LARS Report 112679

ANNUAL REPORT
TO THE UNIVERSITY

FISCAL YEAR 1979

Laboratory for Applications of Remote Sensing
Purdue University
West Lafayette, Indiana 47906 USA

PURDUE UNIVERSITY LABORATORY FOR APPLICATIONS OF REMOTE SENSING

1978-79 Report to the University

The Laboratory for Applications of Remote Sensing

We are pleased to transmit to you this report on the research and educational activities at LARS for the past fiscal year. This year the funding level for all LARS projects rose to a total of $2,313,959, an increase of $137,391 over the previous year. There were 24 faculty, 40 graduate students and 67 undergraduate students whose work was funded by Laboratory projects. Some 62 journal papers and presentations were given during the year.

The educational and training activities continue to be well received. More than a hundred scientists attended LARS short courses during the year and about twice that many attended our Symposium. Several new items of training materials were published during the year including a major one, a textbook based entirely on research done previously at Purdue.

We look forward to another year of continued contribution to the several disciplines involved in remote sensing at Purdue.

Respectfully submitted,

David A. Landgrebe
Director

DAL:mh

Distribution:
- The President
- The Provost
- The Policy Committee
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SUMMARY OF ORGANIZATION, STAFF, FACILITIES AND FINANCING

I. Organization

The interdisciplinary approach characteristic of LARS is fostered by the Laboratory's organizational structure (Figure 1). The common pattern of research is the formation of teams of scientists with a common interest in a problem but from several program areas who work together for the duration of the project. This approach contributes to a dynamic and flexible structure. Planning, coordination and leadership are provided by the director with active participation by the associate and the deputy director and the program leaders.

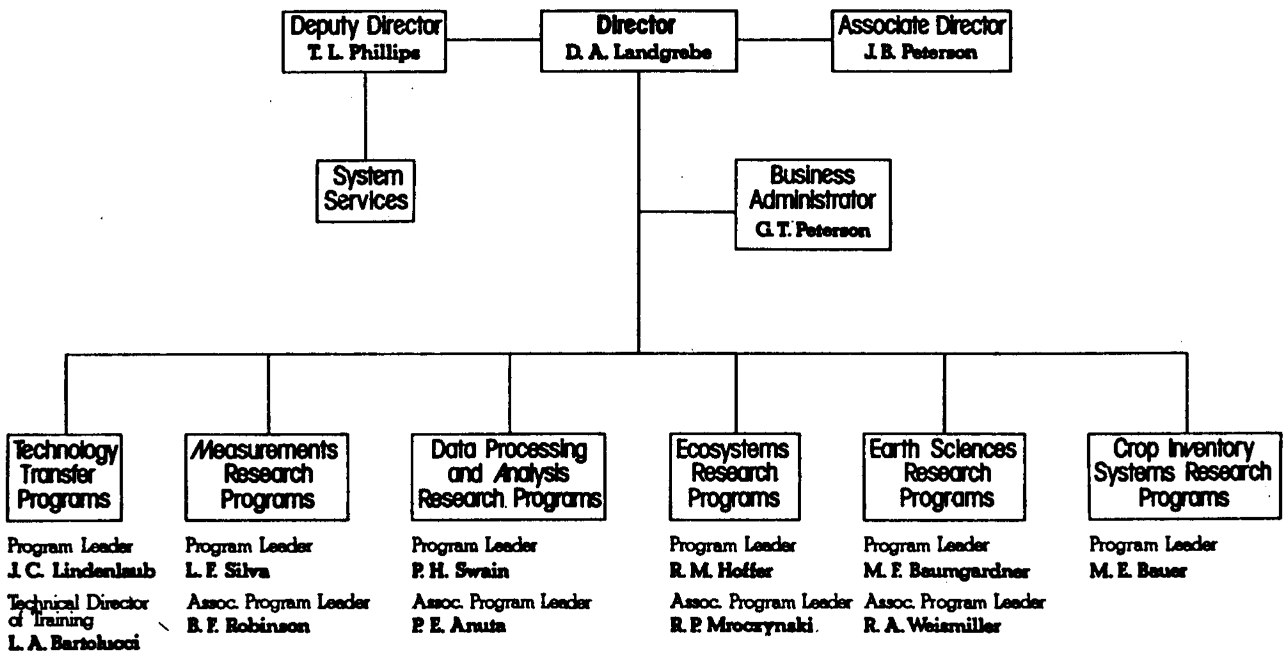


Figure 1. Organization of the Laboratory for Applications of Remote Sensing

II. Staff July 1, 1978 - June 30, 1979

During FY79 there were 195 people (82.59 FTE) from 11 departments in 4 schools assigned to LARS projects. Figure 2 shows a further breakdown of this information:

	Agriculture	Engineering	Humanities Social Science & Education	Science	# of Employees	Full Time Equivalent
Faculty	7	12	1	4	24	5.31
Professional	8	26	1	2	37	31.63
Clerical		19			19	12.22
Service		8			8	3.28
Graduate Students	16	17	1	6	40	13.54
Undergraduates		67			67	16.61
					195	82.59

Figure 2. Staff summary by school

Further details on the LARS staff are provided on pages:

III. Fiscal Summary

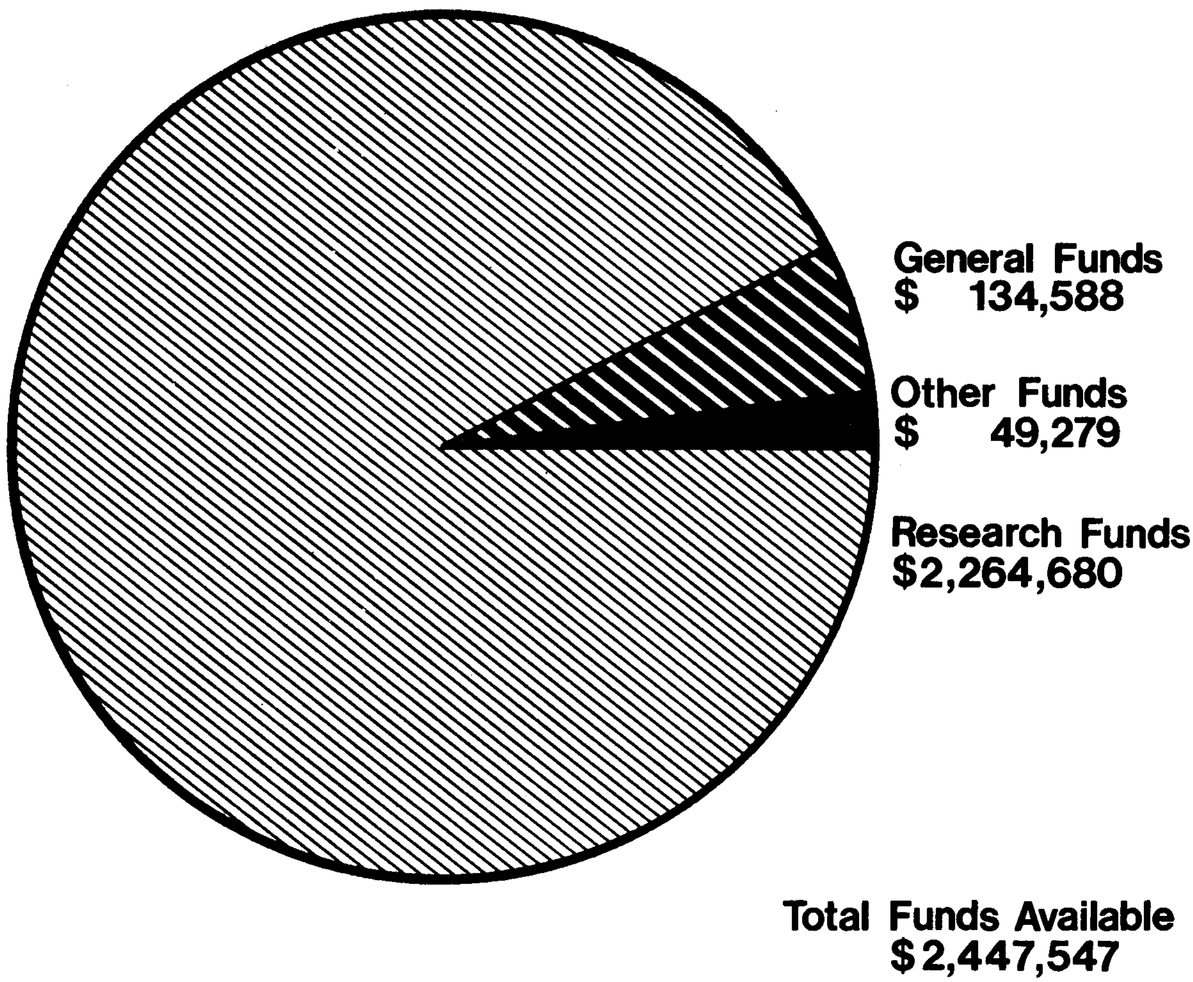


Figure 3. Summary of funds available. July 1, 1978 to June 30, 1979.

IV. Training Program Summary

Following is a summary of Training Program activity during the 1978-79 year.

Basic short course attendance	-	70 participants
Advanced short course attendance	-	32 participants
Visiting scientists	-	16 scientists from 7 countries
Symposium	-	84 papers, 200 participants
Remote terminals	-	20 remote site ports
Minicourse sales	-	766 annual total units
Graduate students	-	40
Advanced degrees	-	9

See pages 38-54 for further details.

V. Facility Summary

Figure 4. Flex Lab I

Figure 5. Flex Lab II

Data processing facilities include both hardware and software resources developed to serve remote sensing research requirements. Hardware included an IBM 370/148 and IBM 2314 and 3350 direct access storage systems. A digital display developed to support Laboratory research efforts was installed in 1970. Currently, 42 terminal ports are connected to the LARS computer to provide user interaction with remote sensing software.

A DEC PDP 11/34 has been attached to the computer system to serve as an intelligent remote terminal and to drive a table digitizer and an electrostatic printer plotter. The table digitizer provides support for precision registration and a means to enter ancillary data not initially in digital form into the computer's classification decision criteria. The electrostatic printer/plotter provides support for graphical and gray level image plotting.

Over the years, several remote sensing analysis software facilities have been developed. LARSYS Version 3.1 is a fully-documented software system designed to provide tools for remote sensing research. The pattern recognition and interactive data handling techniques in LARSYS have been successfully used for research in several disciplines, including crops, soils, geology, hydrology, geography and biomedical. Systems for the display and analysis of laboratory and field collected data, statistical packages, and graphics display routines are also available to the researchers at the Laboratory.

Measurements facilities include both field and laboratory instrumentation systems designed to measure reflective and radiometric characteristics of subjects ranging from agricultural crops to human skin. Equipment exists to collect measurements in the .4-15.0 μm wavelength range.

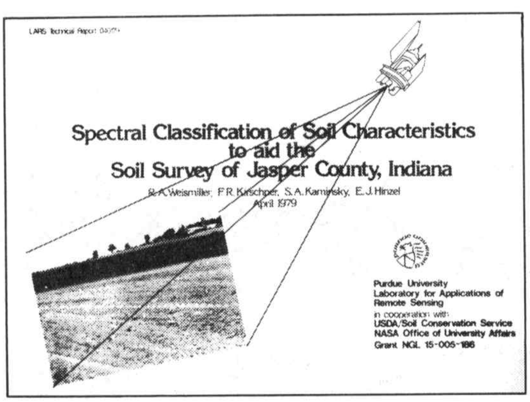
SCIENTIFIC CONTRIBUTIONS OF LARS IN FY'79

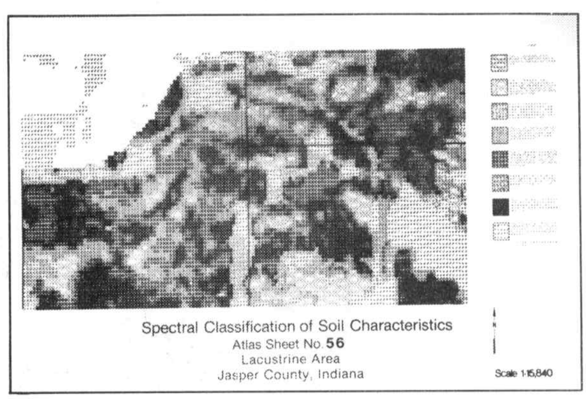
I. Introduction

FY79 was a productive year for LARS in that tangible, meaningful results were achieved both in the development of practical applications of the technology and in the advancement of the technology through the results of basic studies. Not only were several research efforts brought to fruition during the year but ground work was laid for promising results in the future.

II. Milestone Research Achievements of FY'79

1. DEVELOPMENT IN COOPERATION WITH SOIL SCIENTISTS OF THE SOIL CONSERVATION SERVICE (SCS) OF THE CAPABILITY TO EXPEDITE SIGNIFICANTLY THE MAKING OF LAND USE AND SOIL SURVEY MAPS. A prototype study in Jasper County, Indiana demonstrated that the use of computer-implemented multispectral scanner (mss) data could greatly increase the speed and accuracy of making soil and/or land use surveys (Figures 6 & 7).





Figures 6 and 7. Cover and representative page of spectral atlas prepared as an aid to SCS soil survey of Jasper County, Indiana.

2. ANALYSIS AND INTERPRETATION OF RELATIONSHIPS BETWEEN PHYSICAL AND CHEMICAL PROPERTIES OF SOILS AND THEIR SPECTRAL PROPERTIES. The basic relationships revealed in this study have been published in an "Atlas of Soil Spectra" to provide current assistance to all those dealing with soil classification. Ten spectral bands were used in the analysis of 481 soil samples representing major "benchmark" soils of the United States as selected by the SCS. Correlations for soil spectral bands vs. organic matter, moisture content and cation exchange capacity were found to be much higher when soils were grouped into climatic zones.

3. DISCOVERY OF A STRONG CORRELATION BETWEEN SOIL BIDIRECTIONAL REFLECTANCE FACTOR AND SURFACE SOIL MOISTURE.

4. SUCCESSFUL COMPLETION OF LACIE. During FY79 the Large Area Crop Inventory Experiment (LACIE) being conducted by NASA, USDA and NOAA with LARS people supplying much of the supporting research was successfully completed. This large-scale experiment to inventory wheat production in several countries was largely based on the understanding of the spectral characteristics of crops (Figure 8) and computer-aided remote sensing data analyses both of which were developed during the past decade at Purdue/LARS.

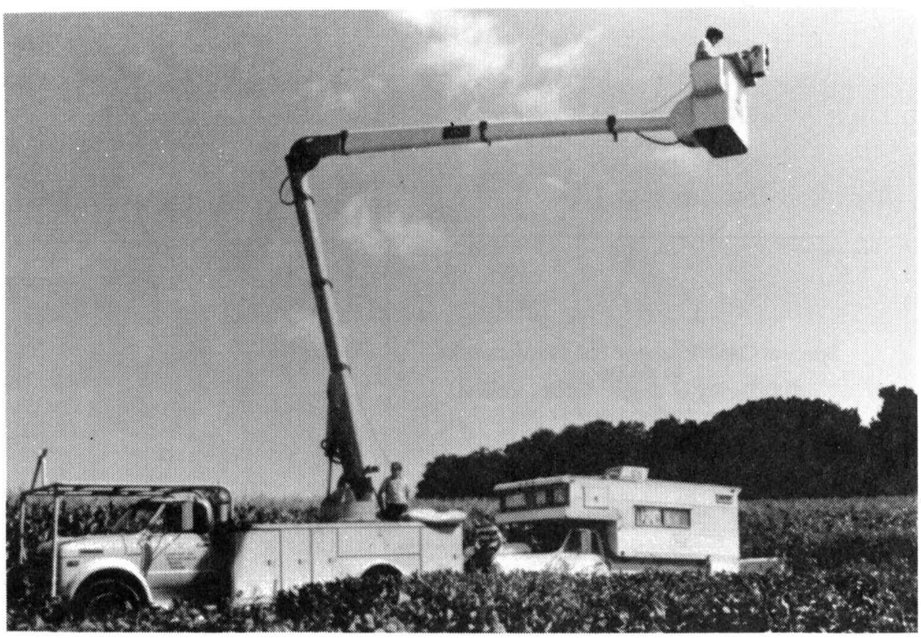


Figure 8. Spectroradiometer mounted on mobile aerial tower

5. IMPROVEMENTS IN CROP AREA ESTIMATION TECHNIQUES BY MORE FULLY INTEGRATING TRAINING, CLASSIFICATION AND SAMPLING TECHNIQUES.

6. ADVANCEMENT IN METHODS OF GEOMETRICALLY ALIGNING MULTITYPE IMAGES OF THE SAME SCENE WHICH NOW ENABLES MULTIVARIATE ANALYSIS AND ANALYSIS OF TEMPORAL CHANGES IN THE IMAGES.

7. DEVELOPMENT OF SAMPLING SCHEMES FOR ESTIMATING ACREAGES OVER LARGE AREAS AS WELL AS METHODS FOR IMPROVING MAN-MACHINE INTERACTION IN THE TRAINING OF MULTITEMPORAL CLASSIFIERS.

8. DEVELOPMENT OF A DATA LIBRARY OF MORE THAN 120,000 CHARACTERIZED SPECTRA CAPABLE OF ANALYSIS BY A SPECIAL SOFTWARE SYSTEM (LARSPEC).

9. SUCCESSFUL CULMINATION OF RESEARCH LEADING TO THE CAPABILITY TO COMBINE TOPOGRAPHIC DATA WITH SATELLITE REFLECTANCE DATA. This research has resulted in a means of mapping individual forest cover types over extensive areas of rugged terrain with greater speed and efficiency than hitherfore possible.

10. PROGRESS IN DEVELOPING A PROCEDURE TO COUPLE COMPUTER PROCESSING OF SATELLITE DATA WITH EXISTING METHODS USED BY THE U.S. FOREST SERVICE IN THEIR FOREST SURVEY PROGRAM. Computer programs were developed to locate sample points to an accuracy of better than 100 meters. These programs can now be used to update forest survey inventories.

11. DEMONSTRATION OF THE UTILITY OF LANDSAT REMOTE SENSING IN INVENTORYING COMMERCIAL FOREST LANDS. A cooperative project sponsored by NASA between LARS and the St. Regis Paper Company has resulted in a successful capability to provide useful information for the management of industrial forests.

12. DEFINITION OF AN EIGHT-BAND MULTIBAND RADIOMETER. A prototype of this radiometer which has been an object of research by LARS staff for several years, is being designed as a relatively low cost, commercially available instrumentation system for the remote sensing community.

13. PUBLICATION OF A NEW CLASSIFICATION SCHEME BETTER ADAPTED TO MULTITEMPORAL DATA SITUATIONS.

14. COMPLETION OF A MAJOR BASIC STUDY OF THE FUNDAMENTAL PARAMETERS OF SCANNER SYSTEMS IN RELATION TO THEIR INFORMATION-BEARING ATTRIBUTES. Among other things this has led to the first analytically based technique for designing spectral bands.

15. BIOMEDICAL APPLICATIONS OF REMOTE SENSING TECHNOLOGY POTENTIALLY BENEFICIAL TO MEDICAL PRACTICE. A technique previously developed in cooperation with the Biomedical Engineering Center at Purdue to evaluate the performance of electrosurgical diffusive electrodes has been extended during FY79 to the evaluation of difibrilating electrodes. This digital thermal system is also being used to evaluate the effective use of hyperthermia (tissue heating using radio frequency energy, Figure 9) on cancer eradication experiments in animals.

Further details of these milestones are contained on pages 12-37 and in LARS technical publications, pages 59ff.

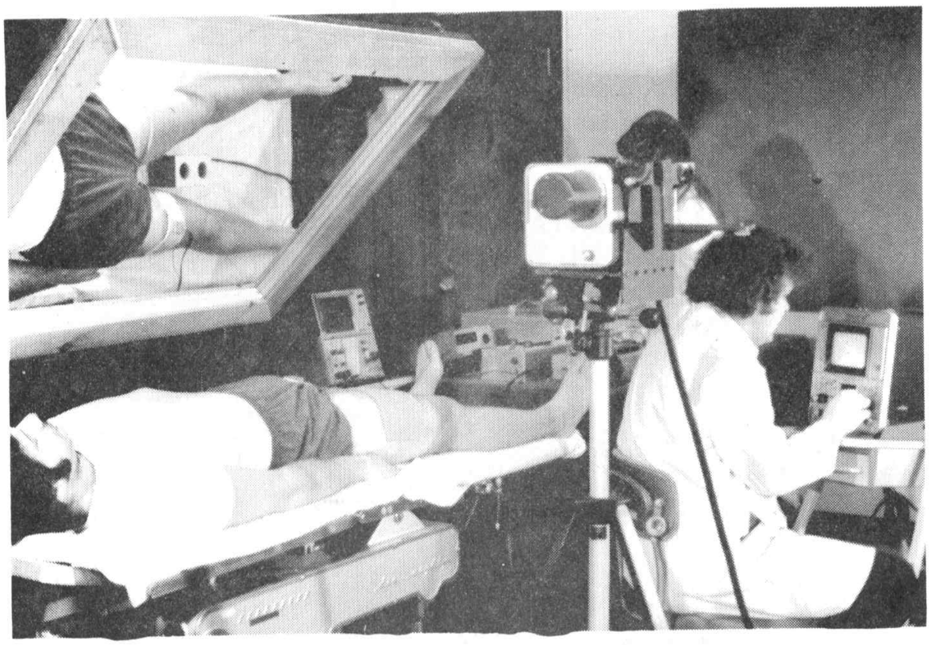


Figure 9. Measuring the performance of electrosurgical dispersive electrodes using a high-speed thermal scanner. The thermal images produced by the scanner are digitized and then processed using algorithms similar to those employed for aircraft and satellite thermal image data.

III. Contributions by Research Program Areas

A. CROP INVENTORY SYSTEMS RESEARCH PROGRAM

During the past year the Large Area Crop Inventory Experiment (LACIE) being conducted by NASA, USDA, and NOAA was successfully completed. This large-scale experiment to inventory wheat production in several countries was based to considerable degree on the understanding of the spectral characteristics of crops and computer-aided remote sensing data analysis technology developed during the past decade at Purdue/LARS.

In 1977 the LACIE wheat acreage estimates for the U. S. were within one percent of the estimates made by the USDA, although yields were underestimated by approximately 10 percent. However, the most graphic example of the LACIE capability to provide dramatically improved wheat production information occurred in 1977 in the Soviet Union (Figure 10). Both winter and spring wheat acreages were accurately predicted early in the season and the yield models responded realistically to the above average growing conditions for winter wheat and below average conditions for spring wheat growth. In summary, the LACIE estimates accurately projected the final production well in advance of the U. S. Foreign Agricultural Service or the official Soviet Union estimates.

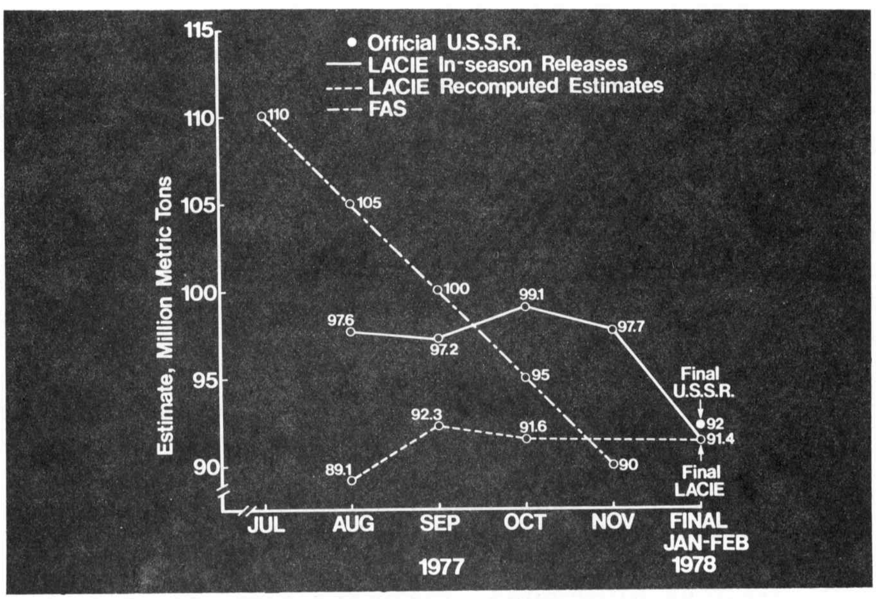


Figure 10. Accuracy of LACIE estimates of wheat production in Russia

LACIE's success in predicting wheat production in test areas is a major step toward developing a remote sensing and survey technology for monitoring global crop production. The next steps are (1) continuing refinement of the technology and transfer of capability to an operational test system within the USDA and (2) extension of the technology to other crops, regions, and applications.

Many improvements in the technology can be visualized. Historically, the LACIE approach used primarily Landsat data to estimate acreage and primarily meteorological data to estimate yield. But, this is an artificial separation; there is much information in the spectral data relating to crop condition (for example, leaf area index and presence of stress) and yield. Also, meteorological data contain much information about planted and harvested acreage. It is anticipated that the survey models used for LACIE will evolve toward forms which simultaneously integrate information from spectral and meteorological measurements, as well as soil productivity and cropping practices. With the advent of thermal sensing with Landsat-D additional information for assessing crop conditions will be available.

The LACIE participants--USDA, NASA, and NOAA-are now planning a technology development program for the early 1980's to support the implementation of operational global food and fiber monitoring systems utilizing the powerful combination of satellite data collection and computer-aided analysis. The program will be directed at not only crop production monitoring, but also mapping and assessment of soil, range, and forest resources. It is anticipated that Purdue will continue to have a major role in the development and evaluation of remote sensing technology for this program.

The overall objective of crop inventory systems research at Purdue/ LARS is to research, develop, and test procedures for obtaining crop production information from remotely sensed spectral, together with meteorological, soils and ancillary data. The specific objectives are to:

- Determine relation of fundamental crop parameters (maturity stage, leaf area, biomass, moisture status, stress effects, canopy geometry, and leaf yield) to reflectance and radiant temperatures of crops.

- Understand and quantify the effect of cultural and environmental factors on the spectral-temporal characteristics of crops.

- Develop methods to assess crop condition and predict crop yield using spectral, meteorological, and ancillary data.

- Develop and test procedures, including sampling, stratification, training, and classification for using Landsat data to estimate the area of crops.

Projects supporting all of the objectives are currently being conducted and are described in the following paragraphs.

1. Field Research: Experiment Design and Data Analysis

Understanding the interaction of radiation with crops and soils is an important component of developing satellite remote sensing technology. The necessary understanding is best achieved from measurements of fields and experimental plots where complete data describing the crops and frequent, timely spectral measurements can be made. This concept and approach is referred to as field research.

Following collection, processing, and analysis of data during 1975-77 for test sites for wheat in Kansas, South Dakota, and North Dakota, experiments on corn, soybeans and winter wheat were initiated in 1978 at the Purdue Agronomy Farm. The experiments were designed to determine the reflectance characteristics of the crops as a function of growth stage and other key agronomic characteristics such as leaf area index, to examine the effects of moisture, disease, and nutritional stresses on spectral responses, and to assess the effects of important cultural and management practices.

Analyses completed during the past year of the agronomic and spectral measurements of spring and winter canopies have shown that the near infrared reflectance of wheat is most strongly related to percent soil cover, leaf area index, and biomass (Figure 11). The near infrared reflectance is most strongly related to plant water content and biomass. It was shown that these important crop characteristics, related to the potential yield of the crop, can be accurately predicted from spectral measurements.

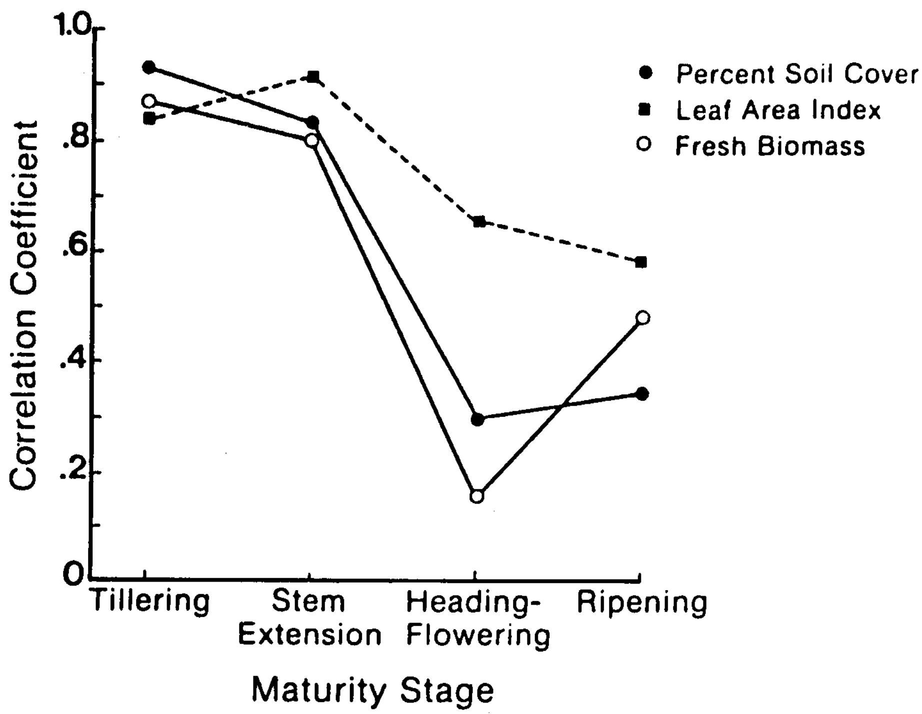


Figure 11. Effect of maturity stage on the correlation of near infrared reflectance (0.76-0.90 μm band) and agronomic characteristics of spring wheat canopies.

2. SPECTRAL INPUTS TO CORN AND SOYBEAN YIELD MODELS

In a second project initiated this past year, the potential inclusion of spectral data to corn and soybean models is being investigated. It is hypothesized that remotely sensed observations several times during the crop year can provide information about the condition and vigor of the crop which would not otherwise be available. Possible sources of yield-related information include: estimates of leaf area index, identification of key growth stages in relation to weather, and assessments of the severity and extent of crop stresses such as drought. Our technical approach is to explore ways to combine spectral measurements or spectrally-derived information with soil productivity and weather data. Currently Landsat MSS and crop data from several Corn Belt test sites are being analyzed.

3. APPLICATIONS AND EVALUATIONS OF LANDSAT TRAINING, CLASSIFICATION, AND AREA ESTIMATION PROCEDURES FOR CROP INVENTORY

This two-year project resulted from a proposal submitted to NASA. The overall objective of this investigation is to advance the development of large area crop inventory systems by applying and evaluating recently developed techniques. The quality of area estimates obtained from Landsat data is affected by choices of training, classification, and sampling procedures. In the past, there has been a tendency to deal with each of these issues separately rather than integrating them in a system approach as this investigation does. Several types of agricultural scenes in the U. S. Corn Belt are being investigated to assess the scene dependent differences in optimal choices of training, classification, and sampling procedures.

The specific objectives are to evaluate: 1) procedures for selecting the size, number, and geographic location of training areas and for obtaining training statistics from multiple areas; 2) newly developed classification algorithms which utilize temporal and spatial as well as spectral information; and 3) area estimation methods including both a systematic sample of pixels and a sample segment approach. Initial results of classifications of multitemporal Landsat MSS data have shown that classifications accuracies of 90 percent can be obtained.

4. REMOTE SENSING EXPERIMENTS FOR ANALOGOUS EXPERIMENTS ON VEGETATIVE AREAS IN THE UNITED STATES AND THE SOVIET UNION

This project, sponsored by NASA, calls for LARS to provide the technical implementation of remote sensing experiments of analogous vegetative areas in the United States and the Soviet Union. This was the third year of a multi-year study and is one of several joint U.S./U.S.S.R. studies on remote sensing of the natural environment. Test sites in South Dakota and the Kursk Oblast of Russia have been selected and data for three crop years have been collected and processed. Several remote sensing systems ranging from ground-level to satellite altitudes are being used (Figure 12). Initially, the study has concentrated on measuring the spectral reflectance of wheat and the agronomic factors affecting its growth and development. Data have been exchanged by the two countries and we are now in the process of analyzing the Soviet data, along with data from the U. S. test site.

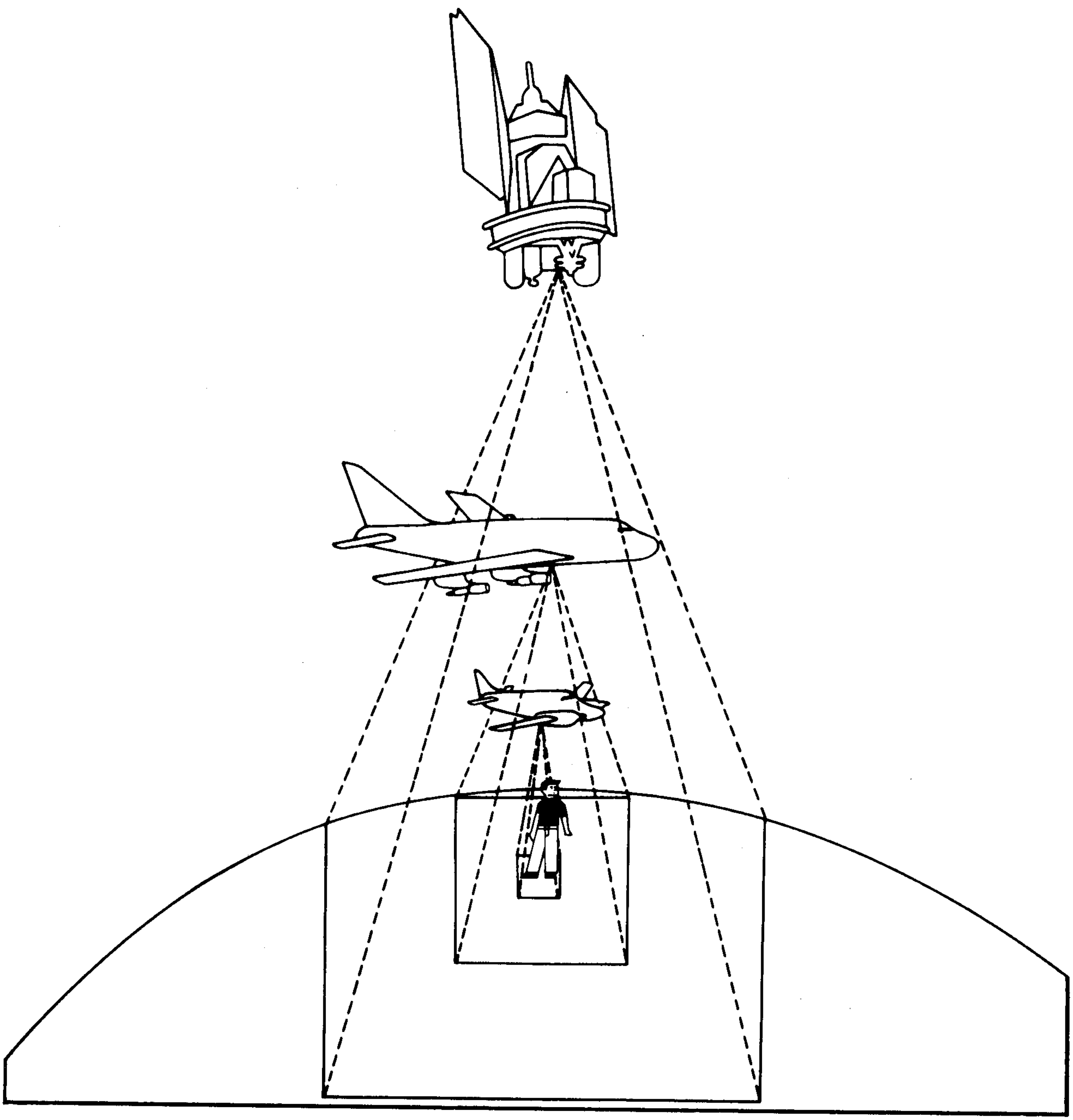


Figure 12. Data can be collected by remote sensing systems from ground level to satellite altitudes.

B. DATA PROCESSING AND ANALYSIS RESEARCH

This area of research has been and continues to be the keystone of the quantitative approach to remote sensing pursued by LARS since its inception. During the year, a textbook, Remote Sensing: The Quantitative Approach, authored by seven LARS staff members, was published by McGraw-Hill Book Company. This is the first book to be published providing an introductory treatment of the subject.

1. Data Analysis Research

As the data environment becomes more complex and the potential applications of the remote sensing technology become more demanding (in terms of the level of detail of the information desired), increasingly sophisticated data analysis techniques must be developed. During this year, researchers at LARS assisted NASA in the conceptualization, development, and evaluation of methods for classifying agricultural data without the aid of ground observations. Key aspects of this effort involved development of sampling schemes for estimating acreages over very large areas, and effective use of man-machine interaction for training multitemporal classifiers. These efforts contributed to the long-term evolution of crop classification methodology initiated more than a decade ago and bridging the transition from aircraft-gathered remote sensing data to the era of Landsat.

During this past year a major study of the interrelationship of the various parameters of scanner systems was completed. The study significantly advanced the understanding of the information-bearing attributes of various spectral, spatial, and signal-to-noise ratio characteristics. One specific outcome of the study was the creation of the first analytically based procedure for designing spectral band sets.

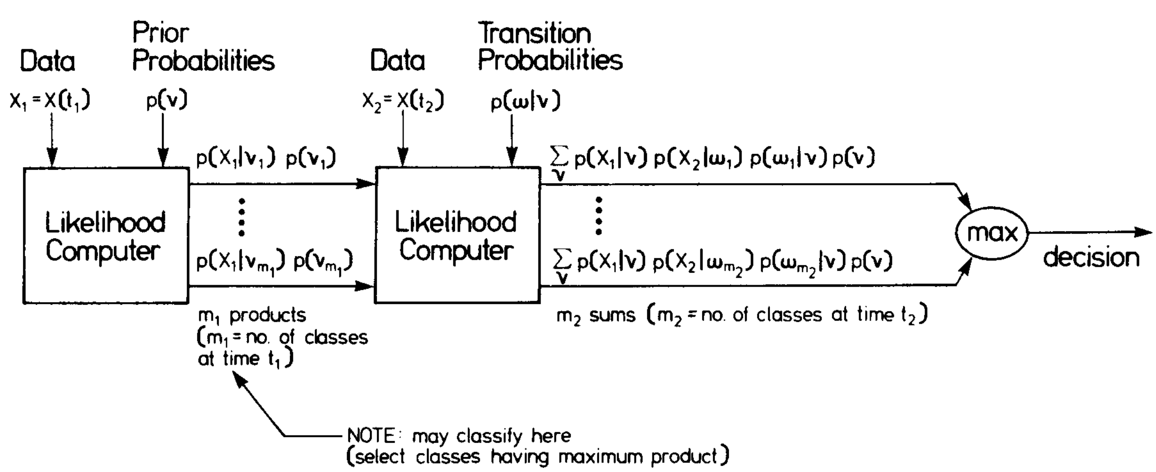


Figure 13. The cascade classifier, a versatile model for classifying multitemporal or multisource remote sensing data.

One of today's pressing needs is to exploit other kinds of information in remote sensing data beyond the spectral domain. Over the past several years, progress in this direction was made in the development of the "object classification" concept whereby entire objects--homogeneous regions--in the data may be classified more accurately and more efficiently than the individual pixels (picture elements). More general dependencies among neighboring pixels are now being scrutinized and shown to yield information useful for improving classification accuracy.

The challenge ahead is clear: making optimal use of still more diverse types of data in increasingly complex data bases (see below) to better meet the information needs of the earth resources monitoring and management community.

2. Data Handling

Over the past several years research has been conducted on methods of geometrically aligning multiple images of the same scene to enable multivariate analysis and analysis of temporal changes in the images. Research addressed the problem of automatically correlating image pairs to find the geometric misalignment between them. The problem of mathematically describing the geometric differences between images was also researched and the results have been incorporated into operational procedures at LARS for registering remote sensor imagery. The capability for registering remote sensor data is being widely applied to Landsat satellite imagery in support of applications research in all of the disciplines embraced by LARS.

In the past year work has continued on the concept of multi-image registration of map and tabular data of many types to support the analysis of remote sensor data. These other data types can be considered "ground truth" or reference data and include variables such as topographic elevation and slope, soil type, land use, zoning, political boundaries and others (Figure 14). Research has been conducted on methods of

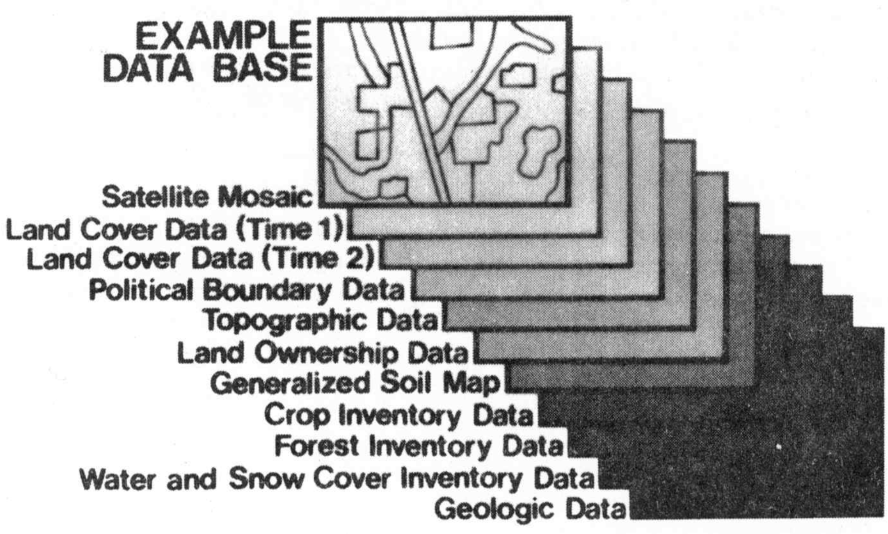


Figure 14. Registration of remote sensor data facilitates multivariant analysis.

converting maps to digital image form and several applications have been investigated. A research project funded by the National Science Foundation continues to explore the use of geophysical data as well as topographic map data and Landsat data to aid in exploration for minerals using remote sensing techniques. The problems of interfacing remote sensing data with a graphics oriented data base were studied for a forest industry application of remote sensing technology. This project is significant in that it is the first large scale industrial application of remote sensing technology which LARS has pioneered over the past 10 years.

C. EARTH SCIENCES RESEARCH PROGRAM

Staff members in the Earth Sciences Research Program with their graduate students have been able to expedite significantly the delineation and mapping of soil series through applying computer implemented pattern recognition techniques to Landsat data. This research, the results of which are proving extremely promising as a means of expediting not only soil surveys but land use surveys and other types of resource inventories, has been possible only through the efforts of an interdisciplinary team of data analysts and soil scientists from LARS and the Soil Conservation Service (SCS, USDA).

In addition to the successful application of remote sensing technology to soil inventories, the group has also been able to quantify many of the relationships among the chemical and/or physical properties of soils and soil spectral properties. Such studies are providing explanations of the good practical results being secured in the use of spectral properties to aid soil inventorying techniques.

1. Application of Remote Sensing to Inventorying Soils

The significant tangible results from these researches include:

a. Capability to delineate, with data from an airborne multispectral scanner (MSS) flown at 5000 ft. above the scene, soil colors with greater separability than is accomplished in the field visually by soil surveyors using Munsell color charts as standards.

b. Capability of using Landsat data to expedite the mapping of soils.

Working with a field crew of SCS soil surveyors making a soil map of Clinton County, Indiana, LARS data analysts (Figure 15) and soil scientists have developed ways to use satellite data to improve the speed, efficiency and accuracy of soil surveying.

In this study, research scientists and soil mapping crews of the SCS aided earth scientists at LARS in developing methods for improving soil survey techniques and of securing quantitative results which are so pronounced that they are attracting the attention of soil classification experts world wide.

An example of the potential benefits from combining remote sensing technology with classical soil survey techniques to produce expeditiously a better soil map is shown in Figure 16. This map of a portion of Clinton County, Indiana, which was developed by the LARS-SCS cooperative research program, is an excellent example of the close relationship which can be found between spectral properties of surface soils and soil series delin-

Figure 15. Newly developed remote sensing techniques have reduced the field time in making soil surveys.

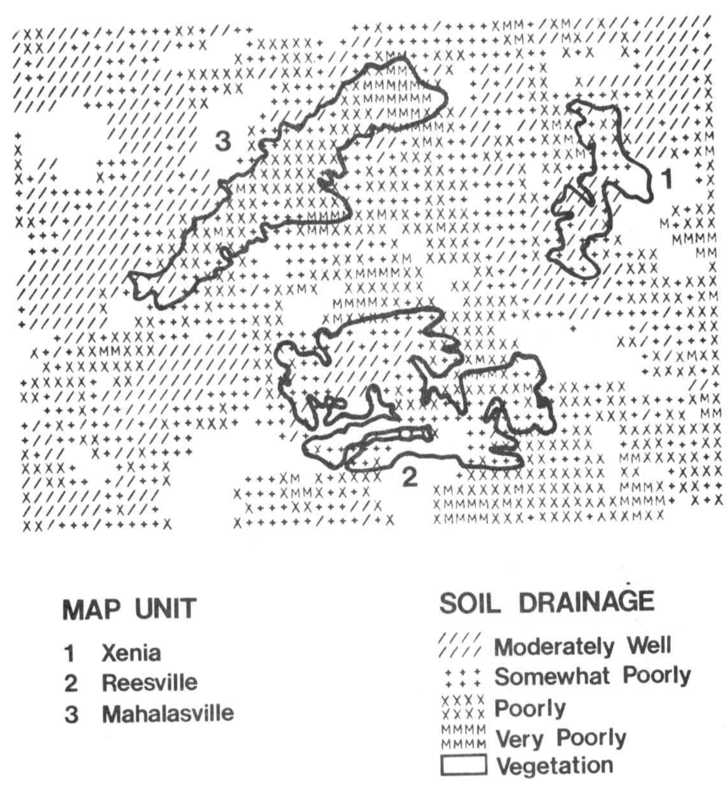


Figure 16. Map units delineated by soil surveyors in the field superimposed upon the spectral soil map show potential for increasing accuracy.

eated in the field by traditional methods. Each alpha-numeric symbol in Figure 16 represents an area of approximately one half hectare, a much smaller area than is economically feasible for a soil surveyor to separate and show in a map of corn belt land using traditional methods.

It was found, however, in mapping larger areas that generally more soil classes would be found in the mapping area than separable spectral classes for the scene. This redundancy could result in several soil series being assigned to the same spectral class. LARS and SCS personnel, in a cooperative study to apply remote sensing techniques to the mapping of soils in Chariton County, Missouri, were able to remove most of the confusion by stratifying the soils according to topography and then classifying them within each topographic unit.

The promising results in Clinton County, Indiana and Chariton County, Missouri, led to the SCS inviting LARS to cooperate in a prototype study in Jasper County, Indiana to appraise the feasibility of using spectral data as a base map for soil mapping. In this study the principle developed for Chariton County, Missouri of using ancillary data to stratify the scene was applied. The technique was improved, however, through the use of satellite data to determine the major areas of uniform Pleistocene parent materials, delineate these and assign spectral classes to each of these geologic areas(Figure 17). Through this method, most of the confusion among soil series was eliminated, resulting in a soil spectral map, closely approximating a soil series map.

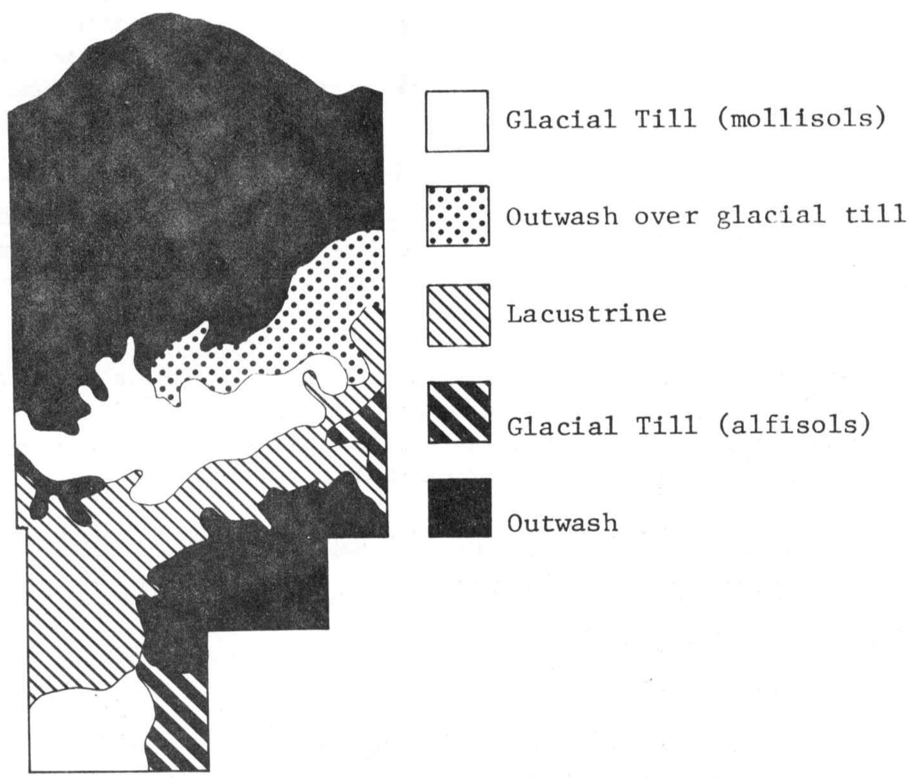


Figure 17. Pleistocene parent material areas delineated from Landsat data.

As a result of the progress at LARS in applying remote sensing techniques to the mapping of soils, the SCS in Illinois invited the Earth Sciences group to work with them in exploring and further developing methods for using MSS data to expedite the soil survey of Ford County, Illinois.

The research results to date of this group can be expected to revolutionize soil survey technology. First, the use of computer-implemented MSS data provides easily and rapidly attained quantitative estimates of the area of different soils. Not only is this true of soil series large enough in extent to be separated and delineated in standard soil survey maps at a scale of 1:15840, but of the smaller areas of different soils (called inclusions) which are too small to be separated out from a more extensive soil series. Where small areas of soils are too intermixed to be mapped separately, the area is called a complex and is named according to the predominating soil series. The percentages of land in the undelineated minor soil series are estimated and listed in the description of the predominating series. Results of the LARS-SCS research program show that the accuracy of these estimates can be increased from approximately 50 to 90 percent by using digitized satellite data.

Notably , the research centered at LARS has resulted in the potential for greatly increasing the speed and efficiency of soil survey techniques, especially for the national soil survey. This is possible because of the greater ease and accuracy in locating, identifying and estimating the extent of inclusions as mentioned above. Also, the use of remotely sensed data makes possible reducing the number of transects which must be made in an area to check the accuracy of soil separations and their boundaries.

As a result it is expected the mapping season can be extended into the early and late winter months and into the full canopy cropping seasons, times when it has been very difficult, in the corn belt, to get on the land to field check boundary locations.

Furthermore, because of the accuracy and consistency of the soil separations being achieved from satellite data, SCS supervisory personnel expect to be able to use the techniques developed at LARS as an aid to quality control in managing the national soils survey.

2. Analysis and Interpretation of Relationships Between Physical and Chemical Properties of Soils and Their Spectral Properties.

a. Soils Data Base Study

As a forerunner to capitalizing on the current capability to characterize soils by their spectral properties, a study in cooperation with the SCS to relate the spectral properties of representative soils of the United States to their physical and chemical properties, begun in FY77 was almost completed in FY79. While this study is aimed at the more basic relationships of these properties in order to facilitate better understanding of their relationships, the immediately useful results of the study for soil classification people are being optimized by the compilation and publication of an "Atlas of Soil Spectra." Graphic display of duplicate spectral curves have been completed for 242 "Benchmark" soil series.

b. Influence of Soil Chemical and Physical Properties of Soils on Their Spectral Properties.

In seeking to understand the relationships of spectral properties of soils to their other properties, correlation studies between soil spectral properties and their physical and chemical properties have been completed for almost all the samples (Figure 18). Ten spectral bands were used in the analysis. Correlations for 481 soils at four soil parameters are much higher when grouped in certain moisture zones or certain temperature regimes (Figure 19). Also, when soils were grouped into specific climatic zones, correlations were improved within most of the zones for the soil parameters of organic matter, natural log of organic matter, moisture content, and cation exchange capacity. Correlations were noticeably high for soil spectral bands vs. the four parameters except for the semiarid frigid soils and semiarid mesic soils.

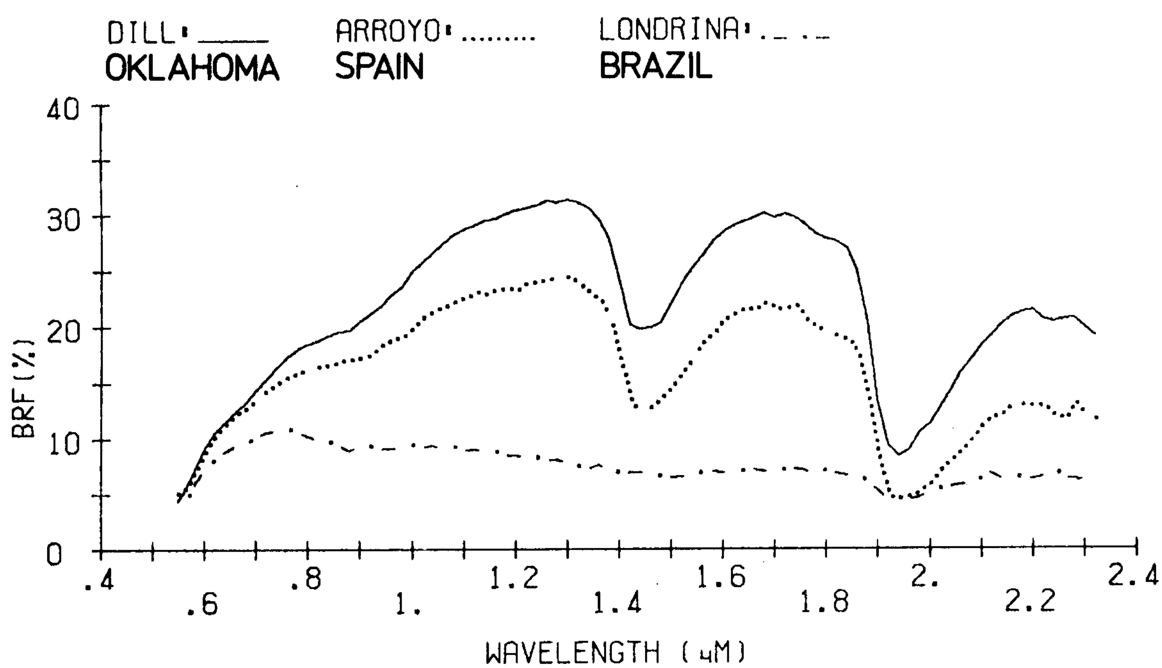


Figure 18. Three Dark Red Soils Described Visually as Having the Same Color Show Distinctly Different Reflectance Curves.

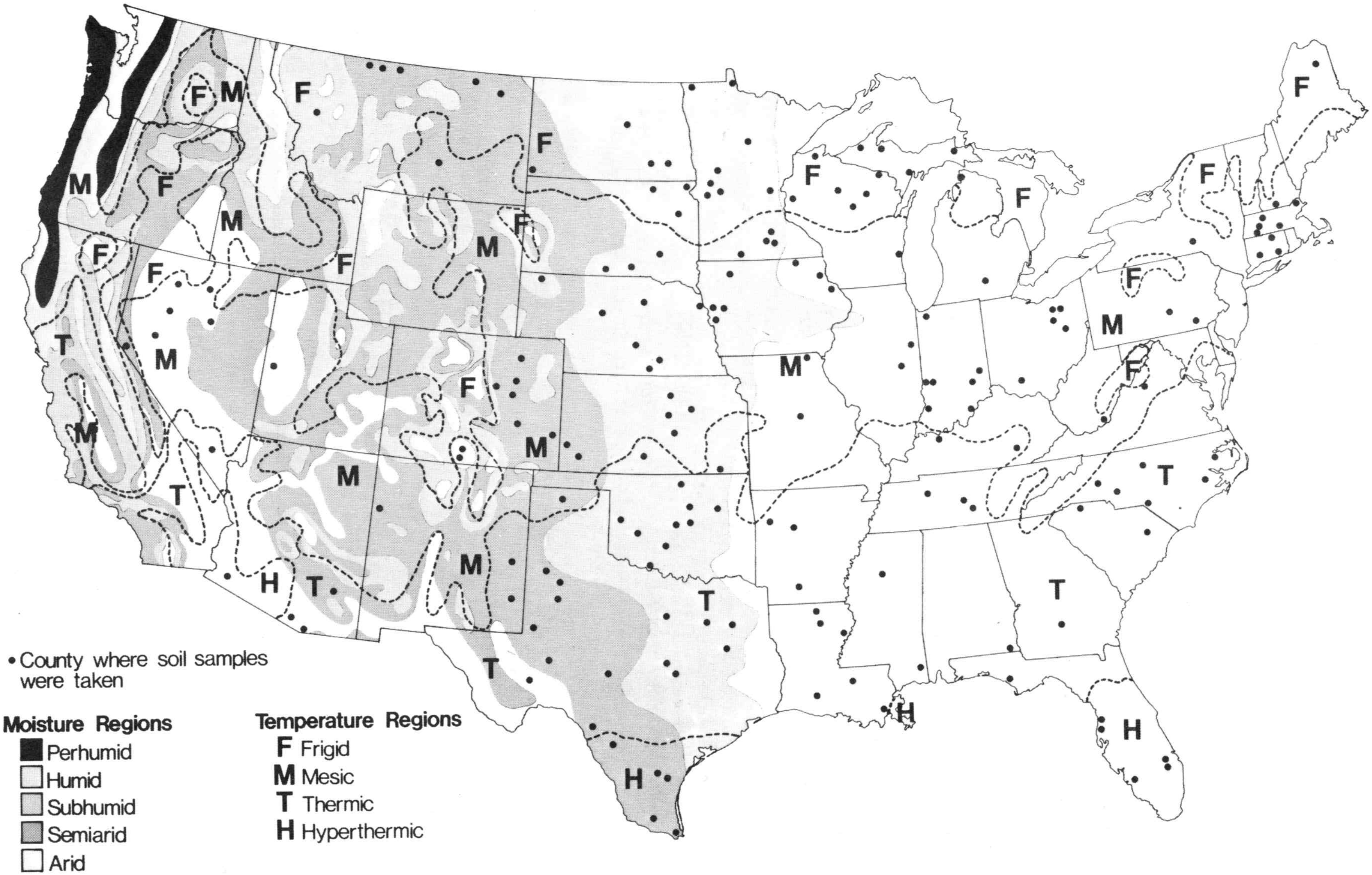


Figure 19. Location within climatic regions of 481 soil samples used in LARS study of soil spectral properties.

The loss of reflectance from the oven dry state to field capacity for 15 surface soils from Central Indiana, representative of the Mollisol and Alfisol great soil groups, is definitely related to the oven dry reflectances of the soils. A regression analysis of the relationship of the darkening effect of wetting on the reflectance of the soils when dry results in regression curves with R^2 values ranging from .9914 to .9291 over the five wavelength bands used, .52-.58μm, .71μm, .76-.90μm, .90-1.22μm and 1.50-1.73μm. The curve for the .52-.58μm band (Figure 20) is representative of those obtained at all five bands.

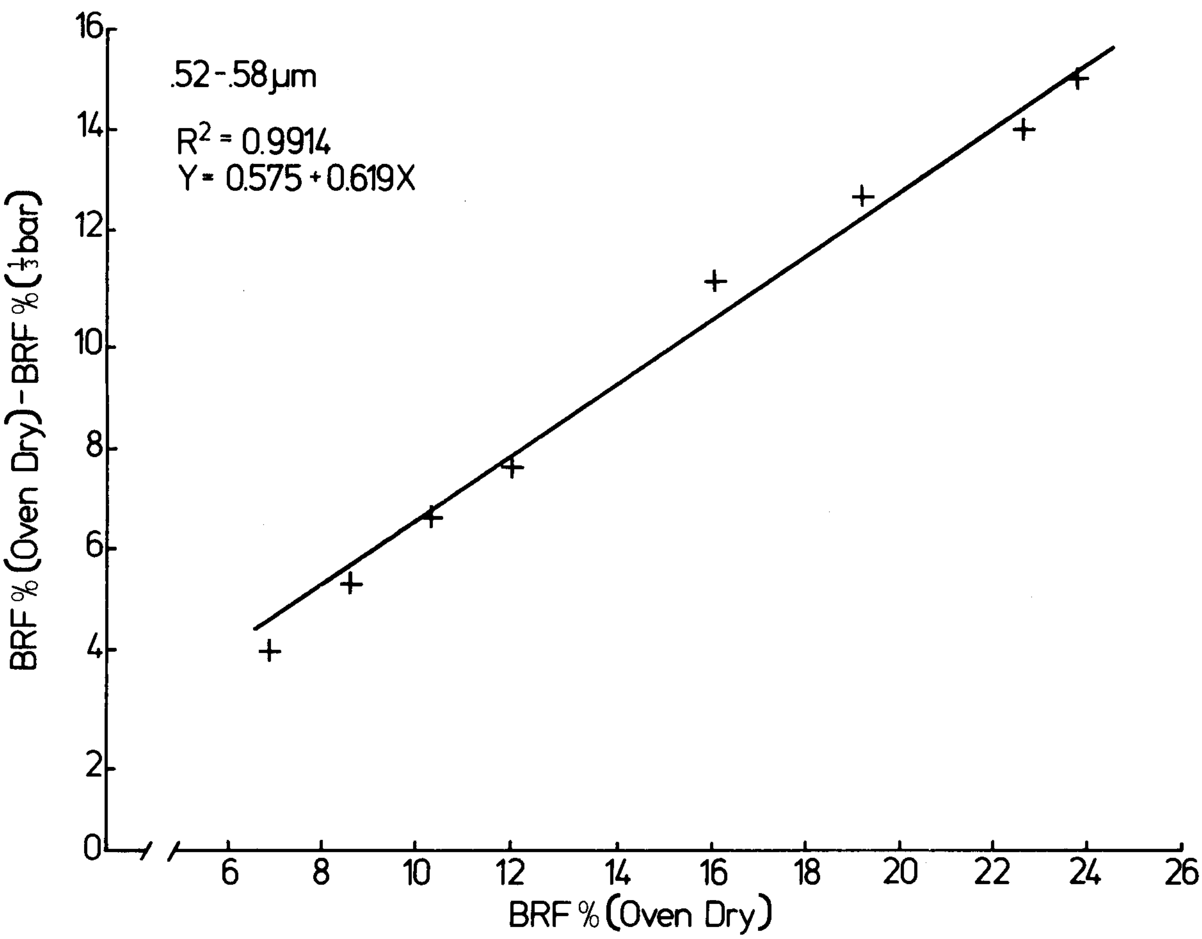


Figure 20. Relation of loss in reflectance on wetting to reflectance values at oven dry for 15 North Central Indiana Soils.

D. MEASUREMENTS RESEARCH

Measurements research at LARS has emphasized field data acquisition, field instrumentation development, basic research into the physical aspects of remote sensing, and spectral data handling and analysis procedural developments. Recent activities have stressed the evolution of a spectral data base of general usefulness to the remote sensing community for research necessary to support the technological development of the 1980's.

During FY79 the following activities were pursued in the Measurements Program area:

1. Field Data Acquisition and Preprocessing

During the past and current growing season the LARS field data acquisition system has been deployed at the Purdue University Agronomy Farm while conducting a series of integrated experiments on wheat, corn and soybeans. The experience of conducting experiments at the North Dakota State University Agricultural Research Station at Williston, North Dakota, led to the development of improved experimental techniques and data acquisition and data handling at the Purdue test site. Data from three instruments (two spectroradiometers mounted on mobile aerial towers and one mounted on a helicopter, Figure 21) are calibrated, correlated and verified and placed in a computerized data library that is available for retrieval and analysis by the remote sensing community.

Figure 21. Helicopter equipped with spectroradiometer hovers at calibration site panel.

The data library contains over 120,000 characterized spectra capable of being analyzed by a special software system (LARSPEC). Additionally, a data display system has been developed that permits the two-dimensional and three-dimensional examination of various components of the data that are stored in the data library. This software system will be directly applicable to the new data display facilities that will be acquired in the near future by LARS. The data library is designed to accept data in several different structures and header formats. To date, eight users other than LARS have accessed the data library and used the spectral data for various research purposes. The availability of the data library assumes increasing importance, due to the start up of the AgRISTARS Project in early 1980.

2. Instrument Development

The specifications for an eight-band multiband radiometer (Figure 22) and an associated data logger (Figure 23) have been developed. A request for proposal was produced and submitted to several potential vendors. A vendor has been selected and a prototype of the instrument produced for testing during the 1980 growing season. The intention is to produce a relatively low cost, commercially available multispectral instrumentation system for the remote sensing community. The anticipation is that up to 100 of these systems may be sold world wide by the commercial vendor. LARS is designing an operational manual and education package to be furnished to purchasers of the multiband radiometer system. In this manner remote sensing researchers around the world could acquire the spectral data following standard procedures that permit accurate comparison and correlation of their results. Additionally, these data could be conveniently deposited in the LARS spectral data library.

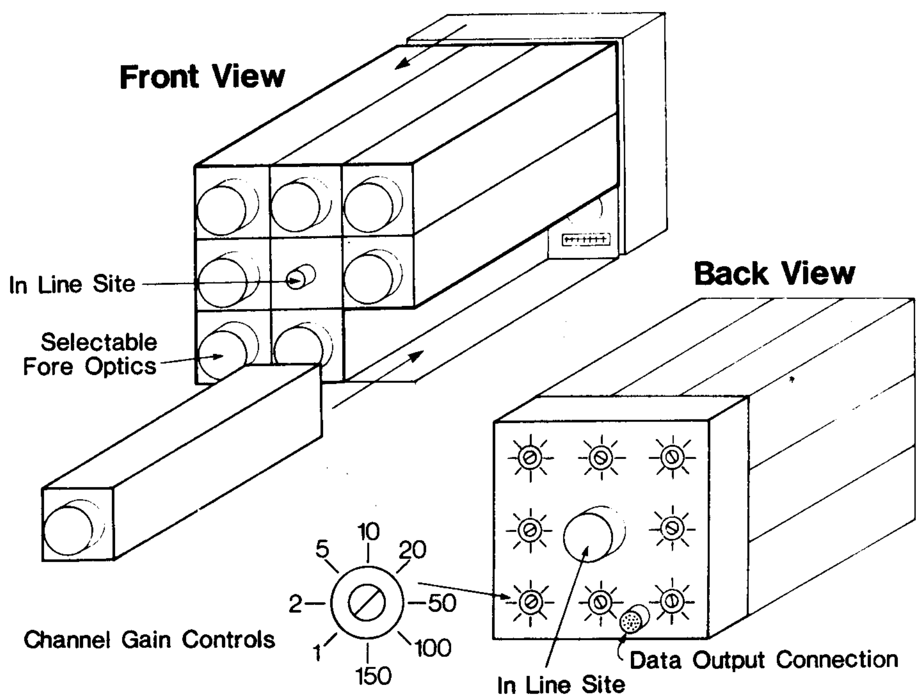


Figure 22. Conceptual view of radiometer

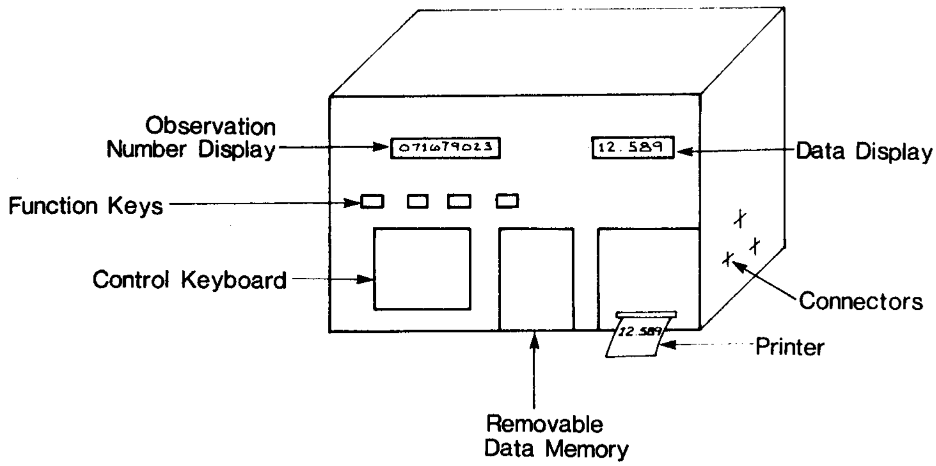


Figure 23. Conceptual view of data logger

A program to develop a spectrometer for measuring the reflectance of plant elements in a field environment was instituted. Preliminary tests of the instrument indicate that the bidirectional reflectance factor of plant leaves can be successfully measured in the field. The intention is to continue the development of this instrument so that the reflectance of several types of plant elements can be measured in-situ. These data are useful in plant canopy radiation interaction studies and are used in studies relating spectral reflectance to nutrient deficiency.

Previous work at LARS led to the development of an instrumentation concept for measuring available soil moisture profile. The method involves the generation of an electromagnetic wave at the surface of the soil by an antenna and the measurement of the reflected waves at the soil surface. The project has been revived and apparently will be funded during late 1979 and early 1980. After the first year of the project an instrument capable of measuring available (for plant growth) soil moisture profile without disturbing the soil surface would be available for field trials approximately one year after the onset of the project. The data produced by such an instrument would be especially useful for the laboratory's crop yield estimation activities.

3. Geometric Characterization of Vegetative Canopies

In order to understand the basic nature of the interaction of radiation with vegetative canopies the program concerning the study of plant geometry continues. One component of this study involves the measurement of the spectral reflectance of a canopy as a function of view angle and solar illumination angle. The other component utilizes a special laser probe technique, developed at LARS, to characterize the distribution of the biomass throughout the canopy. The measurement techniques are especially designed to easily furnish basic parametric information for vegetative models. Such basic studies are necessary to deepen the understanding of the relationship of plant canopy reflectance to the agronomic parameters of the canopy. The results should enable researchers to improve crop yield estimation accuracies from space borne multispectral remotely sensed data.

4. Basic Measurement Studies

A continuing part of the Measurements research activity involves basic studies of measurement technique and instrumentation procedure. For example, during the past fiscal year a theoretical study of the influence of skylight (as opposed to direct solar illumination) upon the accuracy of reflectance measurements was completed. This is part of a larger scope investigation of the sources of error that are always present in any field measurement activity. The objective of the activity is to establish error bounds on all of the reflectance measurements so that researchers who are analyzing the field data can apply proper statistical analysis procedures to the measurement results.

5. Biomedical Applications of Measurements Remote Sensing Technology

Previously, a remote sensing technique utilizing a digital-thermal scanner has been used to evaluate the performance of electrosurgical dispersive electrodes (Figure 24) in a project done in cooperation with the Biomedical Engineering Center at Purdue. During the past year this technique has been extended to the evaluation of the defibrilating electrodes. The data produced by the digital-thermal scanner is fully calibrated with reference blackbodies and after the data are processed temperature measurement accuracies of 0.2 °C are achieved. The results of the research have been used to design improved electrosurgical dispersive electrodes of both the conductive and capacitative type. The instrumentation system mentioned above is also used to check the results of theoretical models being used to study the passage of radio frequency current through human and animal tissue.

The digital-thermal system continues to be used to evaluate the effectiveness of hyperthermia (tissue heating using radio frequency energy) in cancer irradication experiments on animals. This work is being done in cooperation with the School of Pharmacy at Purdue. This activity is expected to lead to the development of an experimental procedure in the use of digital-thermal equipment in evaluating tissue temperature in hyperthermia therapy on human subjects in the radiation therapy clinic at the Indiana University Medical Center in Indianapolis.

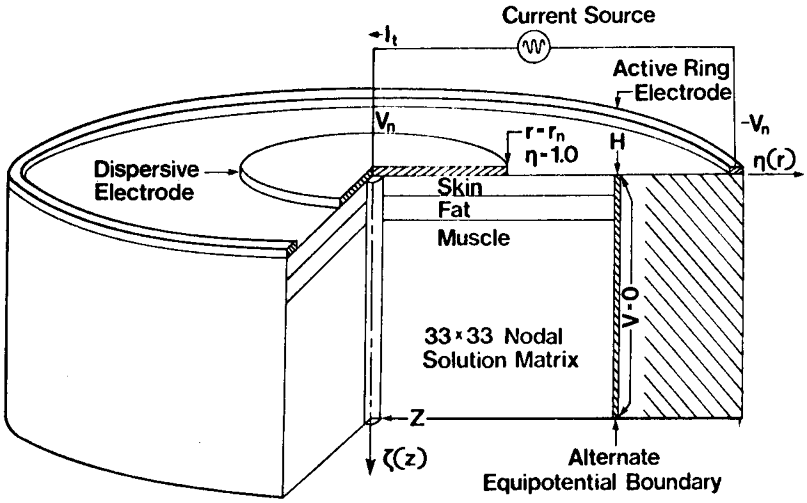


Figure 24. A schematic diagram of the theoretical model used to study the performance of electrosurgical dispersive electrodes.

E. ECOSYSTEMS RESEARCH

1. Methods of Combining Landsat Data with Topographic Data as an Aid to Mapping Forest Cover Types.

Research during this past year has concentrated on two areas of activity. The major research activity during the past year has involved the development and evaluation of different methods of combining Landsat reflectance measurements with the topographic characteristics of areas in mountainous terrain. Previous work had indicated that satellite reflectance measurements from coniferous forest canopies could be used to effectively identify and map the area of coniferous forest cover but could not be used in areas of mountainous terrain to differentiate between individual forest cover types (e.g., species groups). Ecologists know that differences in elevation, aspect, and slope will often influence the type and characteristics of the vegetation growing in any particular location in regions of mountainous terrain (Figure 25).

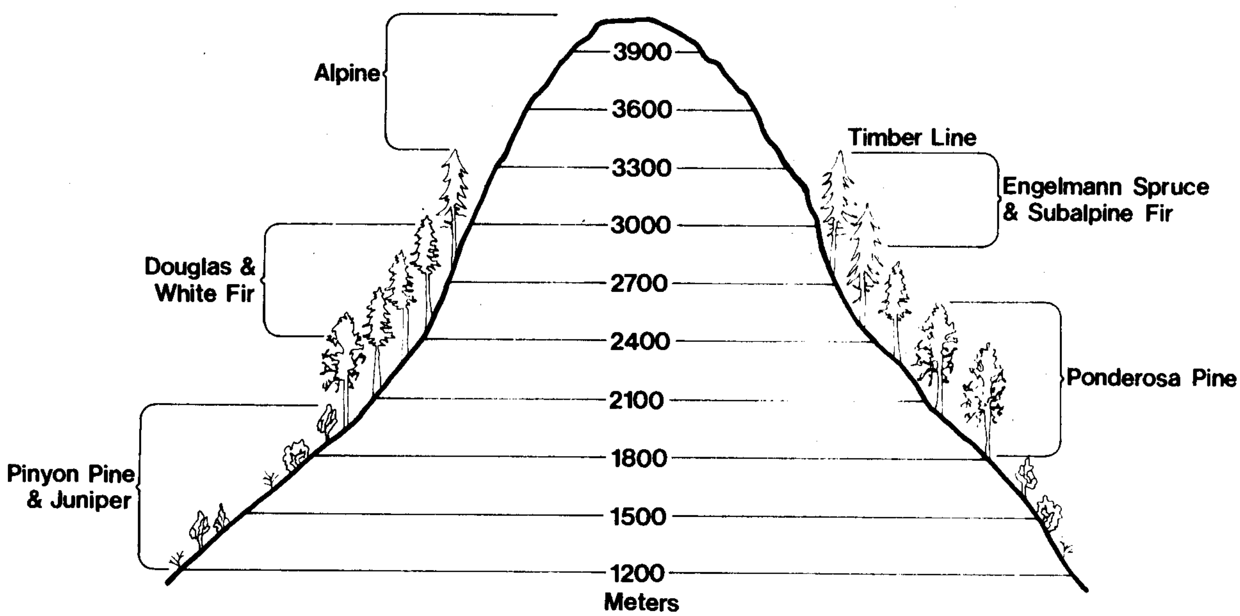


Figure 25. Relationship between elevation and distribution of forest cover types in the San Juan Mountains, Colorado.

The ability to combine topographic data with the satellite reflectance data therefore provides a potential for mapping of individual forest cover types over extensive areas of rugged terrain. A layered classification procedure which utilizes Landsat data in the first layer and topographic data in the second layer was found to be the most effective analysis technique (Figure 26). The final results of this work will enable more

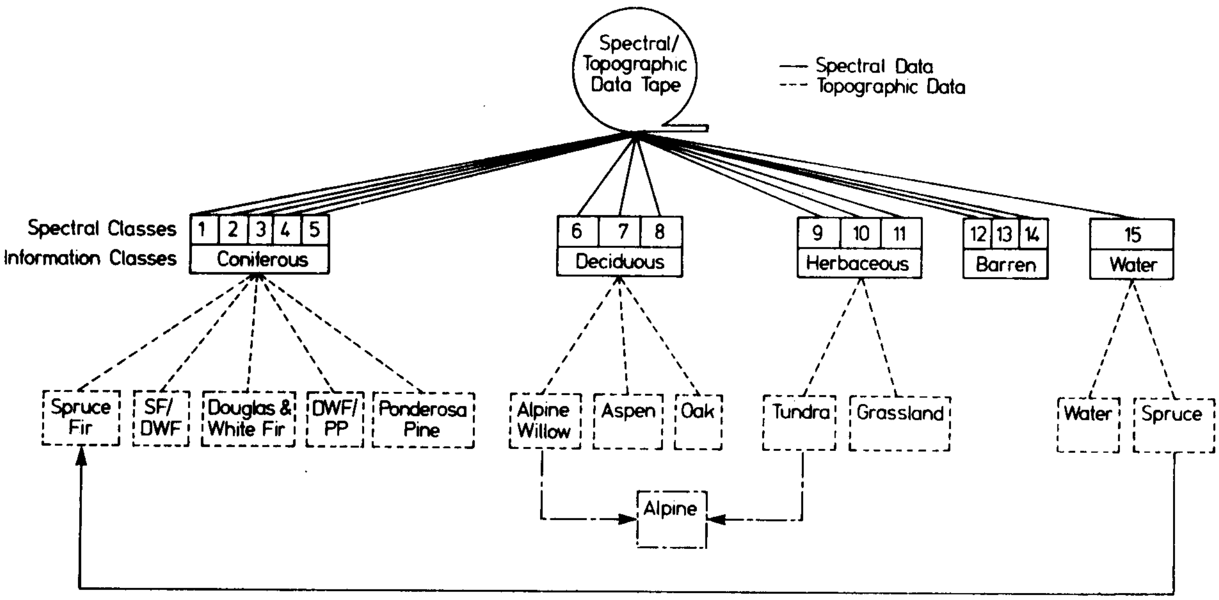


Figure 26. Schematic of the layered classification approach used to merge Landsat spectral data and digitized topographic data (i.e., elevation, slope, and aspect) in order to identify individual forest cover types.

cost-effective and more detailed maps and acreage tabulations to be obtained of individual forest cover types in areas of mountainous terrain. During the past year, one of the more significant results of this work was the development of a "topographic distribution model" which quantitatively characterizes the topographic range and frequency of occurrence for the various forest cover types present in the San Juan mountains of southwestern Colorado (Figures 27, 28, and 29). It is believed that this is the first time that such a quantitative characterization of the distribution of the various species has been obtained. The method developed for obtaining such a quantitative characterization of an area can be applied to any geographic location of interest.

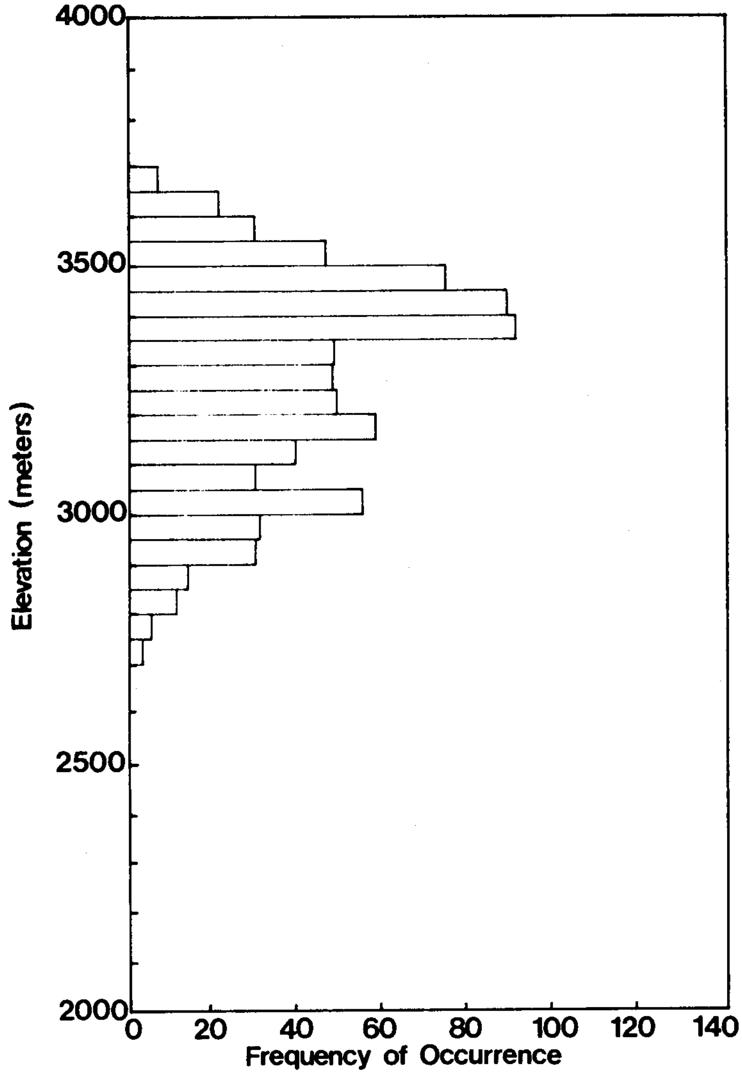


Figure 27. A histogram showing the distribution of Engelmann/spruce/subalpine fir as a function of elevation, obtained from a topographically stratified random sample of picture elements.

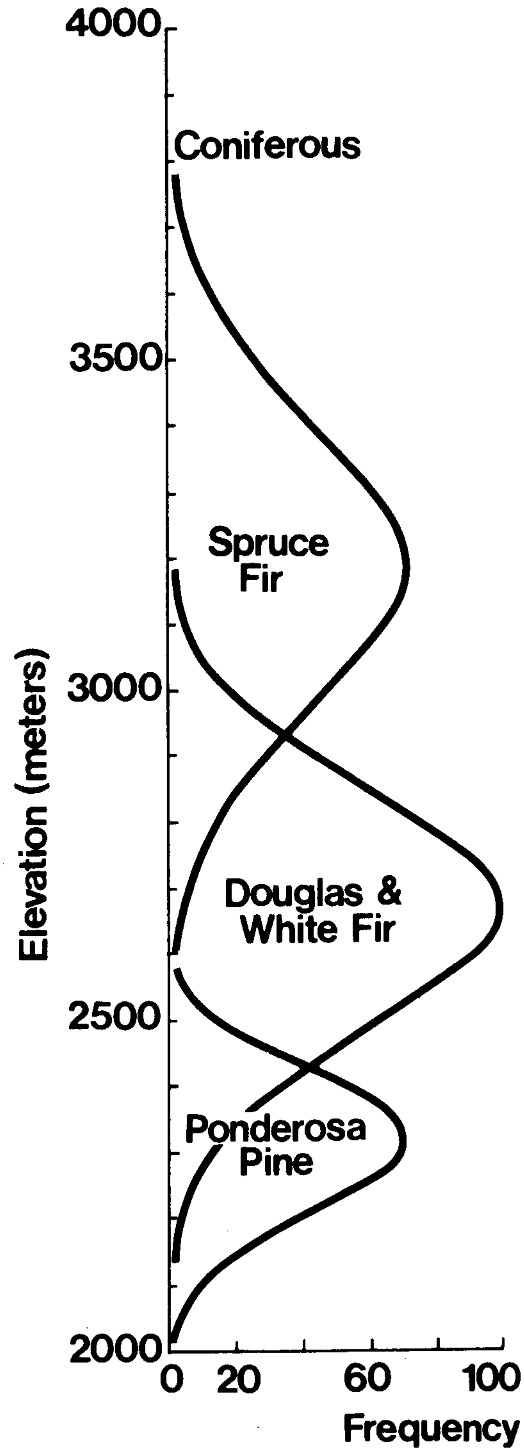


Figure 28. Gaussian estimated curves for frequency of the three major coniferous cover types as a function of elevation.

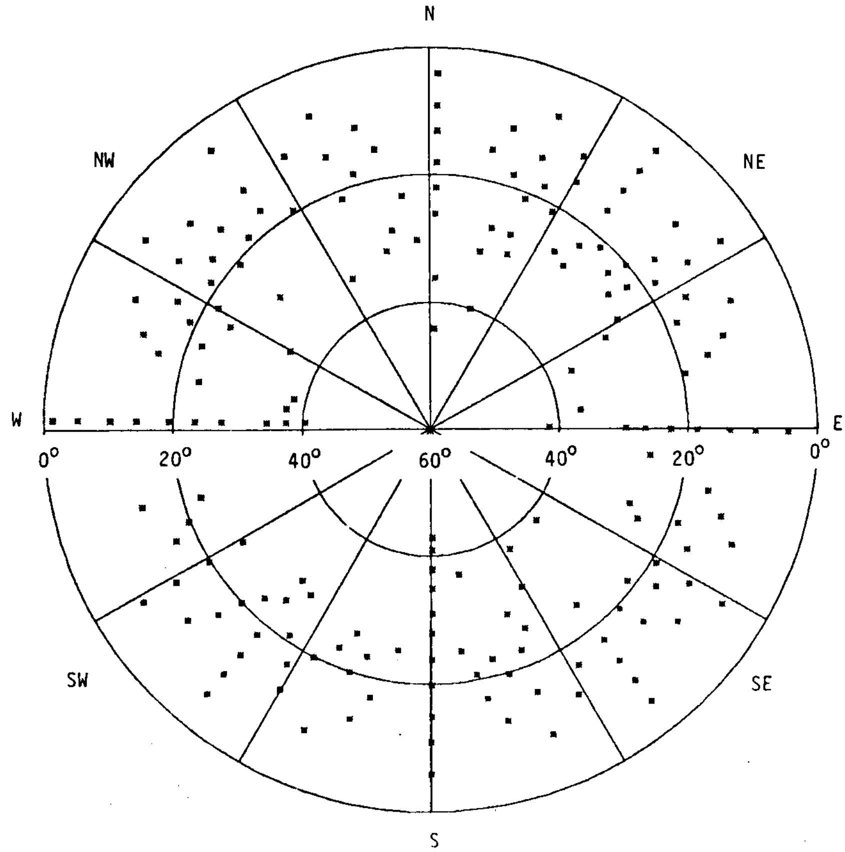


Figure 29. Sample polar plot displaying the distribution of the Engelmann spruce/subalpine fir forest cover type as a function of slope and aspect

2. Procedure to Use Satellite Data to Locate Sample Sites in Statistical Approach to Forest Inventorying.

The second area of activity involved the development of a procedure to couple computer processing of satellite data for mapping forest resources with the existing methods used by the U. S. Forest Service in their Forest Survey Program. U. S. Forest Service periodically conducts an inventory of all forest land areas on a state-by-state basis. In this process they do photointerpretation on a statistically defined sample of data points. Computer programs have been developed this year to locate these same sample points in the satellite data to an accuracy of better than 100 meters, and also to compare Landsat reflectance values on two data sets. These programs will provide an opportunity to use the satellite data to update forest survey inventories on a more frequent basis than the 14-18 years frequently encountered at present.

Together, these research activities have made significant progress in defining ways in which the Landsat satellite data can be utilized to obtain more detailed information on the forest resources of the nation by updating existing information and defining procedures for more accurately mapping forest cover types over extensive and remote areas where existing information is often minimal.

3. Feasibility of Using Remote Sensing to Secure Information Essential to Forest Management.

In October 1977 the National Aeronautics and Space Administration and the St. Regis Paper Company agreed to cooperate in the development of a Forest Resource Information System (FRIS). Ultimately, FRIS will result in the mating of remote sensing and data base technologies to form a comprehensive, interactive system that will help St. Regis foresters manage their forest resources.

LARS was contracted by NASA to provide St. Regis with a demonstration of the feasibility of remote sensing technology and its applicability to provide information useful to forest management. The demonstration phase of the project was successfully completed in March 1979. A system transfer phase involving user education and the transfer of LARS remote sensing software packages to St. Regis was initiated in April. The completion of the project in late 1980 will mark the first time remote sensing technology has been transferred to a non-government user for use in his day-to-day operations.

The significance of this project to date has been in the commitment of the St. Regis Paper Company staff to remote sensing technology. Implicit in this commitment is the understanding that Landsat remote sensing can provide useful information for the management of industrial forests in the southeast.

4. Development of Techniques to Improve Feasibility of Use of Remote Sensing to Inventory Natural Resources of Indiana

The Ecosystems Research program area is involved in two projects with the Indiana Department of Natural Resources, Division of Fish and Wildlife. Both projects are supported by monies from a NASA Office of University Affairs Grant (PY). The general goal of each project is to apply remote sensing techniques to provide information that is necessary for the management of Indiana's natural resources. The two projects undertaken are a wetlands inventory and a survey of habitats for upland game birds.

5. Wetlands Inventory

This project is directed at testing the feasibility of using computer-aided Landsat classification techniques to map wetlands in Indiana. The Pigeon River State Fish and Wildlife area is being used as a demonstration site to evaluate the utility of satellite data for inventorying wetland habitat. Results of a first level classification (wetland/non-wetland) indicate a 70% correspondence between the Landsat classification and aerial photography. This is significant because the State of Indiana does not have an accurate state-wide inventory of wetlands. Landsat and computer-aided analysis techniques can provide the opportunity to provide a comprehensive inventory of this important land use class.

6. UPLAND GAME BIRD HABITAT SURVEY

Changes in federal regulations regarding agricultural set-aside acres, and the serious winters of the late 70's have adversely affected the pheasant population in Benton County, Indiana. In order to counteract a decline in bird population, the State Division of Fish and Wildlife is initiating a habitat leasing program. The State will lease land for the purpose of developing appropriate habitat in order to encourage an increase in bird population.

The preliminary phase of this program involved identifying potentially suitable lands for lease. LARS staff in cooperation with personnel from the Division of Fish and Wildlife are using black and white aerial photographs to identify these potential leasing sites. Standard photo-interpretation techniques are being used in this remote sensing application to identify optimum winter range. The significance of this study relates to the fact that State personnel are being made aware of the suitability of using existing data in the form of aerial photographs and well-tested techniques to get answers to specific management problems.

CONTRIBUTIONS OF LARS TO PROFESSIONAL AND ACADEMIC EDUCATIONAL PROGRAMS

I. Technology Transfer Programs

In response to growing awareness of and demand for up-to-date information in remote sensing, the LARS Technology Transfer program area was established in 1974. The primary aims of this program area are to provide training for a range of audiences and to develop teaching materials that contribute to the effective transfer of remote sensing technology. The program continued to attract representatives from various affiliations (Figure 30). The major Technology Transfer activities during Fiscal Year 1979 were:

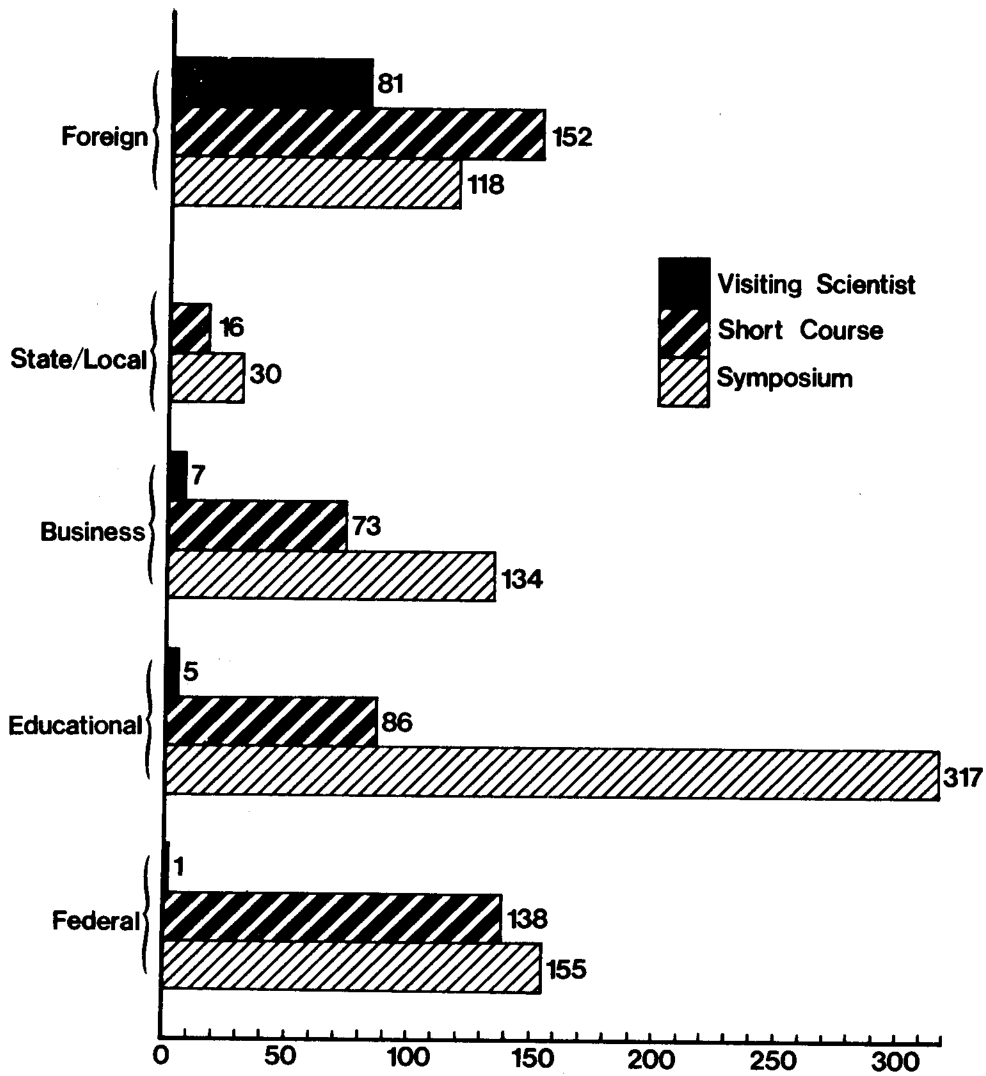


Figure 30. Background of personnel participating through June 1979 in technology transfer programs offered by LARS

A. SHORT COURSES

Short Courses offered during FY 79 included "Numerical Analysis of Remote Sensing Data" and "Advanced Topics in the Analysis of Remote Sensing Data." The former, an updated version of a course first taught in 1972, was offered monthly in FY 1979 with a total of 70 paid attendees, 39 of whom also participated in the "Hands-On" computer exercise option. These 70 included 27 from foreign countries, bringing the total foreign participation to 150, as shown in Figure 31.

As in previous years, the participants were a heterogenous group coming from federal government agencies (21%), state and local agencies (2%), foreign (43%), business and industry (4%), Purdue and other universities (30%).

The five-day "Advanced Topics in the Analysis of Remote Sensing Data" short course has been offered once a year for the past three years with a continously increasing number of attendees: 10 in 1977, 29 in 1978, and 32 in 1979. Both of these short courses are financially self-supporting.

B. VISITING SCIENTIST PROGRAM

The Visiting Scientist Program has been developed to meet the specialized needs of scientists who wish to become intimately acquainted with the remote sensing technology developed at Purdue. It provides an opportunity for personalized, individual study and research at the Laboratory during a period of residence established on a case-by-case basis.

The trainee or the sponsoring agency is expected to pay the cost of the training program. The cost is variable, depending on the duration of the training period and the amount of computer time used. The trainee or sponsoring agency must also provide travel and subsistence expenses.

Since 1972 there has been a total of 94 visiting scientists involved in applying remote sensing technology to problems in the 26 different countries which they represented. During FY 79 there were 16 visiting scientists from 7 different foreign countries bringing the total foreign visiting scientist participation to 81, as shown in Figure 32.

C. SYMPOSIUM

During FY 79 LARS in cooperation with Purdue's Division of Conferences sponsored the Fifth Symposium on "Machine Processing of Remotely Sensed Data." It was attended by approximately 200 participants, 39 of whom came from 8 different countries, bringing the total foreign symposium participation to 118, as shown in Figure 33.

Figure 31. Foreign short course attendees from 1972 through June 1979 (150 total)

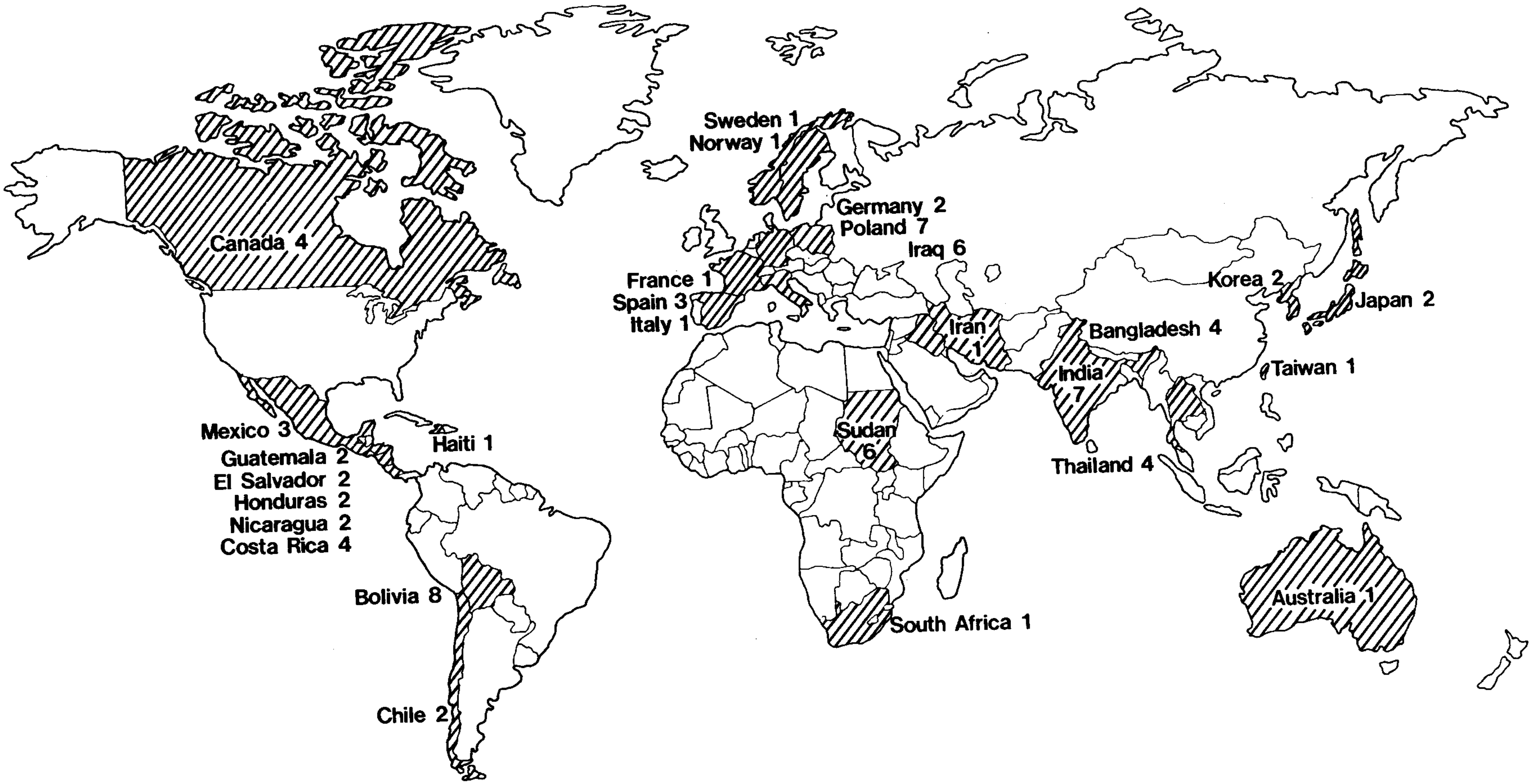


Figure 32. Foreign visiting scientists from 1973 through June 1979 (81 total)

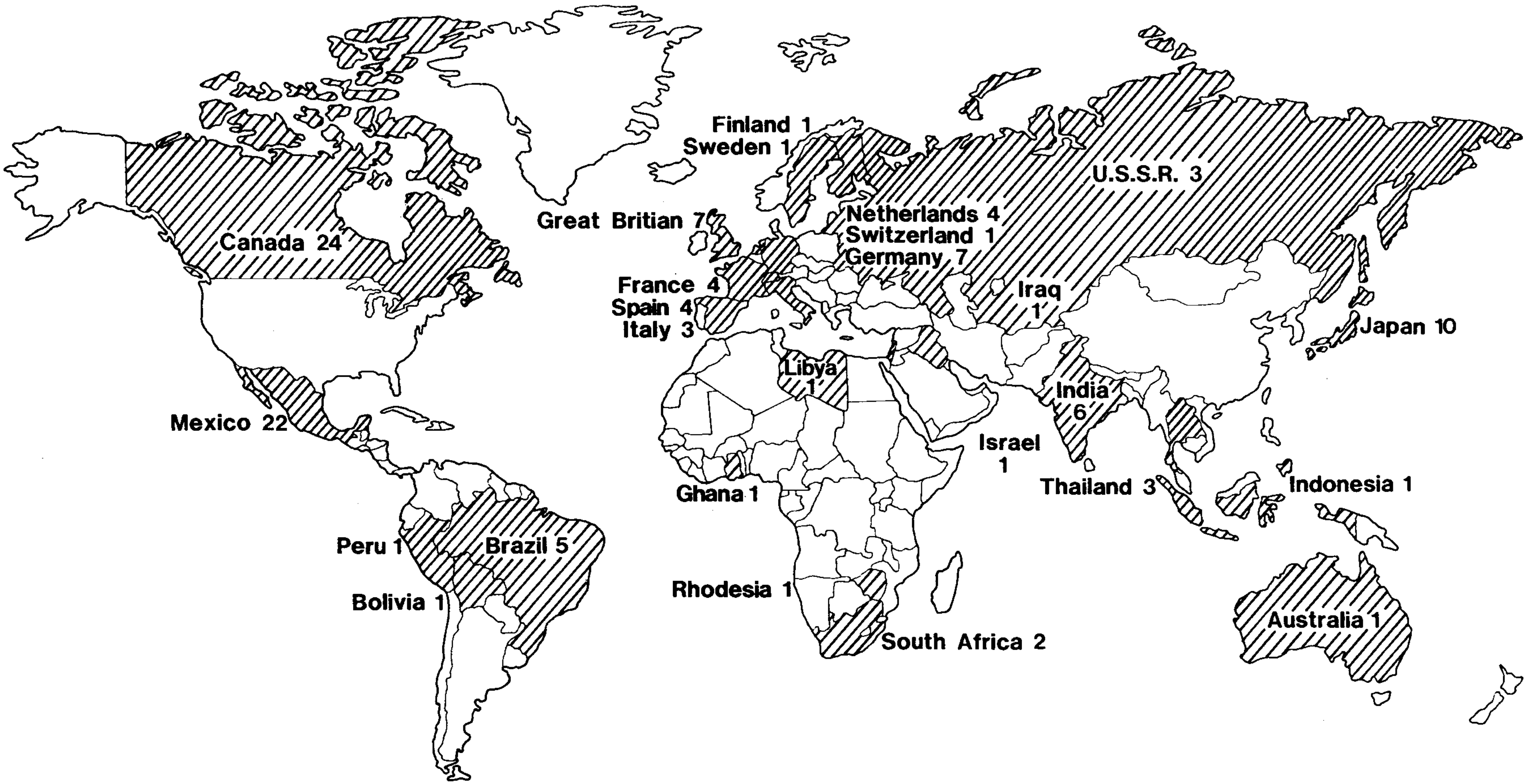


Figure 33. Foreign symposium attendees from 1973 through 1979 (118 total)

D. REMOTE TERMINAL NETWORK

In 1970 NASA approved and funded at LARS the development of a computer terminal network dedicated to the analysis of remote sensing data. The aim of this network is primarily educational:

- to provide a training and research facility to remote sensing scientists and users, and

- to facilitate the communication of new remote sensing technology among researchers and users.

During FY 1979, there were 42 line communication ports for access to the LARS computer. The locations where ports are located are shown in Figure 34. The hardware configuration supporting Purdue/LARS IBM 370/148 and the remote terminal locations is shown on the next page. (Figures 35 and 36).

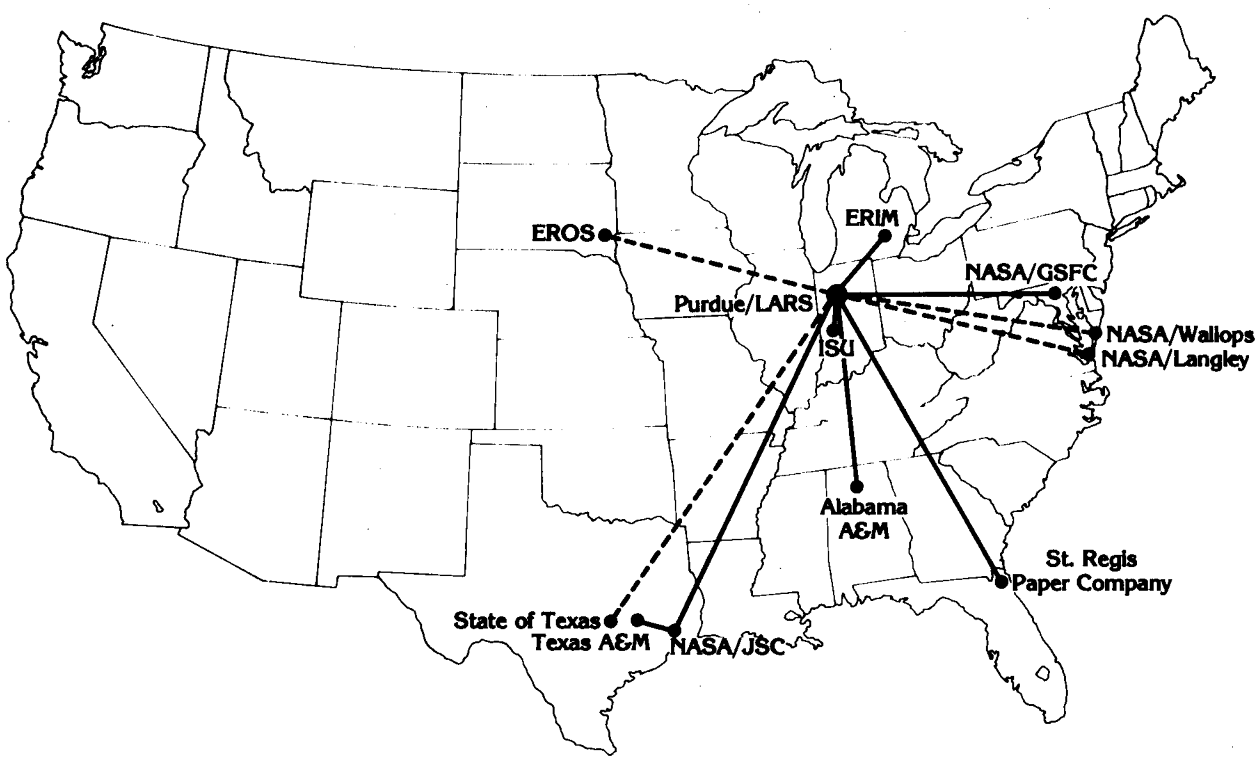


Figure 34. LARS computer terminal network showing both current ——— and previous - - - - - terminals.

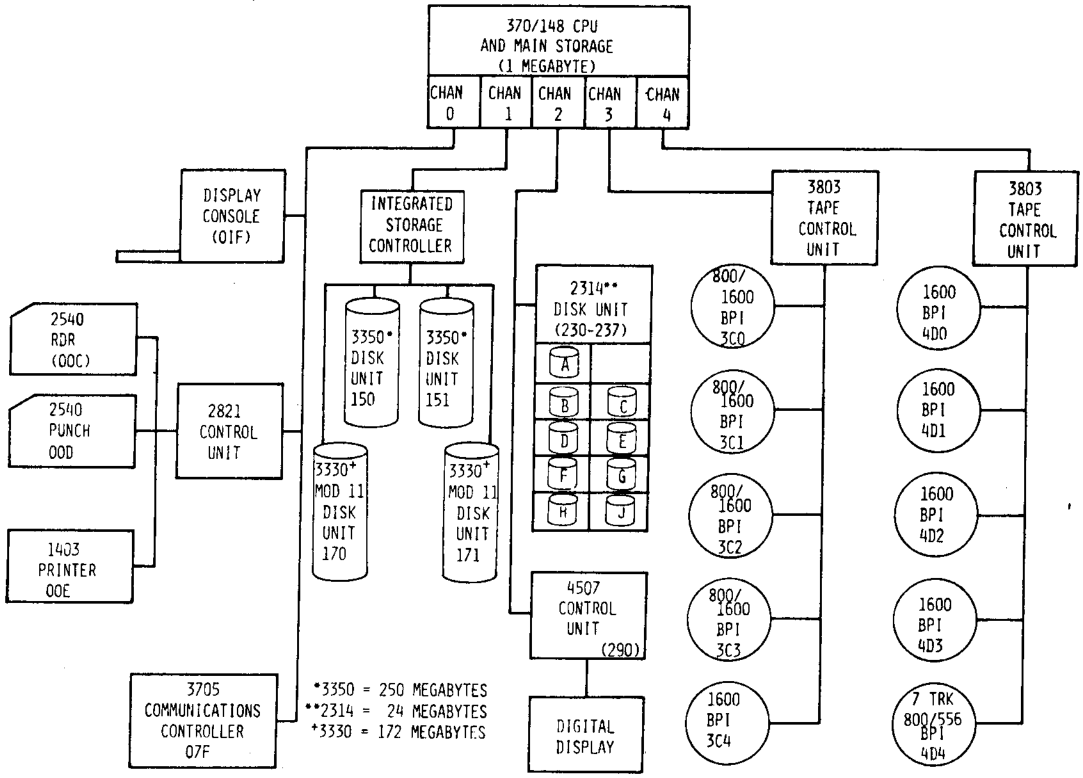


Figure 35. Central processor and peripheral devices.

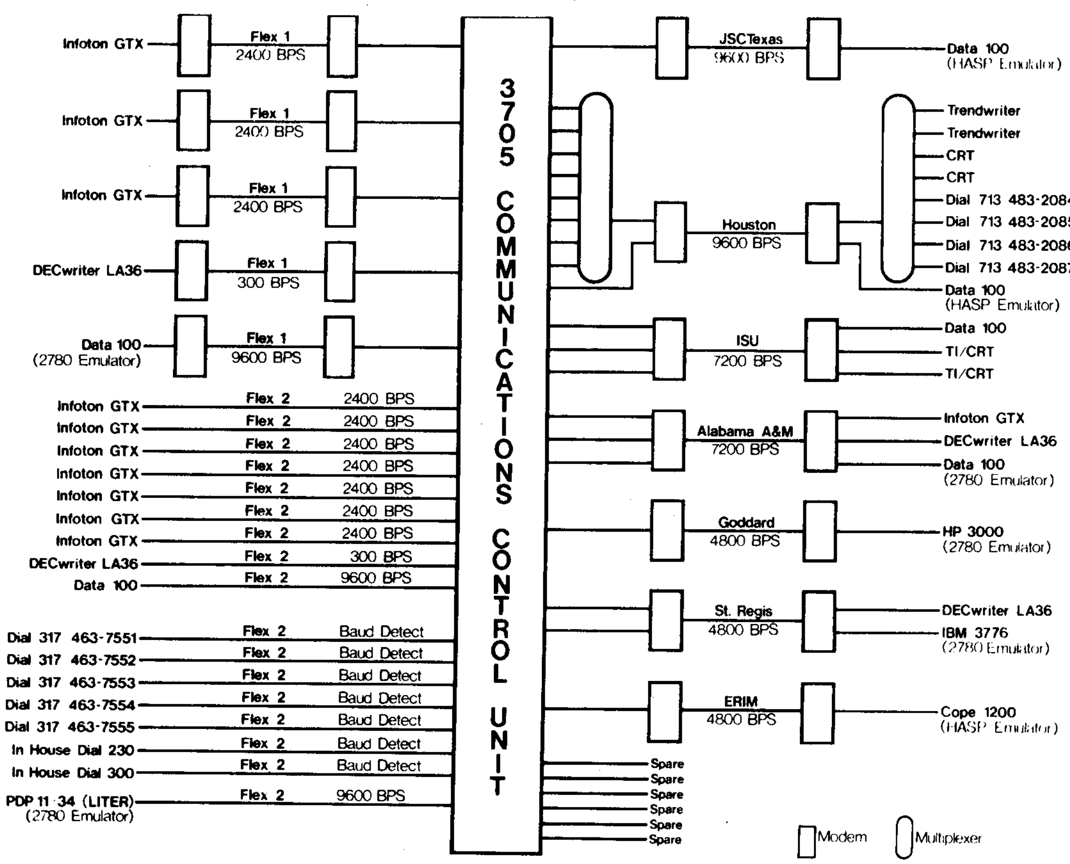


Figure 36. Communications equipment.

E. EDUCATION MATERIALS ON REMOTE SENSING

1. Focus Series

Each Focus issue is a printed two-page foldout presenting a single concept basic to remote sensing through graphics and 300-400 words of text. The series is especially useful for general briefings or introductory treatments of remote sensing topics.

2. The Minicourse Series: "Fundamentals of Remote Sensing"

The minicourses have been developed and funded by Purdue's Division of Conferences and Continuing Education Administration. The original 19 minicourse units have been available for purchase either individually or in full-sets since July 1976. The two accompanying figures indicate the rate of sales over this three-year period (Figure 37) and the percentage of purchases by domestic and foreign organizational types (Figure 38).

In Figure 37, for example, by July 1, 1979 there were 2,457 individual minicourses purchased, equivalent to a total of 129 full-set sales. This is a remarkably consistent sales flow without a single decline in purchases. In fact, there was a sales increase during the recent six-month period.

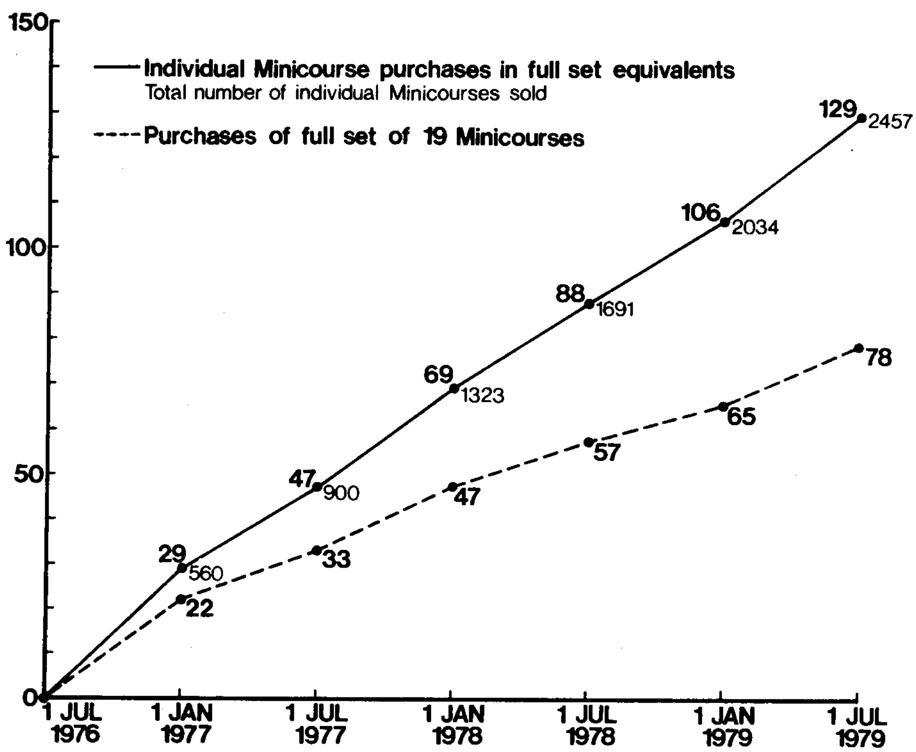


Figure 37. Cumulative Purchases (in six-month intervals) of the Fundamentals of Remote Sensing Minicourse Series, July 1976 to July 1979

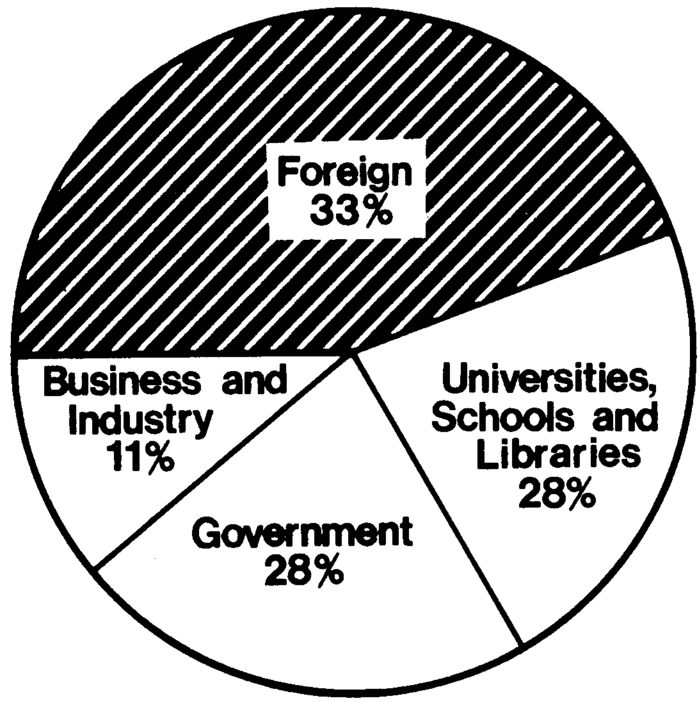


Figure 38. Domestic and foreign acquisition of the Fundamentals of Remote Sensing Minicourse Series, July 1976 to July 1979

Figure 38 divides the minicourse purchases into domestic and foreign customers. The domestic category is further sub-divided to show the wide range of audiences reached by the minicourse series. Governmental agencies usually purchase full-sets, while universities tend to purchase several individual minicourses at one time and often become repeat-customers, adding onto their minicourse collections one or more times.

A minicourse represents 1-1½ hours of student learning time. Each minicourse includes 20-51 color 35 mm slides, an audiotape and a printed study guide. Some of the minicourse units contain special equipment for the student's use and learning experience. Persons with a background in elementary biology, physics and mathematics can understand and work with the basic concepts presented.

During FY 79, four additional minicourses have been under preparation and are scheduled for distribution in Autumn, 1979. They are:

- "Interpretation of Thermal Imagery" by L.F. Silva and J.D. Russell
- "Mineral Exploration Using Satellite Data" by D.K. Scholz and S.M. Davis
- "Principles of Photointerpretation" by R.M. Hoffer and S.M. Davis
- "Spectral Measurements for Field Research" by L.L. Biehl, L.F. Silva and J.D. Russell

3. The LARSYS Educational Package

The LARSYS Educational Package is a set of instructional materials developed to train people to analyze remotely sensed multispectral data using LARSYS, a computer software system developed at Purdue/LARS. A variety of media is used depending on the nature of the subject matter and objectives of each unit. Reinforcement of certain basic concepts, such as the multispectral concept and the multidimensional statistical approach, is interwoven throughout the package. There are ten units in the series.

4. Simulation Exercises

Simulation exercises are designed to lead the student through the professional thought and decision-making processes typical of those required by remote sensing analyst/researchers. The simulations, requiring 3 to 4 hours to complete, illustrate and explain the rationale and decision processes of remote sensing analysis. There are two simulation exercises available.

5. Videotape Series

The videotapes in this series "capture" a subject matter specialist's discussion of a remote sensing topic. The tapes are often refinements of a seminar or series of lectures given by the authors. Each tape runs about 30 minutes. Student viewing notes have been compiled for most of the videotapes.

A current development videotape project is funded from February 1979 through January 1980 by Purdue University's Continuing Education Administration ($31,000). The purpose of the project is to produce five half-hour videotapes that address moderately advanced topics central to remote sensing technology as it has evolved at LARS. The primary use of the tapes will be for regular classes on the Purdue campus, and secondarily for use in Continuing Education Administration-sponsored short courses on remote sensing. These videotapes will also be sold to outside organizations through Purdue's Continuing Education Administration on a cost-recovery basis. Printed support materials for the videotapes will be provided through viewing notes prepared for each program and by a textbook, <u>Remote Sensing: The Quantitative Approach</u>, edited by P.H. Swain and S.M. Davis (McGraw-Hill. 1978).

The tentative titles and technical content consultants for the videotapes are:

- Introduction to Quantitative Analysis (David Landgrebe)
- Correction and Enhancement of Digital Image Data (Paul Anuta)
- Pattern Recognition and Its Role in Remote Sensing (Philip Swain)

- The Role of Numerical Analysis in Forest Management (Roger Hoffer)

- Multispectral Properties of Soils (Marion Baumgardner)

6. Color Booklet and Slide Set

A color booklet and a slide-tape presentation based on the booklet "Remote Sensing of Agriculture, Earth Resources and Man's Environment" are available for use with a general audience. The presentation reveals the role remote sensing has played and will play in monitoring and analyzing earth's resources.

7. Textbook

A textbook, Remote Sensing: The Quantitative Approach, was published by McGraw-Hill International Book Company in late 1978. Authored and edited by staff members of LARS, the book deals with both the theoretical bases and practical aspects of the numerical approach to remote sensing developed at LARS. Prior to the publication of this book, no unified, tutorial treatment of the subject had been available. The book edited by P.H. Swain and S.M. Davis, was authored by S.M. Davis, R.M. Hoffer, D.A. Landgrebe, J.C. Lindenlaub, T.L. Phillips, L.F. Silva, and P.H. Swain.

II. University Courses

FORMAL UNIVERSITY COURSES DEALING WITH PHASES OF REMOTE SENSING

A. Courses with definite emphasis on remote sensing:

Agronomy

545 Surveying Agronomic Resources
cr. 3 Prof. Baumgardner

Electrical Engineering

577 Engineering Aspects of Remote Sensing
cr. 3 Prof. Swain

Forestry

291 Introduction to Remote Sensing
cr. 1 Prof. Hoffer

558 Remote Sensing of Natural Resources
cr. 3 Prof. Hoffer

579 Remote Sensing Seminar
cr. 0 or 1 Prof. Hoffer and Staff

Geosciences

518 Aerology and Remote Sensing:
cr. 3 Prof. Levandowski

B. Courses related to remote sensing:

Agronomy

565 Soil Classification and Survey
cr. 2 Prof. Bryant

585 Soils and Land Use
cr. 2 Prof. Yahner

655 Soil Genesis and Classification
cr. 3 Prof. Franzmeir

Civil Engineering

503 Photogrammetry
cr. 3 Prof. Mikhail

567 Airphoto Interpretation
cr. 3 Prof. Miles

603 Advanced Photogrammetry
cr. 3 Prof. Mikhail

Electrical Engineering

661 Image Processing
cr. 3 Prof. Kak

662 Introduction to Artificial Intelligence and Pattern Recognition
cr. 3 Prof. Fukunaga

Forestry

557 Aerial Photo Interpretation
cr. 3 Prof. Miller

III. Graduate Training with LARS Staff and Facilities

A. DEGREE CANDIDATES FUNDED BY LARS CONTRACTS FY 79

- Azimi, M., M.S., E.E., D. A. Landgrebe, thesis title not yet assigned.
- Caruso, P., Ph.D., M.E., Prof. S. DeWitt, thesis title not yet assigned.
- Crabill, E., M.S., E.E., P. H. Swain, non-thesis option.
- Dickman, K., M.S., C.S., D. Freeman, non-thesis option.
- Ernst, C. L., Ph.D., Forestry, R. Hoffer, "Extraction of Information from Remotely Sensed Data Useful for Wetland Habitat Evaluation."
- Fleming, M.D., Ph.D., Forestry, R. Hoffer, "Computer-Aided Analysis Techniques for Processing Landsat MSS Data and DMA Topographic Data to Map Forest Cover Types."
- Grogan, T., M.S., E.E., P. E. Anuta, non-thesis option.
- Hinzman, L., M.S., Agronomy, C. S. T. Daughtry, thesis title not yet assigned.
- Huang, K. Y., E.E., P. E. Anuta, thesis title not yet assigned.
- Hynes, N., M.S., Education, S. Davis, non-thesis option.
- Jordan, S., Ph.D., Geoscience, Prof. D. Levandowski, thesis title not yet assigned.
- Ju, Y. T., Ph.D., E.E., D. Freeman, "Singular Optimal Control."
- Kast (Kaminsky), S., M.S., Agronomy, R. A. Weismiller and B. O. Blair, "An Investigation of Analysis Techniques of Landsat Multispectral Data Designed to Aid the Soil Survey."
- Keh, E., Ph.D., C.S., D. Freeman, thesis title not yet assigned.
- Kollenkark, J., Ph.D., Agronomy, C. S. T. Daughtry and R. L. Housley, "Relationship of Agronomic and Reflectance Characteristics of Soybean Canopies."
- L'Heureux, D., Ph.D., Geoscience, D. Levandowski, thesis title not assigned.
- Latty, R., M.S., Forestry, R. Hoffer, thesis title not yet assigned.
- Latz, K., M.S., Agronomy, R. Weismiller, thesis title not yet assigned.
- Longer, D., Ph.D., Agronomy, M. E. Bauer, thesis title not yet assigned.

- Muasher, M., Ph.D., E.E., D. Landgrebe, thesis title not yet assigned.

- Nash, L., M.S., Agronomy, M. Baumgardner, thesis title not yet assigned.

- Nelson, R., M.S., Forestry, R. Hoffer, "Computer-Aided Processing of Landsat."

- Noyer, S., M.S., Forestry and Natural Resources, R. Hoffer, non-thesis option.

* - Peterson, C., M.S., Statistics, R. Mroczynski, thesis title not yet assigned.

- Pollara, V., M.S., Agronomy, C. S. T. Daughtry, thesis title not yet assigned.

- Smith, B., M.S., E.E., Prof. H. Siegel, thesis title not yet assigned.

- Sommers, S., M.S., E.E., D. Freeman, non-thesis option.

- Stoner, E., Ph.D., Agronomy, Prof. M. Baumgardner, thesis title not yet assigned.

- Swenson, M., M.S., Statistics, M. Hixson, non-thesis option.

- Tilton, J., Ph.D., E.E., Prof. P. Swain, "Contextual Analysis of Remote Sensing Data."

- Tsuchida, R., M.S., M.E., B. Robinson, non-thesis option.

- Walburg, G., M.S., Agronomy, M. Bauer, thesis title not yet assigned.

*Special non-degree student

B. DEGREES GRANTED FY 79

- Ahlrichs, J., M.S., Agronomy, M. E. Bauer, "Relation of Crop Canopy Variables to the Multispectral Reflectance of Spring Wheat."

- Hanley, E., M.S., M.E., Prof. D. P. DeWitt, "Non-invasive Medical Diagnostics through Multispectral Scanner Reflectance Analysis: Jaundice Detection and Drythema Assessment."

- Hinzel, E., M.S., Agronomy, R. A. Weismiller, "Correlation of Spectral Classes Derived from Landsat MSS Data to Soil Series and Soil Conditions for Jasper County, Indiana."

- Kit, E., M.S., E. E., Prof. P. Swain, non-thesis option.

- Muasher, M., M.S., E.E., D. Landgrebe, non-thesis option. Master's project title, "Training Samples for Classification of Earth Observational Data."

- Smith, J., M.S., E.E., Prof. L. Silva, non-thesis option.

- Stellon, C., M.S., Statistics, M. E. Bauer, non-thesis option.

- Wiersma, D., Ph.D., E.E., Prof. D. Landgrebe, "The Analytical Design of Spectral Measurements for Multispectral Remote Sensor Systems."

C. OTHER GRADUATE STUDENTS ADVISED BY LARS STAFF MEMBERS

- Batista, G. T., Ph.D., Agronomy, M.E. Bauer and M. F. Baumgardner, "Relationship of Agronomic and Spectral Properties of Corn, Soybeans, and Wheat."

- Seubert, C., Ph.D., Agronomy, Prof. M. Baumgardner, "Assessing Erosion - Sedimentation Phenomena by Spectral Measurements."

- Al-Mahawili, S., M.S., Agronomy, M. Baumgardner, thesis title not yet assigned.

APPENDIX I - PUBLICATIONS AND PRESENTATIONS BY LARS STAFF

A. JOURNAL ARTICLES AND PRESENTATIONS

Ahlrichs, J.S., M.E. Bauer, C.S.T. Daughtry and M.M. Hixson. "Estimation of Wheat Canopy Variables from Reflectance Measurements." Agronomy Abstracts, 1978 Annual Meetings.

Anuta, P.E., and C.D. McGillem. 1979. A two-dimensional filter design for isotropic reconstruction of track-type airborne geophysical surveys. In Proc. IEEE Acoustics Speech and Signal Processing Conf. p. 656-660. (LARS Tech. Rpt. 040379)

Bartolucci, L.A. 1979. "Digital Processing of Remotely Sensed Multispectral Data." Pres. at the Latin American Technology Exchange Week Conf., Panama City, Panama. (LARS Tech. Rpt. 040479)

Bauer, M.E., J.E. Cipra, P.E. Anuta and J.B. Etheridge. 1979. Identification and area estimation of agricultural crops by computer classification of Landsat MSS data. Remote Sens. of Envir. 8:77-92. (LARS Tech. Rpt. 031379)

DiPaolo, W.D. 1979. Applications of Landsat data for resource inventories on federal lands in the western United States. In Proc. Fifth Symp. on Machine Processing of Remotely Sensed Data, Purdue Univ. p. 433.

Ernst, C.L., and R. Hoffer. "Spectral Characteristics of Wetland Habitats." Annual Conv. of the Am. Soc. of Photogrammetry, Washington, D.C. March 22, 1979.

Ernst, C.L., and R. Hoffer. Using Landsat MSS Data with Soils Information to Identify Wetland Habitats. In Proc. Pecora Symp., Sioux Falls, SD. June 13, 1979.

Etheridge, J., and C. Nelson. 1979. Some effects of nearest neighbor, bilinear interpolation, and cubic convolution resampling on Landsat data. In Proc. Fifth Symp. on Machine Processing of Remotely Sensed Data, Purdue Univ. p. 84.

Fleming, M.D. R. Hoffer, 1979. Machine processing of Landsat MSS data and DMA topographic data for forest cover type mapping. In Proc. Fifth Symp. on Machine Processing of Remotely Sensed Data, Purdue Univ. p. 377-391.

Freeman, D.M. 1979. Image representation of digital remote sensing data: A perspective. In Proc. Fifth Symp. on Machine Processing of Remotely Sensed Data, Purdue Univ. p. 360.

Geddes, L.A., J.A. Pearce, J.D. Bourland, L.F. Silva and D.P. DeWitt. 1979. "The Thermal Properties of Gelled Metal-Foil Electrosurgical Dispersive Electrodes." Pres. at the Assoc. for the Advancement of Medical Instrumentation, Las Vegas, Nev.

Hixson, M.M., B.J. Davis and M.E. Bauer. 1979. Sampling for area estimation: an evaluation of the bias and precision of several sampling schemes. In Proc. Fifth Symp. on Machine Processing of Remotely Sensed Data, Purdue Univ. p. 97-104. (LARS Tech. Rpt. 062779)

Hoffer, R. "Remote Sensing Techniques." LARS Short Course Seminar, Purdue Univ. Sept. 13, 1978. Invited lecture.

Hoffer, R. "Remote Sensing for Resource Managers." 584 Class, Purdue Univ. Sept. 14, 1978. Invited lecture.

Hoffer, R. "Digital Processing of Landsat MSS and Topographic Data to Improve Capabilities for Computerized Mapping of Forest Cover Types." NASA Research Review, Houston, Texas. Sept. 20, 1978. Invited paper.

Hoffer, R. "Recent Developments in Remote Sensing for Forestry Applications." LARS Short Course Seminar, Purdue Univ. Oct. 4, 1978. Invited lecture.

Hoffer, R. "Experiences in Teaching Remote Sensing of Natural Resources." 45th Semi-Annual Conv. of the Am. Soc. of Photogrammetry, Albuquerque, NM. Oct. 16, 1978. Invited paper.

Hoffer, R. "Key Aspects of Computer-Aided Analysis Techniques for Inventorying Natural Resources." LARS Short Course Seminar, Purdue Univ. Nov. 8, 1978. Invited lecture.

Hoffer, R. "Applications of Remote Sensing to Forestry." Forest Resources Graduate Seminar. (For. 679) Purdue Univ. Nov. 16, 1978.

Hoffer, R. "Computer Analysis of Combined Satellite and Topographic Data for Mapping Cover Types." School of Civil Engineering Surveying and Mapping Seminar, Purdue Univ. Nov. 29, 1978. Invited lecture.

Hoffer, R. "Advances in Basic Understanding of Forest Scene Variables." NASA Program Review, Houston, Texas. Nov. 30, 1978. Invited paper.

Hoffer, R. 1979. Computer-aided analysis of satellite and aircraft MSS data for mapping snow-cover and water resources. In Remote Sensing Applications in Ag. and Hydrology. G. Fraysee, ed. (LARS Tech. Rpt. 020279)

Hoffer, R. 1979. Computer-aided analysis techniques for mapping earth surface features. In Remote Sensing Applications in Ag. and Hydrology. G. Fraysee, ed. (LARS Tech. Rpt. 020179).

Hoffer, R. "Digital Processing of Landsat MSS and Topographic Data to Improve Capabilities for Computerized Mapping of Forest Cover Types." Nationwide Forestry Applications Program Technical Progress Review, NASA, Houston, Texas. Jan. 15, 1979. Invited presentation.

Hoffer, R. "Remote Sensing Techniques for Mapping Forest Cover." Special Seminar, Dept. of Geography, Indiana State Univ. Terre Haute, Ind. March 28, 1979. Invited lecture.

Hoffer, R. "Forest Fire Detection and Monitoring Using Remote Sensing Techniques." Forestry 335 Class, Purdue Univ. Apr. 2, 1979. Invited lecture.

Hoffer, R. "Remote Sensing Techniques to Measure Vegetation Distribution and Structure." In Proc. Conf. of SCOPE, Woods Hole, Mass. May 7, 1979. Invited paper.

Hoffer, R. "Utilizing Computer-Assisted Analysis Techniques for Mapping and Inventorying Forest Resources or 'Putting the Theory into Practice in the Real World'". In Proc. Short Course on Adv. Topics in the Analysis of Remote Sensing Data, Purdue Univ. May 17, 1979. Invited paper.

Hoffer, R. "Identifying Forest Cover Using Computer-Aided Analysis Techniques." LARS Short Course Seminar, Purdue Univ. June 6, 1979. Invited lecture.

Hoffer, R., and M.D. Fleming. 1978. "Mapping Vegetative Cover by Computer-Aided Analysis of Satellite Data." In Proc. Workshop of Integrated Inventories of Renewable Natural Resources. Tucson, Arizona. (LARS Tech. Rpt. 011178)

Hoffer, R., and M.D. Fleming. "Training Procedures--The Key to Effective and Efficient Computer Classifications." Annual Conv. of the Am. Soc. of Photogrammetry, Washington, D.C. Mar. 20, 1979.

Hoffer R., R.P. Mroczynski. 1978. "The Role of Remote Sensing in Forest Inventory--A Perspective on User Requirements." NASA Program Review, Houston, Texas. Nov. 30, 1978. Invited paper.

Hoffer, R., R.P. Mroczynski and R.F. Nelson. "Evaluation of Landsat Data Analysis for Forest Survey." U.S. Forest Service Research Project Review, St. Paul, Minn. Feb. 2, 1979. Invited presentation.

Hoffer, R., S.C. Noyer and R.P. Mroczynski. "A Comparison of Landsat and Forest Survey Estimates of Forest Cover." 45th Semi-Annual Conv. of the Am. Soc. of Photogrammetry, Albuquerque, NM. Oct. 18-19, 1978. Invited paper.

Kit, E.F., and P.H. Swain. 1978. An approach in statistical context in remote sensing data analysis. In Proc. Fifth Canadian Symp. on Remote Sensing, Victoria, B.C. pp. 37-41. (LARS Tech. Rpt. 081278)

Kumar, R., B.F. Robinson and L.F. Silva. 1979. Calibration of long wavelength Exotech Modal 20C spectroradiometer. Applied Optics 18: 2234-2341.

Landgrebe, D.A. 1978. "The Development of a Spectral/Spatial Classifier for Earth Observational Data." In Proc. IEEE Comp. Soc. Conf. on Pattern Recognition and Image Processing. Chicago, IL. (LARS Tech. Rpt. 051578)

Landgrebe, D.A. 1979. "Monitoring the Earth's Resources from Space--Can You Really Identify Crops by Satellite?" In Proc. National Computer Conf., New York, NY. (LARS Tech. Rpt. 060779)

Landgrebe, D.A., and M.J. Muasher. 1979. Training samples for classification of multispectral earth observation data. In Proc. Fifth Symp. on Machine Processing of Remotely Sensed Data, Purdue Univ. p. 359.

Mobasseri, B.G., C.D. McGillem and P.E. Anuta. 1979. A parameter model for multispectral scanners. In Proc. Fifth Symp. on Machine Processing of Remote Sensed Data, Purdue Univ. pp. 213-221.

Pearce, J.A., L.A. Geddes, J.D. Bourland and L.F. Silva. 1978. "The Effect of Arch Establishment Upon the Frequency Spectrum of Electrosurgical Generator Output." Assoc. for the Adv. of Medical Instrumentation, Washington, D.C.

Pearce, J.A., L.A. Geddes, J.D. Bourland and L.F. Silva. 1979. The thermal behavior of electrolyte-coated metal-foil dispersive electrodes. Medical Instrumentation. 13:322-350.

Pearce, J.A., L.A. Geddes, J.D. Bourland, L.F. Silva and D.P. DeWitt. 1979. "The Effect of Perimeter/Area Ratio on the Performance of Electrosurgical Dispersive Electrodes." Assoc. for Adv. of Medical Instrumentation, Las Vegas, Nev.

Peterson, J.B. 1978. Agronomists and the food chain. Agronomy in Today's Society. p. 7-17. (LARS Tech. Rpt. 112077). Invited paper.

Peterson, J.B., B.F. Robinson and R.H. Beck. 1979. Predictability of change in soil reflectance on wetting. In Proc. Fifth Symp. on Machine Processing of Remotely Sensed Data, Purdue Univ. p. 264-274.

Robinson, B.F., M.E. Bauer, L.L. Biehl and L.F. Silva. 1978. "The Design and Implementation of a Multiple Instrument Field Experiment to Relate the Physical Properties of Crops and Soils to Their Multispectral Reflectance." International Symp. on Remote Sensing for Observation and Inventory of Earth Resources and Environment. Freiberg, West Germany.

Robinson, B.F., M.E. Bauer, L.F. Silva and D.P. DeWitt. 1979. "A Multispectral Data Acquisition System for Field Research in Remote Sensing." Gordon Research Conf. on Remote Sensing. Plymouth, NH.

Robinson, B.F., and L.L. Biehl. 1979. "Calibration Procedures for Measurement of Reflectance Factor for Remote Sensing Field Research." Soc. of Photo-Optical Instrumentation Engineers. San Diego, Cal.

Robinson, B.F., and L.L. Biehl. 1979. "Multiband Radiometer for Field Research." Photo-Optical Instrumentation Engineers. San Diego, Cal.

Scholz, D., N. Fuhs and M. Hixson. 1979. "An Evaluation of Several Different Classification Schemes: Their Parameters and Performance." Pres. at the 13th International Symp. on Remote Sensing of Environment, Ann Arbor, Mich.

Seubert, C.E., M.F. Baumgardner, R.A. Weismiller and F.R. Kirschner. 1979. Mapping and estimating areal extent of severely eroded soils of selected sites in northern Indiana. In Proc. Fifth Symp. on Machine Processing of Remotely Sensed Data, Purdue Univ. p. 234-239.

Siegel, H.J. 1979. Interconnection networks for SIMD machines. Computer 12:57-65.

Siegel, H.J. 1979. "PASM: A Partitionable SIMD/MIMD System for Image Processing." CS/EE Seminar, Univ. of Wisconsin, Madison, Wisconsin.

Siegel, H.J., R.J. McMillen and P.T. Mueller, Jr. 1979. A survey of interconnection methods for reconfigurable parallel processing system. In Proc. 1979 National Computer Conf. p. 529-542.

Smith, S.D., and H.J. Siegel. 1979. "An Emulator Network for SIMD Machine Interconnection Networks." In Proc. 1979 International Symp. on Computer Architecture.

Stoner, E.R., M.F. Baumgardner, R.A. Weismiller, L.L. Biehl and B.F. Robinson. 1979. Extension of laboratory-measured soil spectra to field conditions. In Proc. Fifth Symp. on Machine Processing of Remotely Sensed Data, Purdue Univ. p. 253-263.

Swain, P.H. 1979. "Analysis of Multivariable Remote Sensing Data: Are We Ready for Landsat-D?" Pres. at the Second International Seminar on the Use of Remote Sensors. Mexico City, Mexico. (LARS Tech. Rpt. 050879)

Swain, P.H., H.J. Siegel and B. Smith. 1979. A method for classifying multispectral remote sensing data using context. In Proc. Fifth Symp. on Machine Processing of Remotely Sensed Data. Purdue Univ. p. 343-353. (LARS Tech. Rpt. 062379)

Vanderbilt, V.C., M.E. Bauer and L.F. Silva. 1979. Prediction of solar irradiance distribution in a wheat canopy using a laser technique. Ag. Meteorology 20:147-160. (LARS Tech. Rpt. 042079)

Weismiller, R.A., and S.A. Kaminsky. 1978. An overview of remote sensing as related to soil survey research. In Proc. International Soil Science Society Meetings, Edmonton, Canada. Journal of Soil and Water Conservation 33:287-289. (LARS Tech. Rpt. 062678)

Weismiller, R.A., S.K.Kast and M.F. Baumgardner. 1979. Landsat MSS data as an aid to soil survey--an operational concept. In Proc. Fifth Symp. on Machine Processing of Remotely Sensed Data, Purdue Univ. p. 240.

Wiersma, D.J., and D.A. Landgrebe. 1979. An analytical approach to the design of spectral measurements in the design of multispectral sensor. In Proc. Fifth Symp. on Machine Processing of Remotely Sensed Data. Purdue Univ. p. 331-342. (LARS Tech. Rpt. 062279)

B. TECHNICAL REPORTS AND EDUCATIONAL/DESCRIPTIVE PUBLICATIONS

083077 ECHO user's guide. J.L. Kast, P.H. Swain, B.J. Davis and P.W. Spencer.

110477 Analysis of the effects of interpolation and enhancement of Landsat-1 data on classification and area estimation accuracy. N. Chu, C.D. McGillem and P.E. Anuta.

112077 Agronomists and the food chain. J.B. Peterson. Agronomy in Today's Society. p.7-17.

011178 Mapping vegetative cover by computer-aided analysis of satellite data. R.M. Hoffer and M.D. Fleming. In Proc. Workshop on Integrated Inventories of Renewable Natural Resources. Tucson, Arizona.

051578 The development of a spectral/spatial classifier for earth observational data. D.A. Landgrebe. In Proc. IEEE Comp. Soc. Conf. on Pattern Recognition and Image Processing.

061578 A parametric multiclass Bayes error estimator for the multispectral scanner spatial model performance evaluation. B.G. Mobasseri, C.D. McGillem and P.E. Anuta. Thesis.

061678 Methods and performance bounds for constrained image restoration. N.Y. Chu and C.D. McGillem. Thesis.

061778 Analytical techniques for the study of some parameters of multispectral scanner systems for remote sensing. E.R. Wiswell and C.R. Cooper. Thesis.

062678 An overview of remote sensing as related to soil survey research. R.A. Weismiller and S.A. Kaminsky. In Proc. of the International Soil Science Society Meetings, Edmonton, Canada. Journal of Soil and Water Conservation. 33:287-289.

070178 LARS capabilities. Staff.

081278 An approach in statistical context in remote sensing data analysis. E.F. Kit and P.H. Swain. In Proc. Fifth Canadian Symp. on Remote Sensing, Victoria, B.C. p. 37-41.

083078 The evaluation of Landsat data and analysis techniques for mapping tropical forest areas. K.S. Hsu and R.M. Hoffer. Thesis.

112378 Land cover study for the Pulawy Region, Poland, by digital analysis of Landsat data. J.J. Domanski and S.J. Morawski.

122678 The analytical design of spectral measurements for multispectral remote sensor systems. D.J. Wiersma and D.A. Landgrebe. Thesis.

020179 Computer-aided analysis techniques for mapping earth surface features. R.M. Hoffer. In Remote Sensing Applications in Ag. and Hydrology. G. Fraysee, ed.

020279 Computer-aided analysis of satellite and aircraft MSS data for mapping snow-cover and water resources. R.M. Hoffer. In Remote Sensing Applications in Ag. and Hydrology. G. Fraysee, ed.

031379 Identification and area estimation of agricultural crops by computer classification of Landsat MSS data. M.E. Bauer, J.E. Cipra, P.E. Anuta and J.B. Etheridge.

040479 Digital processing of remotely sensed multispectral data. L.A. Bartolucci. Pres. at the Latin American Technology Exchange Week Conf., Panama City, Panama.

041879 LARS computer user's guide. Staff. Supersedes 011977.

042079 Prediction of solar irradiance distribution in a wheat canopy using a laser technique. V.C. Vanderbilt, M.E. Bauer and L.F. Silva. Ag. Meteorology 20:147-160.

042779 Staff. Purdue/LARS organization. Supersedes 042778.

050879 Analysis of multivariable remote sensing data: are we ready for Landsat-D? P.H. Swain. Pres. at the Second International Seminar on the Use of Remote Sensors. Mexico City, Mexico.

060779 Monitoring the earth's resources from space - can you really identify crops by satellite? D.A. Landgrebe. In Proc. National Computer Conf., New York, New York.

062279 An analytical approach to the design of spectral measurements in the design of multispectral sensor. D.J. Wiersma and D.A. Landgrebe. In Proc. Fifth Symp. on Machine Processing of Remotely Sensed Data. Purdue Univ. p. 331-342.

062379 A method for classifying multispectral remote sensing data using context. P.H. Swain, H.J. Siegel and B.W. Smith. In Proc. Fifth Symp. on Machine Processing of Remotely Sensed Data. Purdue Univ. p. 343-353.

062779 Sampling for area estimation: a comparison of full-frame sampling with the sample segment approach. M.M. Hixson, M.E. Bauer and B.J. Davis. In Proc. Fifth Symp. on Machine Processing of Remotely Sensed Data. Purdue Univ. p. 97-104.

C. CONTRACT REPORTS

062978 Quarterly Report for April 1, 1978 - June 30, 1978. R.P. Mroczynski and Staff. Forest resource information system. Contract No. NAS9-15325.

070578 Semi-Annual Status Report for December 1, 1977 - May 31, 1978. R.A. Weismiller and R.P. Mroczynski. Application of remote sensing technology to the solution of problems in the management of resources in Indiana. Grant No. NGL 15-005-186.

082478 Final Report for March 1, 1977 - June 30, 1978. P.E. Anuta, D.M. Freeman, B.M. Shelley and C.R. Smith. Synthetic aperture radar/Landsat MSS image registration system study. Contract No. NAS6-2816.

083178 Quarterly Report for June 1, 1978 - August 31, 1978. D.A. Landgrebe and Staff. Research in remote sensing of agriculture, earth resources and man's environment. Contract No. NAS9-15466.

091578 Quarterly Report for June 16, 1978 - September 15, 1978. R.M. Hoffer and Staff. Digital processing of Landsat MSS and topographic data to improve capabilities for computerized mapping of forest cover types. Contract No. NAS9-15508.

091878 Annual Report to the University. Fiscal Year 1978. D.A. Landgrebe and Staff.

091978 Annual Financial Report to the University. D.A. Landgrebe and Staff. Fiscal Year 1978.

111178 Final Report for March 27, 1978 - July 28, 1978. L.A. Bartolucci. Adiestramiento de profesionales centroamericanos en analisis digital de datos multiespetrales Landsat. Contract No. 030564.

112278 Contract Report. M.M. Hixson, B.J. Davis and M.E. Bauer. Stratification and sample selection for multicrop experiments. Contract No. NAS9-15466.

112578 Final Report for December 1, 1977 - November 31, 1978. M.E. Bauer, M.M. Hixson, L.L. Biehl, C.S.T. Daughtry, B.F. Robinson and E.R. Stoner. Agricultural scene understanding. Contract No. NAS9-15466.

112678 Final Report for December 1, 1977 - November 31, 1978. B.G. Mobasseri, D.J. Wiersma. E.R. Wiswell, D.A. Landgrebe, C.D. McGillem and P.E. Anuta. Multispectral scanner system parameter study and analysis software system description. Contract No. NAS9-15466.

112778 Final Report for December 1, 1977 - November 31, 1978. P.E. Anuta, M.M. Hixson and P.H. Swain. Processing techniques development. Contract No. NAS9-15466.

112878 Final Report for December 1, 1977 - November 31, 1978. M.F. Baumgardner, V.L. Anderson, K. S. Pillai, C.C. Stellon and L.M. Nash. Assessment of methods of acquiring, analyzing, and reporting crop production statistics. Contract No. NAS9-15466.

112978 Final Report for December 1, 1977 - November 31, 1978. J.L. Kast. Computer processing support. Contract No. NAS9-15466.

113078 Final Report for December 1, 1977 - November 31, 1978. D.A. Landgrebe and Staff. Final technical summary. Contract No. NAS9-15466.

022879 Quarterly Report for December 1, 1978 - February 28, 1979. D.A. Landgrebe and Staff. Research in remote sensing of agriculture, earth resources, and man's environment. Contract No. NAS9-15466.

041579 Quarterly Report for January 16, 1979 - April 15, 1979. R.M. Hoffer and Staff. Digital processing of Landsat MSS and topographic data to improve capabilities for computerized mapping of forest cover types. Contract No. NAS9-15508.

042179 Semi-Annual Status Report for June 1, 1978 - November 30, 1978. R.A. Weismiller and R.P. Mroczynski. Application of remote sensing technology to the solution of problems in the management of resources in Indiana. Grant No. NGL 15-005-186.

043079 Quarterly Report for January 1, 1979 - April 30, 1979. R.P. Mroczynski and Staff. Forest resource information system. Contract No. NAS9-15325.

050279 Final Report for September 1, 1976 - August 31, 1978. N.Y. Chu and P.E. Anuta. Multidimensional scaling for clustering of dissimilar data types. Grant No. ENG-7614400.

052379 Final Report for September 1, 1976 - August 31, 1978. D.M. L'Heureux and D.W. Levandowski. Exploration for porphyry copper deposits through multivariate analysis of computer-registered Landsat and geophysical data sets. Grant No. ENG-7614400.

053179 Quarterly Report for March 1, 1979 - May 31, 1979. D.A. Landgrebe and Staff. Research in remote sensing of agriculture, earth resources, and man's environment. Contract No. NAS9-15466.

061579 Final Report for September 1, 1976 - August 31, 1978. P.E. Anuta and C.D. McGillem. Reconstruction of geophysical surfaces from track-type surveys. Grant No. ENG-7614400.

INTERNAL REPORTS

071578 Internal Report. J.R.G. Townshend. A report on the activities of the earth sciences program, LARS.

APPENDIX II - STAFF

A. PROFESSORIAL STAFF

1. Agriculture

a. M.F. Baumgardner - Professor of Agronomy and LARS Program Leader
b. J.C. Callahan - Professor of Forestry
c. R.M. Hoffer - Professor of Forestry and LARS Program Leader
d. D.A. Holt - Professor of Agronomy
e. F.R. Kirschner - Adjunct Professor of Agronomy
f. J.B. Peterson - Professor of Agronomy (Emeritus appointment) and Associate Director of LARS
g. H.F. Reetz - Assistant Professor of Agronomy

2. Engineering

a. D.C. Anderson - Associate Professor of Mechanical Engineering
b. N.Y. Chu - Post-doctoral Fellow of Electrical Engineering
c. D.P. DeWitt - Associate Professor of Mechanical Engineering
d. L.A. Geddes - Professor of Electrical Engineering (Biomedical)
e. R.E. Hanneman - Visiting Professor of Chemical Engineering
f. D.A. Landgrebe - Professor of Electrical Engineering and Director of LARS
g. C.D. McGillem - Professor of Electrical Engineering
h. B.G. Mobasseri - Post-doctoral Fellow of Electrical Engineering
i. H.J. Siegel - Assistant Professor of Electrical Engineering
j. L.F. Silva - Professor of Electrical Engineering and LARS Program leader.
k. P.H. Swain - Professor of Electrical Engineering and LARS Program leader.
l. V.C. Vanderbilt - Post-doctoral Fellow of Electrical Engineering

3. Humanities, Social Science and Education

a. J.D. Russell - Associate Professor of Education

4. Science

a. V.L. Anderson - Professor of Statistics
b. D.W. Levandowski - Professor of Geoscience
c. K.S. Pillai - Professor of Statistics
d. S.B. Vardeman - Assistant Professor of Statistics

B. PROFESSIONAL STAFF

1. AGRICULTURE

a. M.E. Bauer - Research Agronomist and LARS Program Leader
b. L.A. Bartolucci - Technical Director of Training
c. C.T.S. Daughtry - Research Agronomist
d. F.E. Goodrick - Data Analyst in Forestry and Natural Resources
e. S.J. Kristof - Research Agronomist
f. R.P. Mroczynski - LARS Associate Program Leader
g. D.K. Scholz - Data Analyst
h. R.A. Weismiller - Research Agronomist and LARS Associate Program Leader

2. ENGINEERING

a. P.E. Anuta - Research Engineer and LARS Associate Program Leader
b. L.L. Biehl - Project Manager/Engineer
c. J.D. Bourland - Coordinator for Engineering
d. R.K. Boyd - Data Analyst and Training Specialist
e. J. Buis - Systems Analyst
f. M.D. Collins - Computer Operations Supervisor
g. S.M. Davis - Education and Training Specialist
h. J.B. Etheridge - Manager of Systems Analysis
i. S.L. Ferringer - Visual Designer
j. D.M. Freeman - Manager of Data Reformatting
k. N.C. Fuhs - Applications Programmer
l. R.A. Garmoe - Manager of Basic Systems
m. M.C. Hodge - Administrative Assistant
n. J.L. Kast - Program Developer
o. B.C. Kozlowski - Applications Programmer
p. L.A. Kraemer - Applications Programmer
q. D.E. Parks - Publications Coordinator
r. K.J. Philipp - Reformatting Operations Assistant
s. T.L. Phillips - Deputy Director of LARS
t. B.J. Pratt - Administrative Assistant
u. B.F. Robinson - Research Engineer and LARS Associate Program Leader
v. S.K. Schwingendorf - Applications Programmer
w. B.M. Shelley - Reformatting Operations Assistant
x. C.R. Smith - Reformatting Operations Assistant
y. M. Smolen - Administrative Assistant
z. M.L. Tang - Software Analyst

3. HUMANITIES, SOCIAL SCIENCE AND EDUCATION

a. D.P. Morrison - Education and Training Coordinator

4. Science

a. M.M. Hixson - Research Statistician
b. C. Jobusch - Statistician Analyst

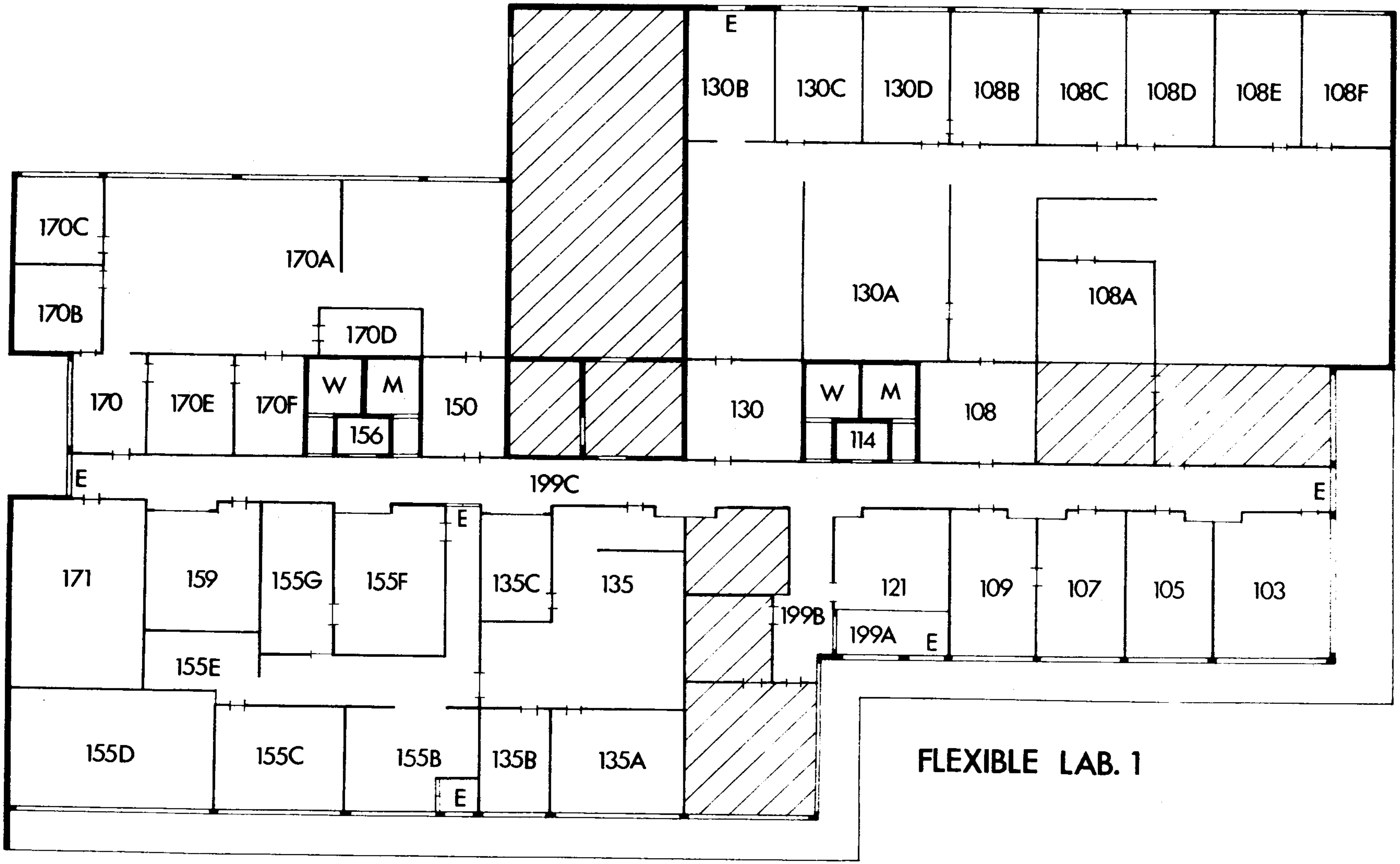
B. STAFF. JULY 1, 1978 - JUNE 30, 1979

STAFF INVOLVEMENT AT LARS BY DEPARTMENT AND CLASSIFICATION

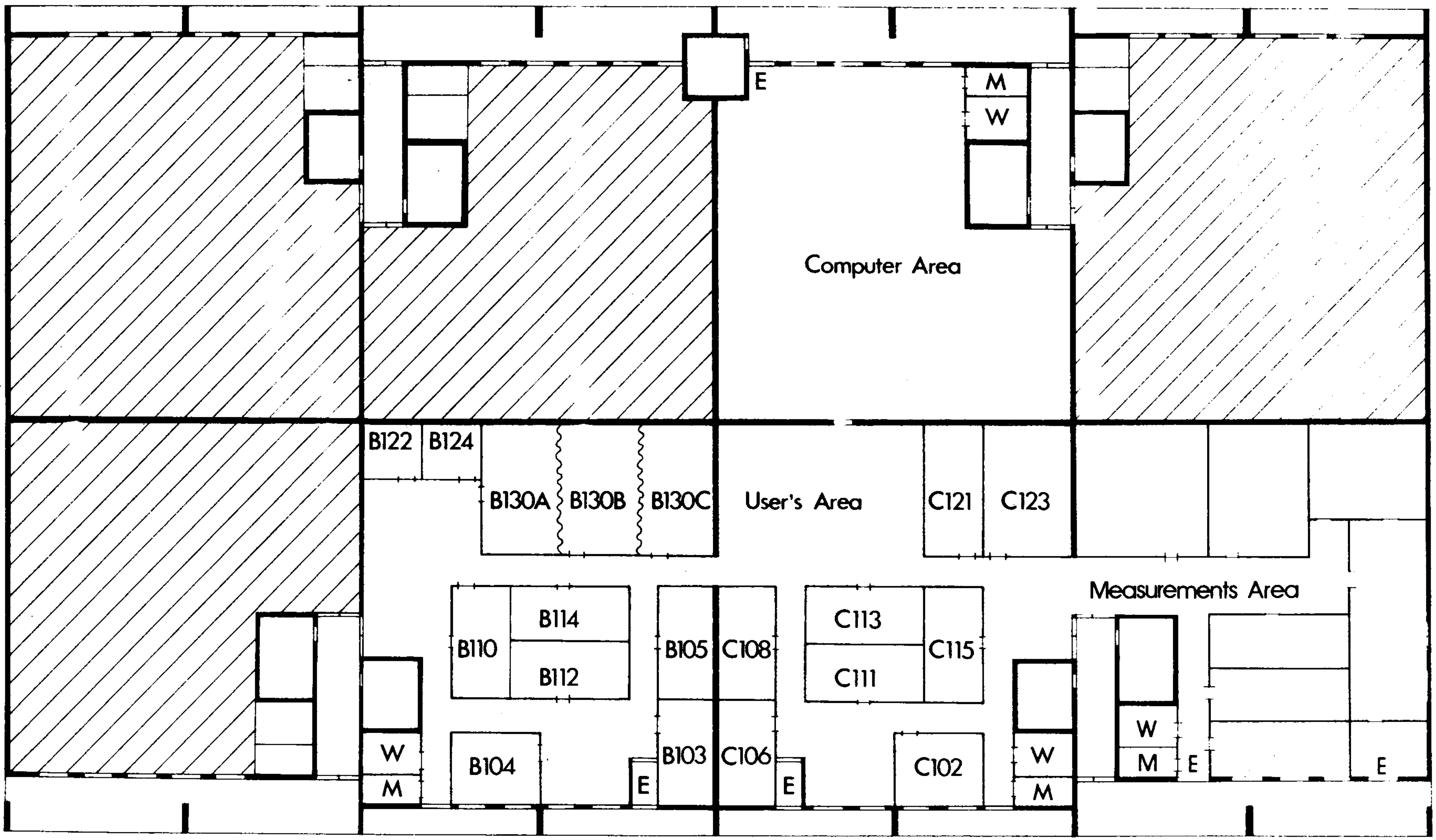
Department	Faculty (Page 67)	Professional (Page 68)	Graduate Students* (Page 52)	Undergraduate Students	Service	Clerical
Agriculture						
Agronomy	5	6	11			
Forestry	2	2	5			
Engineering						
Chemical	1					
Electrical	9	3	14			
Experiment Station		21		67	8	19
Mechanical	2		3			
Bio-Medical		2				
HSEE						
Education	1		1			
Communications		1				
Science						
Computer Science			1			
Geoscience	1		2			
Statistics	3	2	3	—	—	—
TOTAL	24	37	40	67	8	19

*Includes only those graduate students on the payroll. The total including all graduate students is 43. (See pages 52-54)

APPENDIX III – FLOOR PLANS



FLEXIBLE LAB. 1



FLEXIBLE LAB. 2