whether he has met the instructional objectives.

A wide variety of media is employed in the Educational Package, the selection dependent on the nature of the material and the objectives of the unit. Media used include a programmed text, a slide/tape presentation, a live demonstration, operation of a remote terminal, and practice in doing analyses through exercises and an extended case study. The aim has always been to choose a medium which allows the learner to experience the real analysis procedure as fully as possible.

The first unit, entitled, Remote Sensing Analysis: A Basic Preparation, follows the format of a programmed text. The specific purpose of this unit is to provide a common background to students who expect to make use of the LARSYS data analysis software system, to acquaint them with the basic concepts and introduce them to terminology used later on. Since students vary in their previous experience with remote sensing, in this unit each may plot his own course through the 90-page book, reading only those sections containing materials unfamiliar to him. Frequent self-tests help him in these decisions. Typically students spend from one to six hours on this unit, and average about two and a half hours. The second module is designed to give the student a quick, one-hour overview of the software capabilities of LARSYS and an opportunity to follow, step-by-step, through a typical analysis. Since the objective of this unit is to help the student gain an overall picture, the medium used is an audio tape supported by illustrations which are available either as slides or in a flip-chart/notebook format. While a student may stop the tape recorder to take notes or to listen to any section of the tape again, this medium was selected because it tends to encourage students to let the minute details go by in favor of gaining a broader perspective.

The next two minicourses are designed to acquaint the student with the data processing hardware available to him at the remote site where he is working, and to this end the remote terminal is the "medium" used. The student working on Unit 3 witnesses a demonstration of the typewriter, card reader/punch, and line printer in addition to pre-printed student notes. The "hands-on" experience, which is the core of the next unit, gives the student a chance to use the terminal alone. Listening to an audio cassette tape through head phones, he does as the tape directs him, obtaining the list of instructional objectives by using the card reader and continuing this self-guided work for an average of three hours. He runs sample LARSYS jobs, transmits data to and receives data from the main computer. The audio tape is also supported by a detailed set of written notes for the student to use and keep for future reference.

In the final two units of the Education Package, the student, now familiar with the underlying concepts of remote sensing and with the operation of the remote terminal, can begin using the LARSYS processing functions and study the analysis method in detail. Unit 5 contains six short exercises done at the terminal which, when completed, give the student more familiarity with both the nature of the data being analyzed and the processing functions available through LARSYS.

The last component of the instructional sequence, entitled Guide to Multispectral Scanner Data Analysis, provides a detailed description of the analysis process and helps students achieve mastery of the eight analysis steps through a carefully developed sequence of study and activity. The student can read about the theory behind each step, study an example, test his understanding by doing the exercises, and finally carry out the parallel step in a case study analysis. This last minicourse is by far the most time consuming with most students spending 20 to 30 hours on it.

It is estimated that over 600 students have gone through the Education Package. This is based on the figures shown in Table 2.

The Education Package was revised with the present version being issued in October 1973, to coincide with the availability of LARSYS Version 3 on the remote terminal network. A feature of the new materials was the inclusion of a postage-paid evaluation sheet to be filled out by the student upon completion of each unit and mailed to LARS. Although the response to this evaluation mechanism has not been as great as had been hoped for the student comments that have been received have been helpful in evaluating the education materials. Information derived from these forms as well as comments by site experts are being used to further refine the Education Package.

Significant changes in format are being made in the first two units of the Education Package and content changes are being made to reflect the software improvements of LARSYS 3.1. In addition another case study, utilizing ERTS data, is being developed. The area chosen for analysis is part of Monroe County, Indiana and includes the city of Bloomington, surrounding agricultural areas, forest areas, and a portion of the Monroe Reservoir.

2. Site expert training:

Each remote terminal site designates two individuals to serve as site experts. Whenever possible one of these individuals, designated as the systems specialist, has experience in computer systems. The systems specialist is available to trainees and users of the remote terminal to help solve computer system problems. The techniques specialist is the site expert most knowledgeable in LARSYS analysis techniques.

Prior to the installation of a remote terminal the site experts spend two weeks at LARS going through the LARSYS Education Package and receiving additional training on the hardware and software aspects of the remote terminal network. A typical two-week training schedule is given in Table 3.

Table 2. Estimate of Students Trained Using LARSYS
January 1973 through December 1974

Terminal Site	Users Trained	Source of Data
Goddard	100	Estimate, March 1974 Report shows 50
Houston	170	Memo March 30, 1974 plus 40 LACIE Training
Wallops	45	Final Report Names 37 not including WaFC Personnel
Langley/ODU	20	5 Langley and 15 ODU Personnel December 1974 Report
Texas	61	Names in Final Report December 1974
Indiana State	10	Estimate
EROS Data Center	5	Estimate
Purdue/LARS	200	Estimate from Personnel Turnover
TOTAL	611	

Table 3. Typical Site Expert Training Schedule

Day 1 a.m.

- -Orientation
- -Overview of educational package and planned activities
- -Discuss ID's, Passwords and Computer Schedule
- -Unit 1 (Basic preparation, etc.)

p.m.

- -Unit 2 (LARSYS Software System Overview)
- -Settle on and request ID's
- -Unit 3 (Remote Terminal Demonstration)

Assignment

- -Complete reading associated with Unit 1
- -Skim LARSYS Users Manual, Section 2 in preparation for Unit 4 (Hands-On)

Day 2

- -Visit to LARS Computer Facility
- -Prepare input cards for Unit 4 (Hands-On)
- -Unit 4 (Hands-On)
- -Read User's Manual, Sections 1 and 2
- -Begin Unit 5 (LARSYS Exercises)

Assignment

- -LARSYS User's Manual, Sections 3, 4, 5 and organization of the rest of the User's Manual

Day 3

- -2780 Hardware Maintenance Demonstration
- -Complete LARSYS Exercises
- -Begin Unit 6 (Case Study)

Days 4 through 10

- -Complete case study
- -Review Educational Package: Instructor's Notes
- -Introduction to Unsupervised Data Analysis with ERTS Data

Day 7

- -Visit with reformatting group

Assignment

- -Program abstracts 9033 and 9034 and Purdue LARS Computer User's Guide

Day 8

- -Seminar on CP2780 virtual machine software

While the Education Package materials are designed to enable the student to proceed on his own the success of his experience depends to a large extent on the availability of the site experts to interact with him. The function of the site expert is not to plan and preside over formal classroom sessions, but rather to serve as a tutor helping to clarify troublesome points for the student and to provide the necessary corrective feedback and encouragement to enable the student to continue on his own.

3. LARS Techniques Specialist:

To provide further assistance to remote terminal site experts a LARS employee was designated as the remote terminal techniques specialist. This person was contacted by the remote terminal techniques specialist regarding LARSYS analysis problem experienced by users of the system at the terminal site. Provision of a contact person helps to further the success of the training facility.

4. Demonstration Package Concept:

As part of the EROS Data Center remote terminal contract LARS personnel are developing a demonstration package to be used in conjunction with the EROS Data Center terminal. The demonstration package will include posters and charts explaining the remote terminal and showing specific usable examples, a short terminal demonstration and handout material which can be distributed to EROS Data Center visitors and trainees. The EROS Data Center contract extends beyond the termination data or the remote terminal experiment so these materials are not complete at this time.

5. Advanced Analysis Seminar/Workshop:

The LARSYS Advanced Analysis Seminar/Workshop provides an opportunity for the LARSYS user to become more intimately acquainted with the capabilities of the data analysis algorithms at his command. The LARSYS Educational Package, study of which is a prerequisite for participation in the Advanced Analysis Seminar/Workshop, provides background material and a basic working knowledge of LARSYS. However, the student at this point tends to be distracted by the mechanics of using the system and cannot be expected to gain more than a superficial impression of the mathematical foundations of the multispectral data analysis procedures. Yet without a firm grounding in these foundations, he is unlikely to be able to bring to bear on his remote sensing problem the full power of the LARSYS techniques. In fact, he may in some cases even try to use them in inconsistent or conflicting ways which could produce misleading results or erroneous conclusions.

The LARSYS Advanced Analysis Seminar/Workshop consists of three half-days of classroom presentations and three half-days of laboratory exercises using the LARSYS system via the remote terminal network. In the laboratory work, the student is urged to use his own data and problem definition. As a result, the student receives a blend of theoretical considerations and practical work set in a context conducive to thoroughly understanding the material. Topics for the LARSYS Advanced Analysis Seminar/Workshop are shown in Table 4.

Table 4. Topics for the
LARSYS Advanced Analysis Seminar/Workshop

Characterization of Data for Statistical Pattern Recognition
- Discriminant functions
- The multivariate normal distribution

Cluster Analysis for Subclass Determination
- "Blind Analysis" vs. application of ground data
- Interpretation of the CLUSTER "QUOTients"
- The cluster grouping table
- Use of SEPARABILITY for cluster grouping
- Latest information on clustering techniques

Use of Class Weights
- Review of the Bayes Optimal Decision Strategy
- An interpretation of the "equal a priori probabilities" case
- Intraclass (inter-cluster) weights
- Interclass weights
- Iterative estimation of class weights
- Relationship to weights in SEPARABILITY

Unsupervised Analysis Techniques
- Use of CLUSTER for "image enhancement"
- Use of ratios for general cover type determination

Blending Supervised and Unsupervised Analysis
- Extensive and intensive training sample selection
- Use of MERGESTATISTICS

Separability Analysis
- Interpretation of results
- Selecting the number of channels

Multitemporal Analysis
- Benefits and potential pitfalls
- Use of SEPARABILITY

Applications Exercises
- Use of LARSYS techniques on data familiar to the student

C. Remote Terminal Facility Support

Objective 3 of Purdue's participation in the remote terminal project was:

"To provide others the opportunity to evaluate the current implementation relative to their remote sensing needs."

It was clear to the developers of the remote terminal system at Purdue and to the Remote Terminal Steering Committee from the start of the evaluation project that evaluation would not take place unless encouragement and support was continually made available to each site. Therefore, in addition to providing a facility (objective 1) and training resources (objective 2), Purdue assumed the responsibility to provide continued support to key personnel at each remote terminal site. The purpose of objective 3 was to insure user awareness of the availability of services and to measure the awareness and the cost effectiveness of services to users.

1. Awareness of services:

Several procedures were established to insure user awareness of the availability of services to a terminal site. The most important of these was the establishment of the site specialist. Purdue strongly suggested that each terminal site designate two people to serve as system and techniques specialist who would be available to users. The system specialist is responsible for working with his counterpart at Purdue/LARS on the installation of the terminal and then in sorting out hardware and software problems encountered by any user at the terminal site. The techniques specialist is responsible for training all users of the system at the terminal site and for consulting with them on analysis problems.

These two remote site personnel are required to complete the two-week LARSYS Analysis for Instructor's Course at Purdue to prepare for their duties. Personnel from each of the seven sites effectively followed this procedure and therefore established an effective communication link between the user and the Data Processing Center. The effect of the communication link is to respond to the user's needs with a minimum effort required by the user. The established communication channel was designed to answer any questions the user might have even in areas where documented responses do not exist.

The second activity established to insure user awareness of the system was the provision of complete documentation for the user. This activity was established well before the first terminal was installed. However, complete documentation was not available until after the first two terminals were installed. Therefore, some measure of the usefulness of this documentation is available in the user statistics of the system.

A non-documented version of LARSYS was made available to the Goddard and Houston terminals at the time of their installation. This version of LARSYS was used by these two terminals through July, 1973. The fully documented version of LARSYS was put on line in July of 1973 and user's manuals were distributed to the two terminal sites. A two-day LARSYS refresher course was held at Purdue to acquaint the system specialist and the techniques specialist from these sites along with personnel from the Wallops site to introduce LARSYS Version 3. The completeness of this documentation allowed each of the sites to quickly change over to using Version 3.0 and gave the users increased confidence in the system.

In addition to the documentation of LARSYS, two other documents were made available to the terminal sites. One was the Computer User's Guide, and the second was a Terminal Procedures Manual which was developed as experience between the terminal site and the data processing site increased.

Another major activity established to guarantee the user an ability to interface with the system was that of maintaining the data library to meet each user's individual needs. This activity was the principal subject of the Terminal Procedures Manual and a significant portion of Purdue resources spent on the remote terminal project were used to insure availability of data to the users in a format which met his needs. During 1973, one hundred and fifty-eight runs were put into the LARSYS library for remote terminal users. These runs included ERTS scenes, ERIM aircraft scenes, NASA 24-channel scanner scenes, digitized photography, specially preprocessed (geometrically corrected and registered) scenes, and many other reformatted products. By the end of 1973, eight hundred runs were available to every user on the remote terminal system. This activity became quasi operational in 1974 and 1300 data scenes were available by the end of that year.

2. Cost Effectiveness:

There are many references throughout this report alluding to the fact that the terminal system is a cost effective system. Therefore, it is appropriate to report measures of cost and effectiveness of the system. Two of these measures will be discussed.

Since a terminal on the network in essence duplicates the capability of the system installed at Purdue prior to the installation of the network, the effectiveness of the original system closely compares to the effectiveness of any one of the seven terminals. The cost of the system installed at Purdue prior to the establishment of the network was approximately $350,000 annually of which $200,000 was spent on personnel and $150,000 spent on equipment, supplies, and expenses.

One measure of cost effectiveness for the terminal network is that of comparing the cost of a terminal to the cost of the system it duplicates. Table 5 shows the average cost of supporting a terminal site for one year. The costs shown in the table are estimated from the experience of supporting the seven terminals. Since the effectiveness of the Purdue system and a terminal on the network are similar, the cost of both facilities can be compared. The terminal costing $63,250 per year is much more cost effective than the $350,000 per year facility it replaces. This $63,250 terminal can also be compared to other hardware/software systems on the market.

A less effective system could be installed for less than the $63,250. A single programmer could probably implement the algorithms commonly used in remote sensing analysis on a general purpose machine in six to twelve months. This implementation probably would not include user-oriented input-output routines or other programming "frills." Furthermore, probably only one or two individuals who were very familiar with the programs would be able to use the algorithms for analysis purposes. The personnel cost required to achieve this capability, which might be described as a minimum capability, could range from $25,000 to $45,000 depending upon the individual salary and supervisory and overhead charges. Since this level of capability would be highly dependent upon one or two individuals, the associated cost is perhaps more properly interpreted as an investment in the individual rather than in the software.

Providing convenient access to a larger group of analysts, say ten to twelve individuals, would require more careful implementation. User-oriented input-output formats and careful documentation would be recommended. It is estimated that this intermediate level of analysis capability would require a personnel investment of $100,000 or more per year.

Table 5. Annual Terminal Support Costs

Purdue Administrative Staff .6 mm @ $2,400/mm	$1,440
Purdue System Specialist .6 mm @ $1,800/mm	1,080
Purdue Techniques Specialist .6 mm @ $1,800/mm	1,080
Purdue Service Staff 3.0 mm @ $1,000/mm	3,000
Terminal Administrative Staff 1.0 mm @ $2,400/mm	2,400
Terminal System Specialist 3 mm @ $1,800/mm	5,400
Terminal Techniques Specialist 3 mm @ $1,800/mm	5,400
Terminal Service Staff 6.0 mm @ $1,000/mm	6,000
2741 Rental @ $112.50/month	1,350
2780 Rental @ $1,170/month	14,040
Codex Modem Rental	5,580
Phone Line Rental (Average of seven sites)	14,880
Telephone, Supplies	1,000
Travel 2 trips @ $300 per trip	600
TOTAL FACILITY COST	$63,250

One might want to consider establishing a "full service" remote sensing data analysis capability. Such a capability would include at least everything available on a LARSYS terminal, such as preprocessing services, specialized program adaptations, and in-house training. It is estimated that it would take at least two to three years to build up such a capability and would require building expertise in preprocessing operations, system programming capability, and routine service operations. One could anticipate a $300,000 to $500,000 investment in personnel to achieve a "full service" capability with an accompanying $200,000 to $300,000 annual personnel budget to support it.

The second measure of cost effectiveness for the terminal network is in the cost of personnel support for the network. As seen above, the personnel cost for the system installed at Purdue prior to the establishment of the network was approximately $200,000. Also, the cost of maintaining similar capability via any other alternatives is also expected to be approximately $200,000. The personnel costs for supporting the entire network for the two years of the project has been approximately $300,000 per year. Considering that the number of personnel served by the network has increased by a factor of approximately six and that the number of installations served has increased by a factor of eight, an increase of 50 percent for the personnel supporting the system is very minimal. It can be shown that the increase cost effectiveness of a network over separate facilities is primarily in the area of personnel. That is, there has been a corresponding increase in cost of equipment of approximately five which is approximately the increase in effectiveness from a hardware standpoint.

3. System Usage Parameters:

Table 6 shows the terminal computer use in hours from the time the first terminal was installed in August 1972 through the end of the project December 1974. Other statistics with regard to computer use are also shown in the table. These include the total CPU time used per month during the project by the terminals and the average time used per terminal by month. The average CPU time used for each of the terminals is also shown along with the maximum and minimum monthly usage figures.

Tables 7, 8, and 9 show the use of the analysis software for six-month periods of the entire network during the remote terminal project. Table 7 shows these statistics for the six-month period in which most of the terminals were added to the network. The information in Table 7 includes the

Table 6. Terminal Computer Use August 1972 - December 1974

	Goddard	Houston	Wallops	Langley	Texas	ISU	EDC	Total	Average per Terminal
1972									
August	1.9							1.9	1.9
September	.1							.1	.1
October	.1							.1	.1
November	.8	1.4						2.2	1.1
December	.9	4.6						5.5	2.8
1973									
January	.0	6.7						6.7	3.3
February	.5	7.0						7.5	3.8
March	2.3	12.5						14.8	7.4
April	13.2	9.6						22.8	11.4
May	27.9	11.0						38.9	19.5
June	15.4	10.2	.5					26.1	8.7
July	11.6	10.6	1.1					23.3	7.8
August	34.8	5.0	1.6					41.4	13.8
September	27.3	2.0	.1					29.4	9.8
October	6.5	2.6	.2					9.3	3.1
November	12.4	4.0	3.1	8.8				28.3	7.1
December	1.2	4.2	2.4	.0				7.8	2.0
1974									
January	2.0	6.4	3.8	1.3	.8			14.3	2.9
February	2.4	8.3	1.8	1.8	.0			14.3	2.9
March	4.6	15.2	3.7	1.8	3.9			29.2	5.8
April	.9	16.4	2.4	.9	4.1			24.7	4.9
May	15.9	5.9	1.1	.6	4.3			27.8	5.6
June	1.1	5.9	5.4	.8	2.9			16.1	3.2
July	7.1	7.0	4.8	3.3	10.1	.3		32.6	5.4
August	2.6	19.0	3.7	1.4	4.9	.3	.5	32.4	4.6
September	1.7	29.6	8.6	1.3	4.5	.4	1.6	47.7	6.8
October	2.4	33.1	.6	1.1	4.9	2.2	2.4	46.7	6.7
November	.6	12.4	2.9	4.7	4.4	3.1	.6	28.7	4.1
December	.1	32.8	1.5	2.0	10.5	1.6	.2	48.7	7.0
Total	198.3	283.4	49.3	29.8	55.3	7.9	5.3	629.3	163.6
Months	29	27	19	14	12	6	5	29	29
Average	6.8	10.5	2.6	2.1	4.6	1.3	1.1	21.7	5.6
Maximum	34.8	33.1	8.6	8.8	10.5	3.1	2.4	48.7	19.5
Minimum	.0	1.4	.1	.0	.0	.3	.2	.1	.1

Table 7. Network Usage Statistics for
June 1, 1973 - November 30, 1973

	Times Used	Hours Used (CPU)
Computer Usage	19296	1371.9
LARSYS Usage	9407	308.4
Classifypoints	734	95.9
Sampleclassify	24	.2
Cluster	1626	86.2
Statistics	737	11.2
Separability	236	10.7
Printresults	1152	12.1
Copyresults	36	.5
Listresults	52	1.9
Punchstatistics	0	0.0
Pictureprint	1040	14.8
Imagedisplay	1027	71.3
Linegraph	154	.2
Columngraph	194	.5
Histogram	214	1.9
Graphhistogram	49	.1
Idprint	310	.1
Duplicaterun	38	.1
Transferdata	54	.6
Runtable	1730	.1
Data Library Times Accessed	7098	
Data Library Runs Accessed	764	

Table 8. Network Usage Statistics for December 1, 1973 - May 31, 1974

	Times Used	Hours Used (CPU)
Computer Usage	39160	1380.1
LARSYS Usage	20951	557.4
Classifypoints	1736	191.1
Sampleclassify	164	23.7
Cluster	3453	132.2
Statistics	1405	21.6
Separability	656	19.9
Printresults	2731	25.7
Copyresults	95	1.4
Listresults	98	2.7
Punchstatistics	10	.1
Pictureprint	2108	37.2
Imagedisplay	1424	94.2
Linegraph	290	1.0
Columngraph	406	1.2
Histogram	344	3.7
Graphhistogram	132	.1
Idprint	1141	.5
Duplicaterun	133	.3
Transferdata	196	.6
Runtable	4429	.2
Data Library Times Accessed	9494	
Data Library Runs Accessed	1038	

Table 9. Network Usage Statistics for
June 1, 1974 - November 30, 1974

	Times Used	Hours Used (CPU)
Computer Usage	25588	1305.2
LARSYS Usage	31619	655.8
Classifypoints	3119	267.0
Sampleclassify	341	23.5
Cluster	4548	126.3
Statistics	1723	28.4
Separability	1527	32.9
Printresults	5863	45.5
Copyresults	540	5.8
Listresults	386	12.7
Punchstatistics	110	.6
Pictureprint	2458	35.2
Imagedisplay	1132	70.0
Linegraph	499	.7
Columngraph	538	1.7
Histogram	216	3.3
Graphhistogram	113	.1
Idprint	744	.3
Duplicaterun	220	.5
Transferdata	232	1.0
Runtable	7320	.3
Data Library Times Accessed	9869	
Data Library Runs Accessed	1007	

number of times the computer was used during this six-month period and the CPU hours used. It also includes the total number of times LARSYS was used and the number of CPU hours involved in this use. The number of times each of the 18 processors and the runtable was used is also shown with the corresponding hours of CPU times used by that processor. Finally the number of times the data library was accessed and the number of runs accessed in the data library was also shown for this six-month period of time.

Tables 8 and 9 then show a more steady-state analysis of the terminal system use. It should be noted that the computer usage for each of the six months is approximately constant. However, the LARSYS usage increased during each six-month period. Most of this increase is in the area of the CPU time used for Classifypoints. Tables 7 and 8 also show that the number of runs accessed and the average number of times each run was accessed did not significantly change. This indicates strong direction toward classifying larger data sets during the last six-month period. These statistics are strongly indicative of progress in the ability to train a classifier over an area and then classify a larger area. It should be noted that the classification processes increased from 6.9 percent during the first period of the total CPU usage to 13.8 percent during the second period and finally to 20 percent during the third period.

All of these usage statistics continue to be available from the network. They are considered to be of great value to anyone interested in developing similar facilities for remote sensing analysis.

D. Transfer of Technology

Objective 4 of Purdue's participation in the remote terminal project is:

"To provide a facility for immediate access to and knowledge of present and future techniques (transfer of technology)."

When the LARSYS remote terminal went on line at Goddard Space Flight Center in August 1972, it was the only available facility at Goddard for performing LARSYS-type analysis of remote sensing data. Since that time the terminal has been used for a wide range of purposes, from providing quick overviews of the data analysis procedure, to remote sensing education, to applications research. It has been observed in operation by a wide community, including personnel from NASA Headquarters, Wallops Station, Langley, the National Bureau of Standards, the Department of Agriculture, three universities, three private industrial companies, and many others. This exposure and range of users has been fairly typical of all of the remote terminals on the LARS network. Most notable in virtually every case has been the educational use of the remote terminals; the educational process has been greatly enhanced by the "hands-on" availability of the remote sensing data processing technology.

As the remote sensing data processing technology has continued to evolve, so has the state of the LARSYS software, to the benefit of all users concerned. The period of more than two years since the initial terminal was installed at Goddard has seen considerable upgrade in the LARSYS system. The installation of LARSYS Version 3 and associated training programs discussed earlier are of significance. Since then ten modifications to the system have been made which have enhanced the use of LARSYS and 39 software errors have been detected and repaired (of these five enhancements and 31 repairs have effected the remote terminal users, the remainder bearing on the digital display system located at LARS). Some of the software errors were found by users at the remote sites. These modifications have been realized by 40 separate amendments incorporated in the system during the two year period.

Still more substantial upgrades of the system have been made on an experimental basis and implemented in an experimental version of the system. The new techniques so developed have been made available on a controlled basis to users both at LARS and at the remote sites so that they could be evaluated and thoroughly debugged.

Availability of a common data processing technology to so wide a community of users has produced a stimulating environment for the interchange of ideas and experiences. At one point it was suggested by the Steering Committee that a LARSYS users group be formally established so that interchanges of this nature could be further facilitated. It turned out that this was not now feasible, primarily because of limitations on government travel funds. However, it has been possible to maintain the interchange largely by means of communication between the site specialists and the representatives to the Steering Committee.

Also observed has been a "reverse transfer" of technology, that is, the inflow of new data processing techniques and methodology from the remote sites to the central LARS location. For example, a linear combination feature extraction capability developed at the University of Houston with the support of the Johnson Space Center has been communicated to LARS and may be made available to network users after appropriate test and evaluation.

Also made available to the remote site users has been the considerable data handling technology developed at LARS, particularly in connection with the data from ERTS. This has included capabilities for geometric correction, temporal overlay, sun angle effect correction, and processing of data in the NASA universal imagery format (in which SKYLAB data is supplied).

Still another use of the technology made available at the remote sites has been verification of local implementations of the LARSYS algorithms. At the Johnson Space Center, the terminal was used to run separability analysis, the results of which were compared with the results of a similar processor implemented on-site.

Of course, there have been difficulties to deal with as well. Not long after installation of the first remote terminal, it became apparent that the terminal could not be used effectively without adequate support from site specialists. This had been a premise of the system design and of the formulation of the LARSYS Educational Package as well; because the technology was evolving rapidly, this was necessary to smooth transmission of system updates and educational material revisions to users at the remote locations. Nonetheless, because of the pressure of other responsibilities at the remote sites, there was an early tendency to assume that new users could get on the system and carry out effective analysis with very little attention. This was not the case, however, and the result was a very slow start in utilization of the remote terminals; despite availability of the hardware, the data processing technology was not truly available until active local support was provided.

The greatest apparent problem associated with the network has been the trade-off between the costs of achieving major update to the LARSYS software system and the costs of interchanging techniques without the availability of extensive documentation. Major modifications in two of the processing algorithms have been used on the system for more than a year without available documentation. These modifications have been shared between sites but are not available to all users on the system. The time lag between the initial availability of technology and complete documentation of the technology has been approximately 18 months. The principle reason for this delay has been the time and cost required to update pertinent documentation and making this documentation available for distribution. Of course, this is the first time that such an update has been made to LARSYS since the release of Version 3. Some of the delay has been the result of the development of effective procedures not only for the update of the software but for the documentation revision and dissemination as well. Although this is sometimes frustrating to users of any system of this type, the effectiveness of the procedures established have been close to optimal. Personnel who require a faster rate of technology transfer can speed the availability of new techniques through special procedures and at a higher cost. On the other hand, personnel who are not willing to pay the higher cost still participate in the knowledge made available at a slower rate.

E. System Evaluation

Objective 5 of Purdue's participation in the remote terminal project is:

> "To evaluate the current implementation of those techniques (remote sensing data processing) in the Purdue/LARS remote terminal system and associated software."

Soon after inception of the first remote sensing data processing system designs it became apparent that operational application of the objective technology implied that users of the developed system would be from many disciplines having a wide range of technical backgrounds which may not include the use of computer systems. Also apparent was the requirement for large scale system access and data dissemination. Although development of processing algorithms, user interface techniques and applications research have enjoyed a decade of progress, realization of large scale system access and data dissemination have only undergone conceptual design and initial testing. In this project testing of an approach to providing large scale access to state of the art remote sensing data processing capabilities was achieved. The approach was access to a centralized hardware/software system via remote terminals.

1. Machine-Data Interface:

Of primary importance when providing access to a processing capability is the analyst-to-computer and analyst-to-data interfaces. To analyze image data the analyst must be provided means of interacting with the data and to utilize machine processing techniques he must have effective means of interacting with the machine and thus the processing techniques.

a. The software interface. Given the criteria that an effective remote sensing data processing system must have wide and general use and that users would ultimately be of diverse backgrounds, not necessarily including the use of computers, LARSYS was developed to make the user's interaction with the analysis functions as straight-forward and easy to learn and remember as possible. Thus, user convenience was given first consideration when developing user interaction aspects of the system. This method of easing the learning and operations burden for users has been very beneficial to remote users. The most significant effect has been the large number of users who have received training on the system and made use of its capabilities.

With the advent of wide-spread use and reduced cost of the alphanumeric cathode ray tube conversational terminals additional convenience may be possible by employing the menu selection technique for user-system interfacing. This method of executing LARSYS can be more effective and convenient depending on the user and application. This method would be cost effective for remote sites, since LARSYS could be accessed without the use of keypunch, card read, or card punch machines. A disadvantage of the method is that the user would not have a hardcopy of his execution control stream; however, this function could be provided through user storage areas in the central system.

Early in the experiment users voiced a need to generate experimental versions of various LARSYS functions. This capability was provided when LARSYS Version 3 was placed on line in June, 1973. Version 3 is implemented with a modular structure, so that users may generate experimental versions of only those processor functions of interest.

b. The hardware interface. With exception of the image interaction digital display device, LARSYS was developed around the use of long standard computer peripheral devices, card reader, card punch, line printer and conversational teletypewriter. These devices are available in easy-to-use standard configurations and are readily available for remote connection to the central facility.

Prior to the beginning of the remote terminal experiment, an IBM 2780 reader/printer/punch remote terminal unit was installed at the central facility for development of support software. This unit in combination with an IBM 2741 typewriter make up the basic peripheral equipment needed for operating LARSYS. With exception of a Data 100 Corporation equivalent of the 2780, this configuration was used at all remote sites. This configuration served well in providing access to the system and effective use of LARSYS. It became apparent, however, to achieve successful general application of the remote terminal concept and thus large scale access to the remote sensing data processing technology, support of a more complex and diverse array of terminal equipment would be required. From this realization has grown the need for development of the "remote terminal family concept." The family concept provides for cost effective access to the central facility via a family of terminal configurations. The concept is required largely due to the wide range of applications for which remote terminals are installed and range of usage requirements at various installations. The family of equipment selected for system support should allow graceful upgrade and degradation, therefore, allowing a remote user or user group to not only select a cost effective initial terminal configuration, but to modify terminal capabilities as the application and usage dictates.

To satisfy the requirements of the family concept, three general categories of terminal equipment are needed. The level 1 or minimum capability terminal, the level 2 or limited capability terminal, and the level 3 or intelligent terminal. To allow ease of terminal reconfiguration, each terminal system should be a subset of the largest level 3 system; thus repurchase, reinstallation and user reorientation of basic components can be avoided when upgrading to larger configurations. Implementation of this concept will allow more diverse application of the remote terminal concept through availability of user-application and usage-tailored terminal configurations.

c. The data interface. From the time the first line printer gray scale image was generated the need for a higher quality interactive image display was recognized. Line printer images became less effective as remote sensing data gathering platforms increased in altitude and ground resolution elements became larger. A high quality black-and-white disk-refreshed cathode ray tube digital interactive image display was procured for the LARS central facility in 1970. No such image display capability has been provided for remote sites which is probably the single most critical disadvantage remote users have relative to local LARS users. Currently, all remote image displays are provided by the PICTUREPRINT processor on line printer output. Although line printer images can be effectively used for image interaction, a 10 to 16 gray level cathode ray tube image display device could offer analysts significantly extended capabilities to more accurately and thoroughly analyze gray images. The GSFC and Wallops remote site final reports state that terminals were not fully utilized because it does not have an image display device.

In addition to providing high quality gray images the LARS interactive display provides a machine-aided means of selecting and cataloging image coordinates. This on-line interaction capability avoids the time consuming, tedious task of manually locating, recording, and keypunching image coordinates, and eliminates opportunities for introducing errors into the analysis.

To remove this remote terminal handicap, currently available interactive image display devices should be evaluated and LARSYS support of a suitable device developed. It is believed that growth of the remote terminal concept for earth resources data processing will be seriously hampered without LARSYS support of one or more readily available low cost interactive image display devices.

d. The central facility. The general objective of the central computer system and staff is to provide an optimal facility for testing concepts and applications of remote sensing data processing techniques. As discussed in another section of this report, particular attention has gone into the LARS computer facility design with respect to providing remote access to the system, thus providing a cost effective means of exporting the technology. The facility has successfully provided: (1) access at remote sites to data and a processing capability, (2) sharing of expensive portions of the processing hardware and of software maintenance, and (3) a readily usable system through which users may share experiences through standard data formats, terminology, and simplicity of communication.

A primary factor in the overall effectiveness of the central facility from the remote users point of view is response time. Response time not only with respect to computer processing speed but to all matters related to remote user interaction with the facility: machine malfunctions, software upgrades and maintenance, special requests, and general user inquiries. For the remote terminal experiment ample computer resources were available to provide adequate machine response, except for brief periods of heavy usage. During this experiment several machine upgrades were implemented as the number of remote and local users increased. It is clear, however, that the on-line interactive mode of operation requires greater machine resources than batch mode, where the system rather than its users can dictate the allocation of system resources.

The concept of site specialists provided efficient communications between sites including the central facility. By distributing lists designating specialists at each site for terminal operations and analysis techniques and coordinated communication between sites, users were able to enjoy reasonably prompt response to questions and problems.

One capability not provided to remote site users is high quality continuous-tone hard copy image output. The need for such output is well recognized throughout the remote sensing data processing community for imaging of both raw data and processing results. Although local users may get medium quality low-resolution hard copy displays from the LARS cathode ray tube image display, the display system is primarily designed for image editing and thus is not cost-effective for production hard copy display work. Due to the high cost of hard copy image output devices it does not seem practical to locate the capability at all data processing sites. It is believed that the "sharing of expensive system components" advantage of the remote terminal concept itself is directly applicable to the hard copy device; that is, the device should be one of the shared components at the central facility. Through prescribed procedures, remote and local users would specify data for hard copy recording, the recording would be made at the central facility, and finished products sent to the users. Delivery time to remote users should be longer than for local users only by the air mail transit time (1 to 3 days). This method of machine utilization is expected to cost-effectively provide a highly needed capability to a large number of users.

2. Data Base Management:

For the remote terminal project, remote access to the central facility includes access to a large multispectral image storage tape library and extensive data reformatting and handling services. Thus, each remote site not only may immediately access any of over 1500 data sets but may utilize data reformatting services to generate additional data sets for the library. Reformatting services frequently used include image registration, ERTS rotation and geometric correction, Goddard/ERTS-to-LARSYS format conversion, ERIM aircraft data-to-LARSYS format conversion, library entry of user-generated LARSYS-formatted data sets, and sun angle or MARC (mean angle response correction) radiometric correction. The user may himself generate LARSYS-formatted data tapes to be sent to the central facility for library entry. The philosophy implemented, therefore, includes the data base and all data preparation as a part of the central facility. The basis for this philosophy coincides with the basis of the remote terminal concept itself. That is, it provides user access and sharing of an expensive portion of the remote sensing data processing capability; centralization of reformatting software and operations personnel is achieved; and immediate access to implemented reformatting techniques is provided at many user sites.

A large number of reformatting services were provided to remote sites. Some problems did arise but were solved with communication procedures. By November, 1974, 157 remote site user generated LARSYS formatted data sets were entered into the LARSYS data base library, 32 Goddard/ERTS data sets were converted to LARSYS format, 15 ERIM aircraft data sets were digitized and reformatted, 3 MARC corrections made, 2 ERTS geometric corrections and 2 ERTS image registrations were generated. Significant problems in providing reformatting services were in the area of procedures and communication. At the onset of the terminal experiment a specific procedure for transmitting multispectral image data and reformatting services requests to LARS had not been prescribed. Difficulty in communicating a procedure to many users at several remote sites mounted quickly and prompted a procedures document. Another problem was in messaging users at remote sites that requested data had been entered into the library and was available for analysis. Users were being informed, but often several days after the fact. This problem was solved by a procedure in which a message was transmitted to the appropriate remote terminal line printer for posting in the terminal area and sending by mail a brief form stating pertinent information to the originator of the reformatting request. In most cases following initiation of this procedure, line printer messages were transmitted almost immediately after the requested data set entered the library and the forms were mailed on the same day.

Even though a central facility serving remote sites may have a large existing data library, remote users will often be involved in applications projects requiring very recent data not yet stored in the central library. In addition, many applications require nearly immediate access to newly collected data. Ideally the central facility must have a means of directly receiving data from primary ground data dissemination points by the use of communications links. Also, remote sites having data processing capabilities other than the LARS terminal may require a terminal feature for transmitting large amounts of data to the LARS facility for subsequent analysis. This requirement was indicated in the JSC, Wallops and GSFC final reports.

IV. SIGNIFICANT ACCOMPLISHMENTS

As a result of Purdue's participation in the remote terminal project, a number of accomplishments have been achieved and are documented in Chapter III of this report. These accomplishments are summarized below and are organized so that they relate to the objectives of Purdue's participation in the project stated in Section II-D.

A. A remote terminal facility was provided which connected seven separate sites to an earth resources data processing system located at Purdue University in the Laboratory for applications of Remote Sensing. Although most of these sites experiences some start up difficulties, only at one site (Langley) were these so severe and so extended as to make the installation at that site be considered less than highly successful.

B. The basic approach to the development of a facility for training personnel in the use of advanced data processing techniques for remote sensing is sound and has proved itself to be effective. The instructional materials designed for individual use with a minimum of instructor participation meet the needs of most remote terminal situations and may be adopted for group use by an imaginative instructor. Through the use of these materials and the remote terminal network 600 personnel have been trained in the use of the techniques.

C. A remote terminal has been shown to be a cost effective facility for training of personnel, transferring technology, and meeting most of the current data processing requirements. The cost of lesser effective systems to meet similar needs has been shown to range between slightly less than the cost of a terminal to much greater than the cost of a terminal. From the system point of view the cost of personnel to support a network has increased insignificantly with respect to services provided when compared to the cost of providing separate facilities at each location.

D. It has been demonstrated that the remote terminal approach is an effective way to make available the evolving remote sensing data processing technology to a wide community of users. As a result of the commonality of data processing environment to a broad community of users, the interchange of ideas and experiences between sites has been facilitated. In some cases, a reverse flow of technology has occurred in which new techniques and methodology developed at the remote sites are transmitted to the central location to be made available across the network.

E. It has been shown that the initial requirements of a terminal site are necessary to provide training, transfer of technology, and adequate data processing services. These requirements briefly stated are: 1) access to computer facility services which provide a specialized analysis technology, 2) a hardware link to these services, 3) a personnel link between the remote site and the central site consisting of a systems specialist and a techniques specialist which provide reasonable responses to the users needs, 4) a training concept including materials, documentation, and instructors available to the potential users, 5) an available data library and access to data preprocessing services.

V. CONCLUSIONS

In addition to the significant accomplishments listed in Chapter IV of this report, a number of conclusions can be drawn, based on the material in Section III, which are related to Purdue's participation in the remote terminal project.

A. Purdue successfully met each of its objectives as listed in Chapter II-D which were established at the beginning of the project.

B. From a systems point of view a reasonable amount of latitude is desirable in allowing for "compatible" replacements of supported terminal types. Useful experience was obtained relative to two vendors of terminal equipment (IBM and Data 100). Similarly, useful experience was obtained relative to low speed teletype "compatible" cathode ray tube terminals. Purdue worked with three vendors of modems (AT&T, Codex, and Paradyne), and two vendors of communications lines (AT&T and Western Union) in addition to interfacing with local common carriers. Although a wide variety of unexpected problems occurred during these experiences, none were insoluble and the ones associated with the terminals were solved quickly. The problems associated with the modems and the communications lines required the bulk of the attention. Therefore, from a systems point of view it seems more appropriate to standardize the modem/communication lines than the terminals. From a user point of view the standardization of terminals might be more important as discussed in item C below.

C. Since most of the terminal installations were completed about three weeks behind schedule due to delays in delivery and/or malfunctions in the equipment, it seems reasonable to expect approximately a month of start-up operation. For this reason, requested delivery dates and system tests should be scheduled approximately one month in advance of the date when operational use is required.

D. The remote terminal project has not only established a workable education and training procedure but it has also shown the need and developed the capability to maintain and revise the instructional package to reflect the requirements of hardware/software changes and the dynamic nature of remote sensing technology. This capability was demonstrated in the revision of the Educational Package to reflect the change from LARSYS Version 2 to LARSYS Version 3 and in the format changes accompanying the release of LARSYS Version 3.1.

E. Although the LARSYS Educational Package has been demonstrated as a useful tool, experience has shown that the package is not sufficient in itself. Key components in the training facility are the local site experts who are available to administer instruction and provide the vital link between the instructional material and student problems and questions. These personnel are also key in the decision of the standardization of the terminal hardware. If these personnel can effectively communicate the changes in the terminal hardware to all of the students, then the standardization of the terminal hardware is not required.

F. Although the remote terminal concept has demonstrated a highly effective mechanism for transferring technology, this approach is maximally effective only when adequate support is provided at the remote terminal site to compliment the physical availability of the hardware and software. This is particularly true for the techniques specialist. The absence of a techniques specialist at some remote sites seriously effected the transfer of technology.

G. The remote terminal project has demonstrated that large scale access to the remote sensing data processing techniques can be achieved through remote terminal systems. The three key elements of the remote terminal system -- hardware, software, and training -- were successfully implemented and were used by a multitude of personnel.

H. In addition to demonstrating both feasibility and practicality of the concept, the experiment provided a basis for further development of requirements for more effective terminal systems. The following hardware requirements were recognized and reconfirmed as a result of the experiment. In order of their priority these are: 1) a low cost interactive image display device supported by LARSYS, 2) a wide range or "family" of terminal configurations should be identified and supported by the system, 3) a high quality hardcopy display capability should be located at the central facility for operational use by remote sites, and 4) the concept of high volume communications links between the central facility and the primary data dissemination facilities should be developed to provide near immediate access to remote sensing data by users of the entire network.

VI. RECOMMENDATIONS

Several recommendations with respect to future remote terminal sites and for follow-on activities have resulted from Purdue's participation in the remote terminal project. The background for these recommendations are documented in Chapter III of this report.

A. Since the goal of the remote terminal project was to demonstrate the feasibility of the approach to providing a facility for immediate access to and knowledge of present and future techniques, this report and the reports from the remote terminal sites demonstrate the success of the project and the appropriate conclusion at this point in time. However, the system is continuing to evolve and it is clear that we have not yet determined the full extent to which this approach can be utilized for the effective transfer of new data processing technology. It seems in order, therefore, to consider continuation of the project in order to further probe the extent to which such effective transfer is possible.

B. The remote terminal "family" concept should be developed in the areas of terminal system and software support. Attention should be given to a minimum capability characterized by dial up voice grade communication links, low speed interactive typewriter or cathode ray tube terminals, and, optionally, a low speed printer. A second capability would include implementation of a low cost remote interactive image display device with associated software support. This capability would include displaying gray-scale images and user selection of image element coordinates and possibly cassette tape units for control and data information exchange. Thirdly, a full capability terminal system should be developed. This facility would provide a wide range of data interaction devices. The software or LARSYS support for all of these facilities should be designed to support any combination of the terminal family.

C. A high quality hardcopy image display system should be implemented at the central processing facility for operational access to remote users.

D. A communication link between the central processing site and data distribution centers should be implemented to speed access to data for users of the system. Also, remote terminal equipment should be implemented so that data could be exchanged between the remote sites and the data processing facility.

E. To assist the site experts in their roles as instructors it is recommended that future remote terminal contracts include the support of a LARS education and training consultant who would be available by the telephone to assist in solving individual training problems and to provide a direct feedback path to the developers of the educational package. The LARS education and training consultant should initiate calls to remote terminal sites on at least a monthly basis if the site experts have not called in with specific requests.

F. To stimulate local interest, remote terminal sites should be encouraged to work with LARS personnel in the development of a demonstration and/or case study geared specifically to a problem of general interest to personnel and/or visitors to the remote terminal location.

G. Add to the site expert training at LARS two to three hours on general aspects of educational philosophy and the specific philosophies around which the Education Package was designed.

H. Continue to pursue the concept of a LARSYS user group in conjunction with the remote terminal network. The full potential for furthering the technology by interchange of ideas and experiences which would be facilitated by such a users group can only be speculated on at this point. Even the exchange which has taken place between site experts and at long distance users of the system has proven most beneficial.

I. Include in future remote terminal contracts resources to support a LARSYS advanced analysis seminar/workshop. The timing and topics to be included in the seminar/workshop should be arranged by the remote terminal site and LARS techniques specialist.

J. LARSYS execution by menu selection techniques should be evaluated as an effective user convenience.

K. The task of coordinating the procurement and installation of remote terminals and communications links, as well as the responsibility for keeping them operational, should be vested in one coordinator located at the central computer site.

L. Where possible standardization of one vendor and model of modems is recommended. This would make all personnel more effective in troubleshooting because of greater familiarity with one type of equipment. It would facilitate the development and use of standard diagnostic techniques to isolate problems and would provide greater possibility of substitution of one unit for another as a diagnostic aid. A greater variety of test equipment and diagnostic hardware is desirable at the central site than was available at Purdue throughout this experiment.

M. A final recommendation which has grown out of the experiment and was suggested by the remote terminal steering committee is that the LARSYS be further modularized in order to facilitate transmission of the data processing software to other locations.

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