LARS Report 090380

ANNUAL REPORT
TO THE UNIVERSITY

FISCAL YEAR 1980

Laboratory for Applications of Remote Sensing
Purdue University
West Lafayette, Indiana 47907 USA

PURDUE UNIVERSITY LABORATORY FOR APPLICATIONS OF REMOTE SENSING

1979-80 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. Total expenditures for the year were $2,924,670, an increase of nearly 20% over last year. The year also saw the installation of an IBM 3031 computer with about three times the computational capacity of the previous machine and two new digital display systems, thus significantly improving our computational capabilities.

An important milestone on the national level this year was the creation by Presidential order of an operational land remote sensing system. A significant effect of this order is that it permanently guarantees the collection of new data, thus making a commitment to this technology an attractive possibility for user agencies. Research in the field will, of course, be continued.

It is appropriate that we give careful consideration as to what the University's response to this significant event of the field should be. Indeed, planning at LARS for this new working environment has already begun.

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:gcb

Distribution:
- The President
- The Provost
- The Policy Committee
- The Division of Sponsored Programs
- Interested Department Heads

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ANNUAL REPORT
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FISCAL YEAR 1980

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LARS Program Summary

Organization

LARS functions as a research laboratory within the University structure. The logistics of financing, project expediting, and facility availability and management, including computer hardware and software, are handled through the administrative staff of the Laboratory. Academic and professional personnel are members of individual University departments and/or the Engineering Experiment Station.

Organizational and discipline barriers are minimized through the common pattern of scientists from various disciplines grouping as teams of common interest to prepare proposals, accept grants or contracts, and work together to solve problems. Research, planning, coordination and leadership are provided by the director with active participation by the associate and the deputy directors and the program leaders.

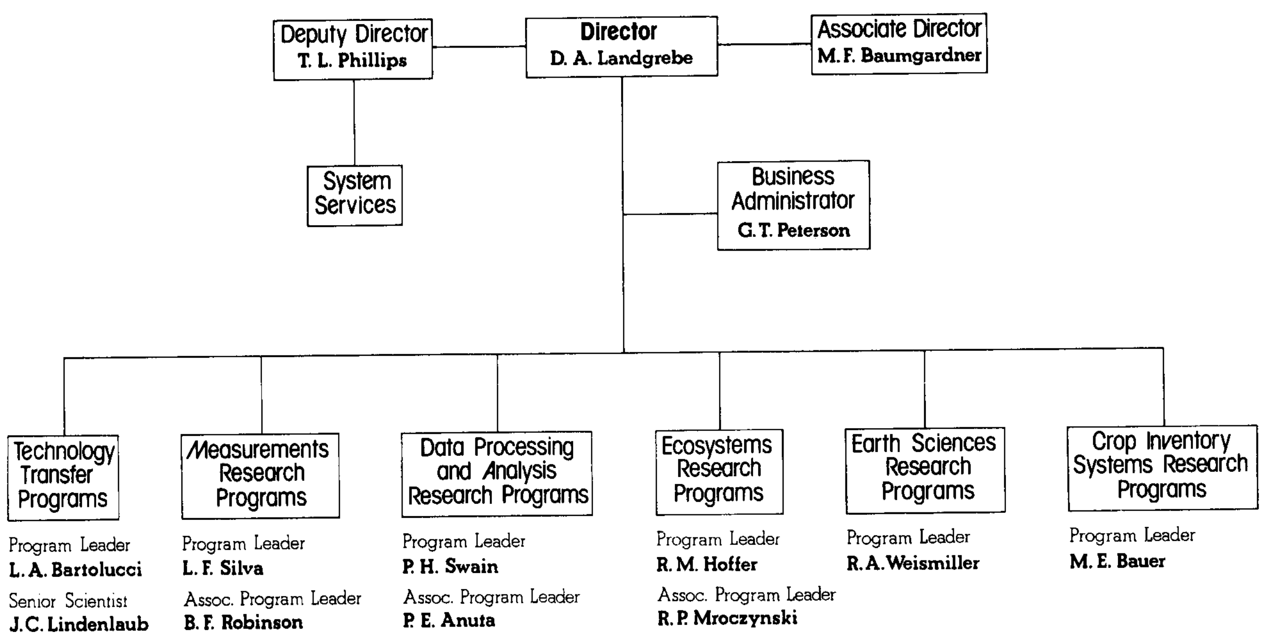


Figure 1. Organization of the Laboratory for Applications of Remote Sensing.

Staff July 1, 1979 to June 30, 1980

The LARS staff is accommodated principally in the two buildings Flex Labs I and II. Flex Lab I houses the administrative staff, the staff of the Earth Sciences, Ecosystems and Crop Inventory program areas and part of the staff of the Data Processing and Analysis program area (Figure 2). It also houses four of the in-house remote terminals and Data 100 equipment.

Flex Lab II provides space for all other computer hardware, the System Services administration and staff, part of the Data Processing and Analysis program staff, and the staff of the Technology Transfer and Measurements program areas.

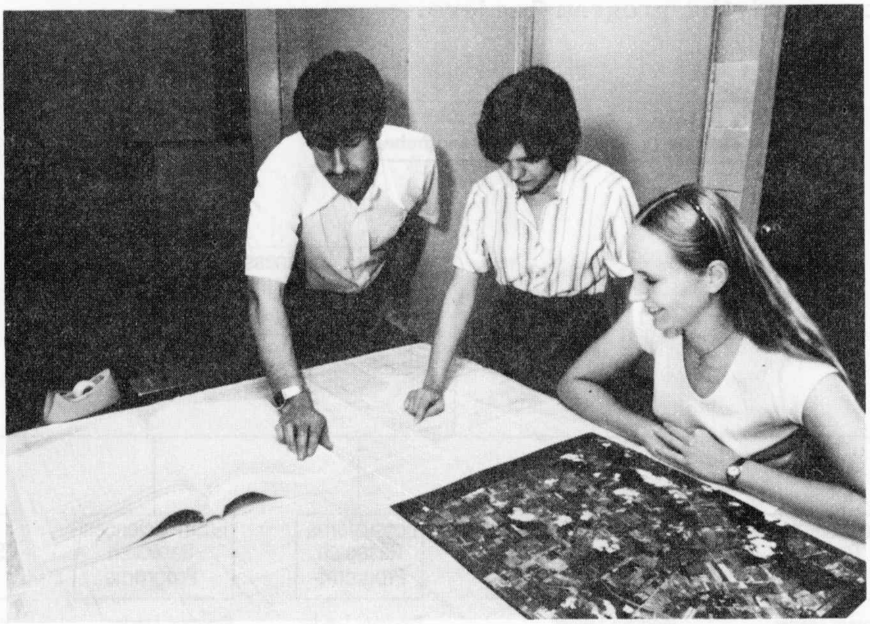


Figure 2. Systems analysts team with research engineer to interpret computerized printout for land use inventory.

During FY80 there were 205 people (83.71 FTE) from 11 departments in four schools assigned to LARS projects. Table 1 shows a further breakdown of this information:

Table 1. Staff summary by school.

	Faculty	Professional	Clerical	Service	Graduate Students	Under-graduates
Agriculture	5	8		1	17	11
Engineering	7	32	18	5	17	71
Humanities, Social Science, and Education	1	1			1	
Science	4	2			4	
No. of Employees	17	43	18	6	39	82 (205 total employees)
Full Time Equivalent	4.37	33.56	10.80	32.47	13.71	18.02 (83.71 total FTE)

Further details on the LARS staff are provided on pages:

Summary of Research Accomplishments

During FY80 the results of the interdisciplinary research effort at LARS were rewarding, with tangible results both in the successful advances in practical applications of remote sensing technology and in more basic research. The reputation of the Laboratory as a research organization and as a leading "technology transfer" training area continues to bring in scientists from all over the world.

Among the FY80 research accomplishments of the various program areas the following may be listed:

Earth Sciences Research

- Marked advances from ongoing research at LARS in cooperation with the Soil Conservation Service and the Bureau of Land Management into ways of utilizing Landsat data to expedite soil and/or land use surveys which are resulting in acceptance of the newly developed methods by these agencies in their national survey programs.

- Discovery of high correlation at the 1.92-2.02 μm wavelength between loss in reflectance of soils when wet to a specified moisture tension versus their reflectances when oven dry. This relationship indicates possible capability to discriminate between wet and dry soils with multispectral data.

Crop Inventory Research

- Successful analysis and improved understanding of factors contributing to the spectral discriminability of certain important staple crops.

- Successful analysis of the reflectance characteristics of corn and soybeans as a function of development stage, soil background condition and agronomic practices.

- Quantification of the relationship of leaf area index to the reflectance of wheat, corn, and soybeans.

- Explanation and quantification of the effect of nitrogen deficiency on the spectral response of corn and winter wheat.

- Development of a model relating solar illumination angle, row azimuth direction and canopy geometry.

- Further evidence that polarization properties of crop canopies may be indicative of crop development stage and condition.

- Evidence that percent of solar radiation intercepted by a crop canopy can be estimated from spectral data.

Measurements Research

- Development of instrumentation necessary for the Exotech Model 20 system to access accurately solar irradiation during data acquisition.

- Completion of design and fabrication of a relatively low cost boom for the model 100 system which permits acquisition of data at appropriate altitudes over crop canopies of interest.

- Design of specifications for an eight-band multiband radiometer (designated Model 12-1000) based on experience gained at LARS with the model 100 multiband radiometer. The design includes a special data-logger with a detachable solid state memory to digitize and store data for later interface with the digital computer.

- Perfection of a successful method of using a digital-thermal scanner to evaluate the performance of electrosurgical dispersive electrodes used in electrosurgical applications.

- Improvement of the LARSPEC software system, used in reformatting, preprocessing and analyzing spectral data to provide easy interface with spectral data by the analyst.

- Modification of LARSPEC software to allow convenient inclusion of ancillary data into the spectral-data base.

Data Processing and Analysis Research

- Resolution of the problem of mathematically describing the geometric differences among images and incorporation of the results into operational procedures at LARS for registering remote sensor imagery.

- Perfection of the concept of multi-image registration of map and tabular data and its successful application in the exploration of mineral deposits in southeastern Arizona. In this work several prospects were located using Landsat spectral data, gamma-ray radiation, earth magnetic field and geological data.

- Demonstration of the feasibility of optimizing spatial information in image data by approaching the image as a two-dimensional random process and by utilizing the characteristics of this process in classification strategy. The complexity of this approach is believed to be manageable through use of newly developed digital computer components and multiprocessor implementation.

- Promising investigation of the sensitivity of analysis to the accuracy of interband registration. These results have provided information of potential value to NASA in determining how rigidly instrument design specifications need to be followed to secure anticipated performance by the Thematic Mapper.

Ecosystems Research

- Successful development and testing of the value of analytical techniques which permit the inclusion of ancillary data with spectral data in analyzing forest cover types in mountainous terrain. An increase in classification performance of approximately 15% was realized through the use of combined topographic and spectral data as compared to spectral data alone. Furthermore, in another study it was indicated that the incorporation of Forest Survey data with Landsat data could result in marked efficiencies for the Forest Service's survey program.

- Implementation by LARS and the St. Regis Paper Company of the first successful operational remote sensing capability to inventory commercial forest lands.

Summary of Publications and Presentations

Table 2. Summary of reporting activities by LARS personnel during FY80.

Type of Activity	Number Completed
Technical Journal Articles	32
Talks, Seminars and Symposia	83
Technical Reports	50
Contract Reports	34
Internal Reports	3
Special Professional Activities	38

Fiscal Summary

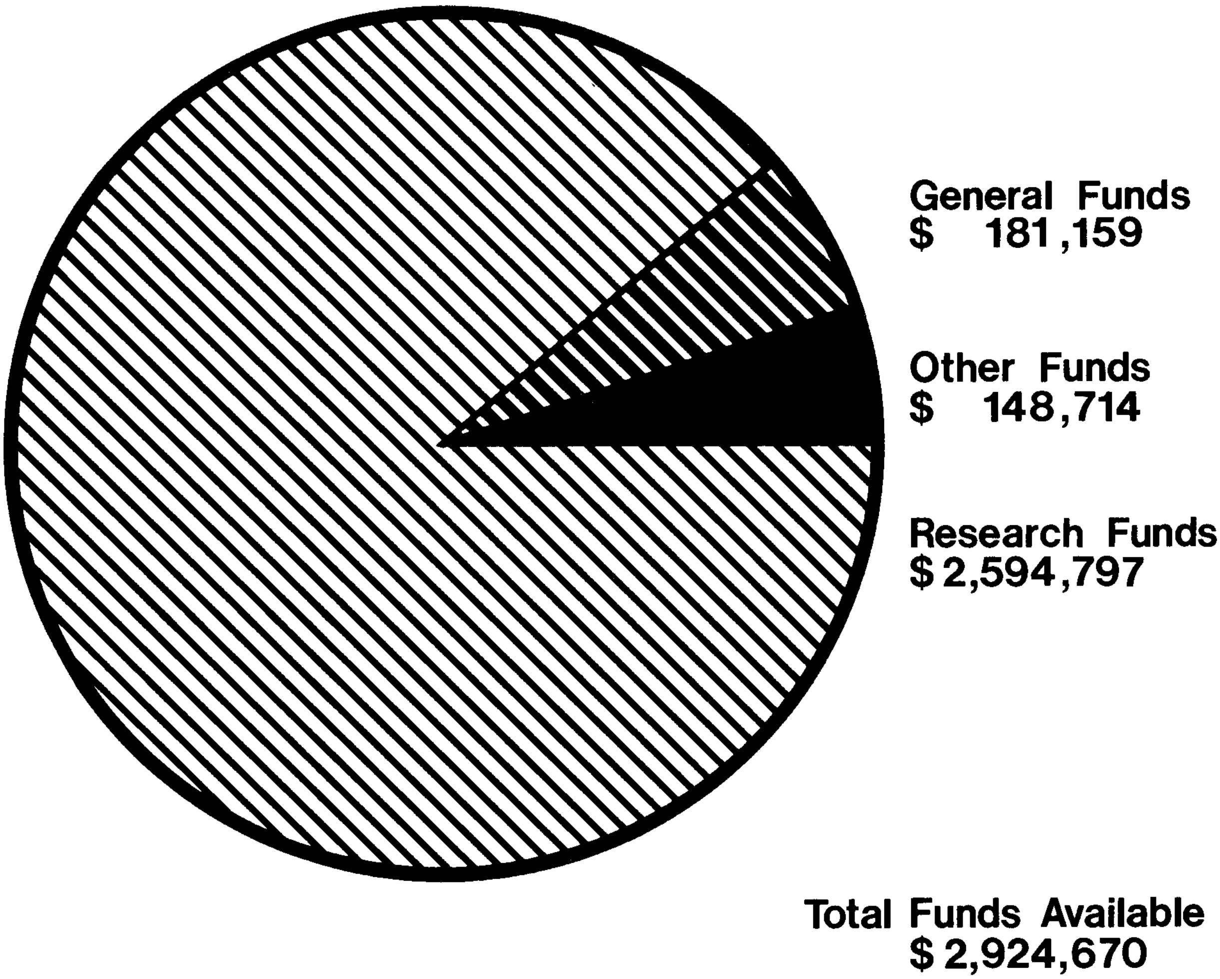


Figure 3. Summary of funds available, July 1, 1979 to June 30, 1980.

Development of Remote Sensing Research

Facility Summary

1. General Purpose Interactive Computing Environment

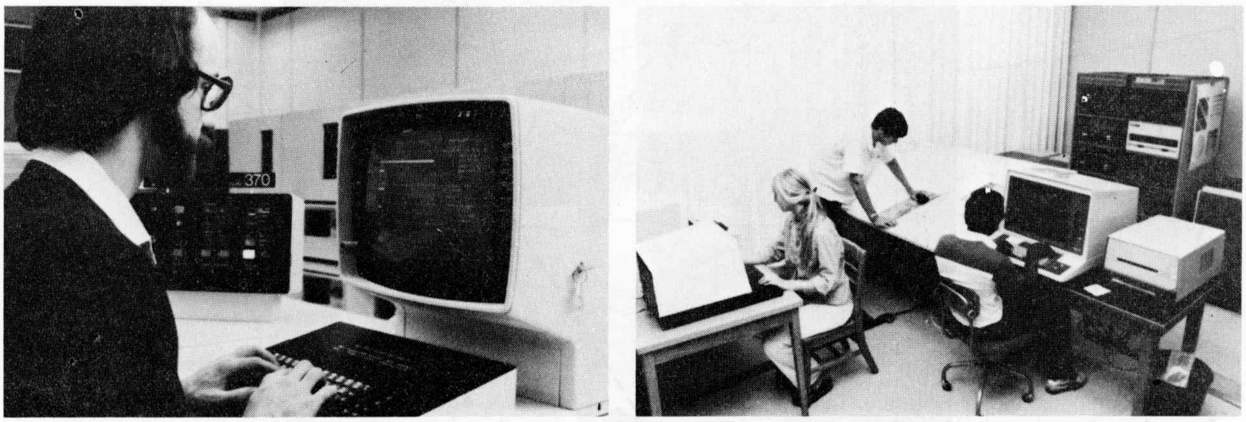


Figure 4. (Left) IBM 3031 console showing heavy demand for service. (Right) PDP 11/34 provides a significant processing support independent of the 3031 mainframe.

LARS has elected to supply a highly interactive, multi-user, general purpose computing environment in order to maximize the accessibility of software tools and the speed and ease of program development.

Computer hardware includes the following:

(1) IBM 3031 with over 2 gigabytes of direct access storage (Figure 4);

(2) More than 6000 reels of magnetic tape store scanner, radiometer, meteorological, political boundary and other data;

(3) A DEC PDP 11/34 (Figure 4) attached to the computer system to serve as an intelligent remote terminal and to drive a table digitizer, electrostatic printer/plotter, and the color and graphics display systems.

(4) Distributed research data processing system with extensive man/machine interactive capabilities implemented with a Tektronix 4054 graphics display system, a Comtal Vision One/20 color display system, the IBM 3031 and the PDP 11/34; and

(5) Currently 66 terminal ports are connected to the LARS computer to provide interaction with remote sensing software.

The table digitizer provides support for precision registration and a means to enter non-digital ancillary data into the computer's classification criteria. The electrostatic printer/plotter provides support for graphical and gray level image plotting.

2. Research and Analysis Network

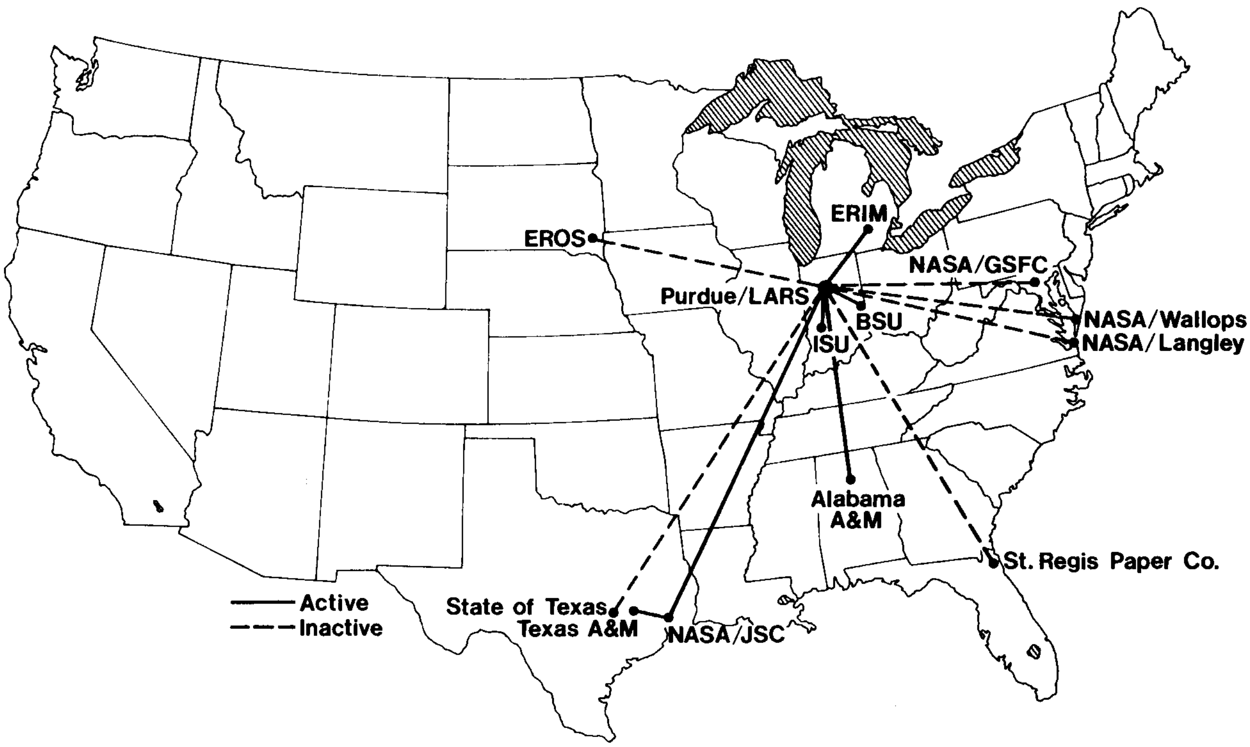


Figure 5. The remote terminal network helps to transfer and exchange technology quickly while also helping to reduce per unit cost.

The capability and flexibility provided by a general purpose machine has allowed LARS to supply data processing to Purdue researchers and simultaneously pursue the establishment of a remote terminal network (Figure 5). This network has been utilized to transfer and pool technologies developed by groups working at several levels of technology generation, from university to government to industry. The procedures, software and data shared by the users of this network have helped to propagate remote sensing technology rapidly, have enhanced the reputation of Purdue University, and have provided tools to researchers at LARS that they would not otherwise have had, while at the same time defraying the cost associated with the high quality of service available to Purdue research projects.

3. Implementation of Software Facilities

Over the years, several software facilities have been implemented to support research. LARS has developed LARSYS and LARSYSDV, multispectral data processing systems and LARSPEC, a processing system for spectroradiometer data. LARSYS Version 3.1 is a fully-documented software system which is a widely recognized standard in the remote sensing community (Figure 6). LARSYS is distributed nationally and internationally through the Federal Government's Computer Software Management and Information Center (COSMIC). LARSYSDV is a partially documented software system containing the new processors, options and other improvements which are continuously added to the ensemble of multispectral analysis capabilities by the researchers at LARS. LARSPEC is a software system developed at LARS to access and analyze data obtained by spectrometer and multiband radiometer systems. Like LARSYSDV, LARSPEC is constantly being upgraded. A number of commercially available software packages for data analysis and display are also available to researchers accessing the LARS computer system (SAS, SPSS, GCS, IGL, SSP, etc.).

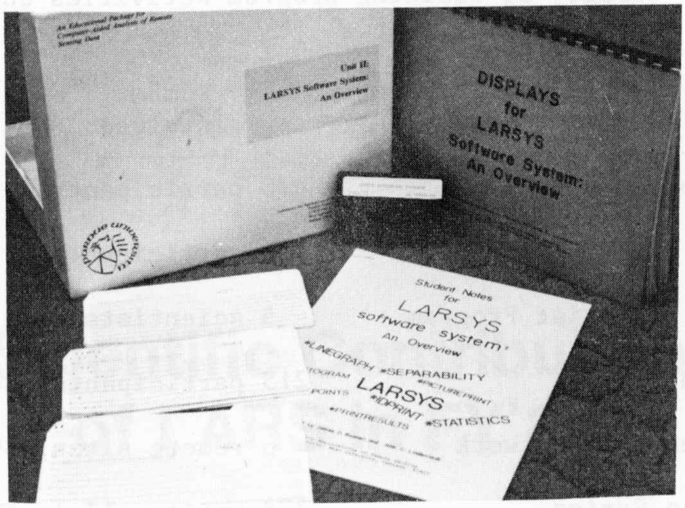


Figure 6. LARSYS is a fully-documented software system recognized as a "standard".

4. Field and Laboratory Instrumentation Systems

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 (Figure 7).

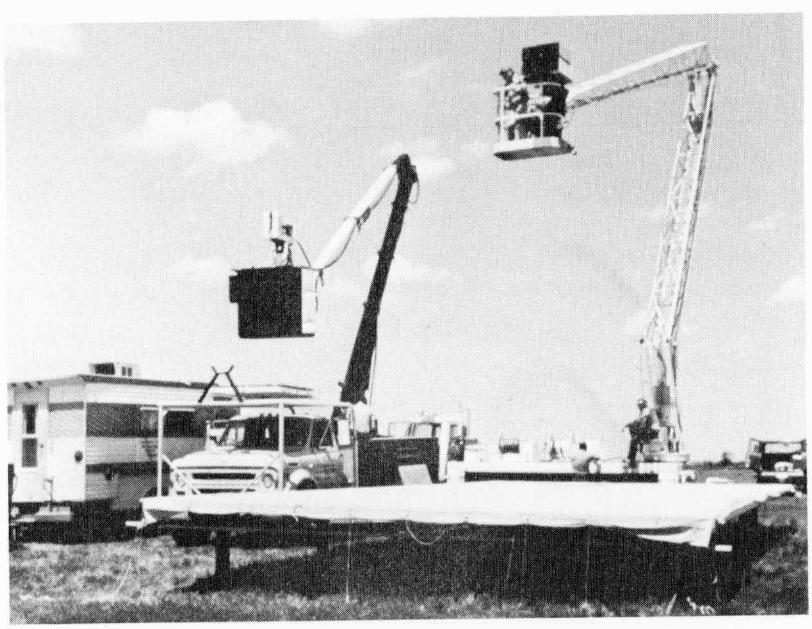


Figure 7. Exotech 20C collects high density spectral data in situ to support basic research studies.

Training Program Summary

Table 3. Summary of training program activities during the 1979-1980 year.

Type of Activity	Number Involved
Basic Short Course	70 participants
Advanced Short Course	19 participants
Visiting Scientist Program	5 scientists from 4 countries
Symposium	215 participants, 84 papers
Remote Terminal Network	6 remote sites, 39 remote ports
Minicourse Series	378 units sold in FY80
Graduate Students	39
Advanced Degrees	9

See pages 50-63 for further details.

Scientific Contributions of LARS in FY'80

Development of Research Capabilities

LARS System Services

1. Background

The primary thrust of System Services has been to provide an excellent research computation facility to meet the needs of Purdue's remote sensing research community. The research data processing environment at Purdue/LARS attracted three additional remote terminal sites during FY80. Several Purdue research scientists in areas other than remote sensing have displayed interest in LARS because of its research-computing orientation and because of a desire to use one of the large number of commercially available software packages which may only be implemented on IBM operating systems.

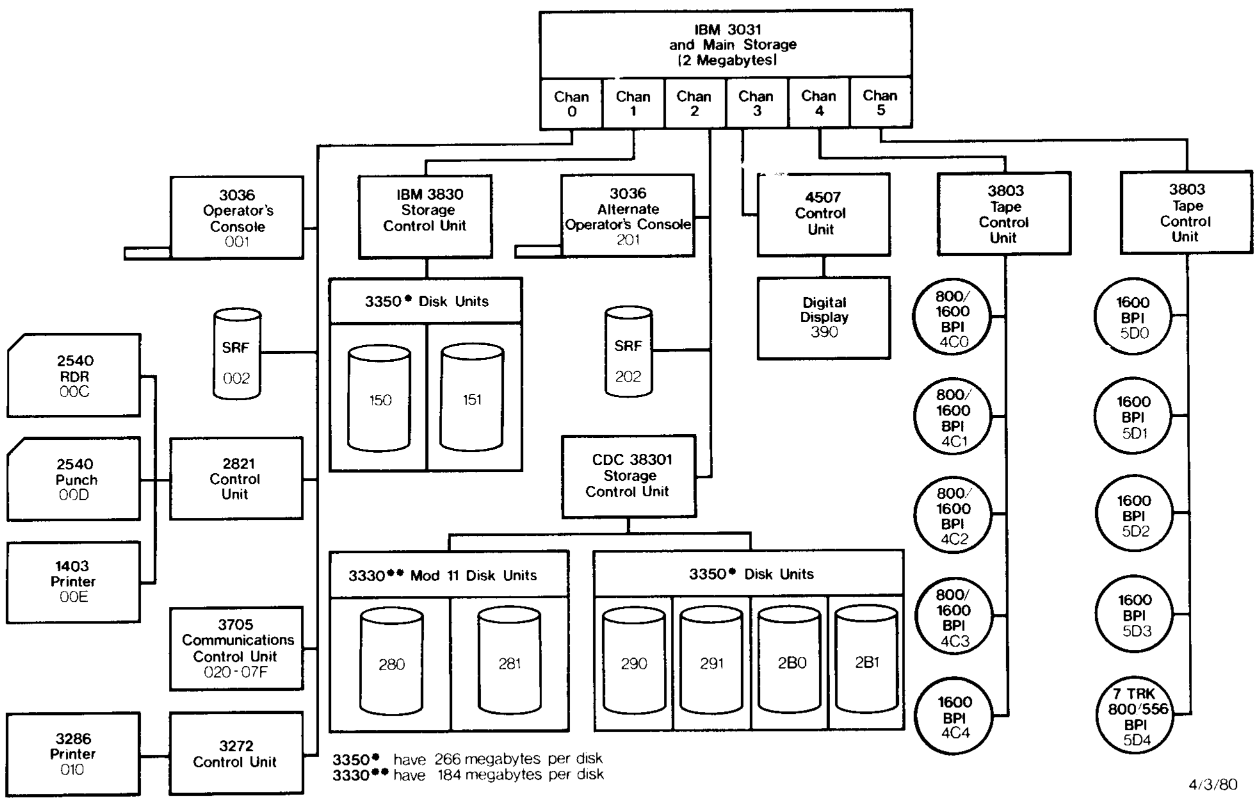


Figure 8. Hardware configuration of IBM 3031 which LARS installed during FY80. The 3031 is roughly three times as powerful as the computer it replaced.

2. New Hardware

Chief among the FY80 System Services' accomplishments was a change in the computer system. In September 1979, the IBM System 370, Model 148 was replaced by an IBM 3031 (Figure 8). The 3031 provides roughly three times the computational capacity but increased total costs only ten percent. The installation of the 3031 was made possible and necessary by heavy, sustained use of the LARS computer facility by researchers at the Earth Observations Division of Johnson Space Center (JSC), LARS and other remote sites. Sharing a computational environment with JSC has improved communication between LARS and its chief sponsor and provided many opportunities for cost savings and software exchange. The additional capacity provided by the 3031 made possible an 80% increase in the amount of computation performed in FY80 over FY79 (Figure 9). In spite of inflation, the effective rate charged for computer usage at LARS was reduced by one-third during FY80.

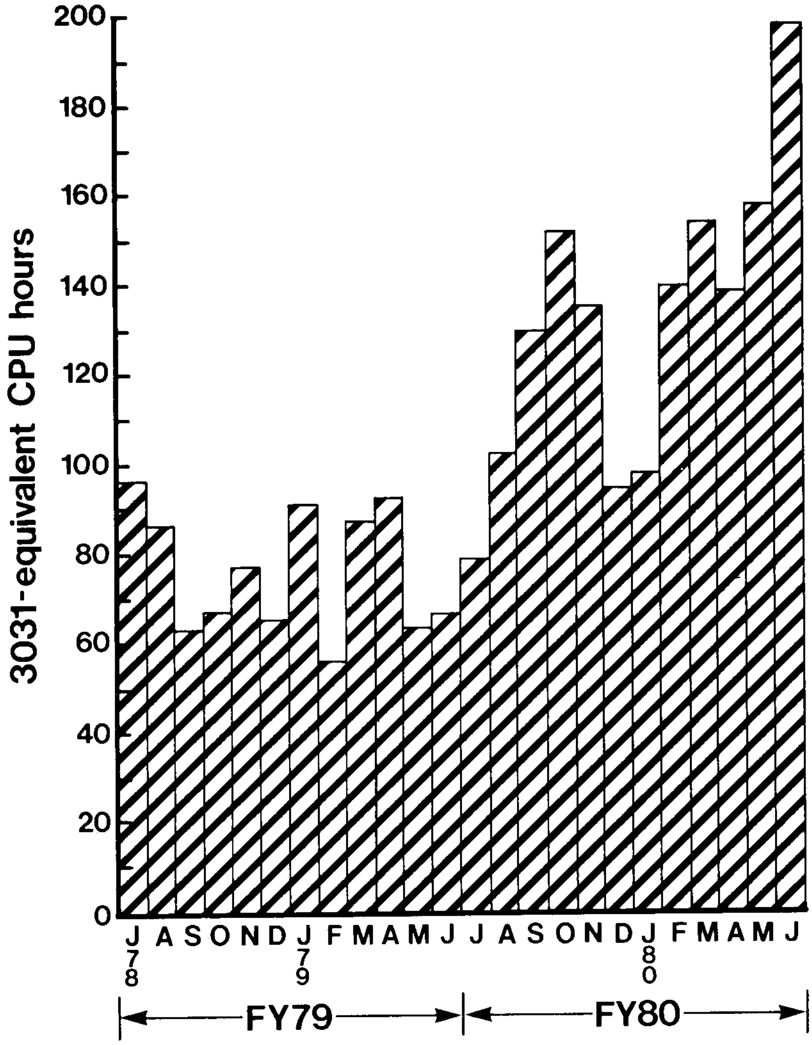


Figure 9. Effective computer usage in FY80 was nearly double FY79 usage.

A second major hardware acquisition during FY80 was the Comtal Vision One/20 color display system (Figure 10). In 1972 LARS installed the first digital display device built. This one-of-a-kind piece of equipment could display up to 16 gray levels of a single multispectral scanner wavelength band. The purpose of the digital display was to display multiband spectral scanner data pictorially in a form with which human interaction was easy.

The Comtal uses color to increase the dimensionality of the data which can be displayed and puts a programmable micro computer under analyst control, making it possible to enhance greatly the efficiency, speed, flexibility and power of the image processing functions through distributed processing.

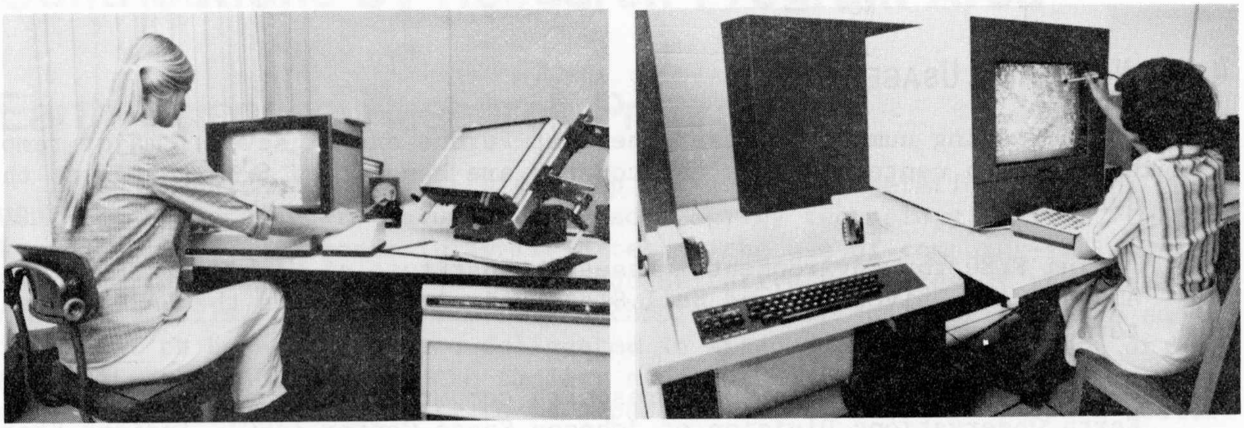


Figure 10. During FY80 LARS replaced its historic Black-and-White Display (right) with a new Comtal Microprocessing Color Display Unit (left).

A high resolution Tektronix 4054 graphics terminal was also acquired during FY80 (Figure 11). The Tektronix already interfaces with some of the graphics packages at LARS and will be utilized by the LARS Multispectral Data Analysis System (LARSYS) and the LARS Spectroradiometer Analysis System (LARSPEC).

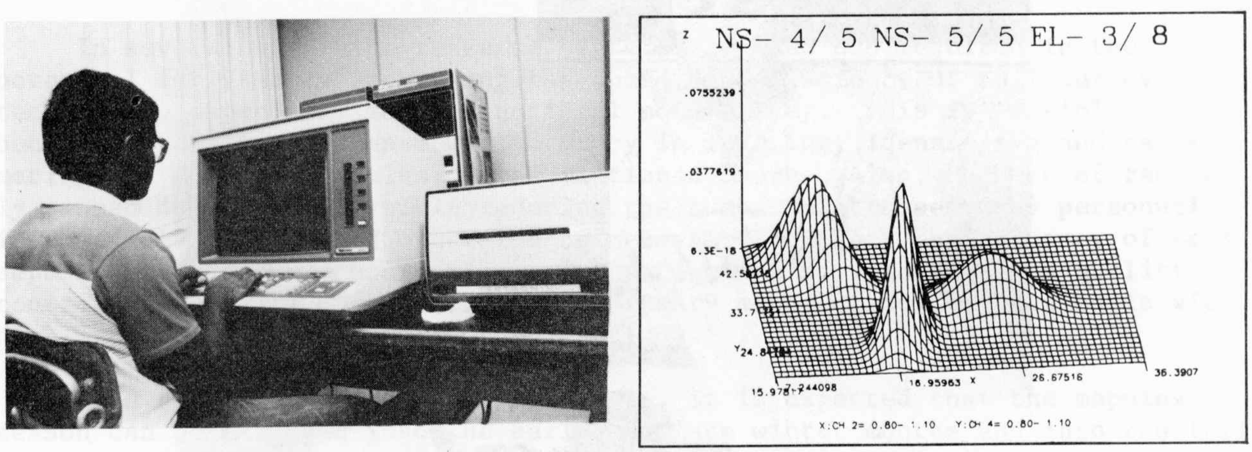


Figure 11. (Left) With only a few commands, SAS/GRAPH allows users to display data in a wide variety of formats. (Right) High resolution graphics output help to train the computer to recognize ground cover types.

3. New Software Tools

Several new software tools were installed on the LARS system to enhance the data processing and display capabilities of LARS users. The Statistical Analysis System (SAS) and a special graphics package designed for the display of data sets and results associated with SAS (SAS/GRAPH) were installed during FY80 (Figure 12). The Interactive Graphics Language (IGL), which interfaces with the Tektronix 4054, has been installed on both the IBM 3031 and the PDP 11/34. The previously acquired Graphics Control System (GCS) has been modified to work with an electrostatic printer for high resolution graphs and with a modified DECwriter to allow users at remote locations to acquire graphics output with a very small investment in specialized hardware.

4. Non-LARS Usage

An increasing number of researchers at Purdue and at several major remote sensing research centers across the country are benefiting from access to the LARS system:

*During FY80 the Environmental Research Institute of Michigan (ERIM), Alabama A&M University and Ball State University joined the LARS remote terminal network.

*LARS has provided the primary research computing environment for the Earth Observations Division of Johnson Space Center (JSC), Indiana State University, and Alabama A&M University as well as Purdue during FY80.

*Twenty-four Purdue departments have established accounts in order to make use of one or more of the LARS System Services (Figure 12).

Figure 12. Sue Schwingendorf accesses the LARS machine through a dial-up terminal.

5. Training

In order for new users from within Purdue University and at the remote terminal sites to become familiar more quickly with the LARS computing environment, a 14 module, tape/slide Introduction to the LARS Computer and Its Operating System has been developed.

Contributions by Research Program Area

Earth Sciences Research Programs

The research results of this group working in cooperation with the SCS, USDA can be expected to revolutionize soil survey technology. First, they have developed and successfully field tested the use of computer-implemented MSS data to attain easily and rapidly quantitative estimates of the areas of different soils. Not only was this accomplished for soil series large enough in extent to be separated and delineated in standard soil survey maps at a scale of 1:15,840, but for the smaller areas of different soils, called inclusions, which are too small to be separated at the standard mapping scales from a more extensive soil series. Where such small but significant 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 this 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. At the same time, the new technique makes possible a great savings in man hours that otherwise would be spent making such estimates by traversing the land.

In several ways, 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 by personnel in the field which would otherwise be necessary to check the accuracy of soil separations and their boundaries. The data are also valuable as a quality control aid and are being used as the primary means of delineating soils with high iron content in Jasper County, Indiana.

As a result of using these new tools, it is expected that 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. Utilization of the spectral data allows the soil scientists to anticipate the soils and the subtle differences between them before entering the field instead of reacting to the situation at the time of mapping.

As a direct result of these accomplishments, the SCS is now beginning to utilize remote sensing techniques as standard aids in the national soil survey program.

Research in this area has continued as a cooperative effort between LARS scientists, their graduate students, and scientists of the USDA/Soil Conservation Service. The past year saw an expansion in the application of computer-aided analysis of Landsat multispectral data as an aid in expediting the soil survey and land resource inventories. Efforts were continued to quantify the basic interrelationships between the spectral characteristics of soils and their important physical and chemical properties. Because of the understanding of these fundamental scientific relationships, increased numbers of agencies are utilizing remote sensing technology as a tool to inventory and monitor our valuable land resources.

1. Application of Remote Sensing to Inventorying Soils

Significant results from these researches include:

- An improved capability of using Landsat data (MSS and RBV) to expedite the mapping of soils for 2nd and 3rd order surveys in both humid and semi-arid moisture zones.

- Capability of using computer-aided analysis of Landsat MSS data for inventorying severely eroded soils.

With the urgency throughout the country to complete the modern soil survey at the earliest possible date, many agencies world wide, both private and public, are carefully following the successful new techniques and tools being devised at LARS to expedite soil mapping programs. One such new mapping tool is a series of maps, derived from computer-aided analysis of Landsat MSS data, depicting the pattern and boundaries of the spectral characteristics of soils on the landscape. These spectral maps contain information not found in conventional black-and-white aerial photographs since one-half of the data is represented by wavelengths in the near infrared portion of the spectrum. The individual spectral soil classes comprising these maps are correlated with meaningful soil properties such as surface texture, color, organic matter content and internal drainage.

Whereas Jennings County, Indiana, was the first county in the nation to be mapped using aerial photographs as base maps, Jasper County, Indiana, is the first county in the nation to be mapped using satellite-derived spectral maps as an aid in the county soil mapping program.

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 13. This portion of a spectral map of Jasper 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 delineated in the field by traditional methods. Each symbol in Figure 13 represents an area of approximately 0.2 hectare, a much more detailed and smaller area than is economically feasible for a soil surveyor to separate and show in a conventional 2nd order survey (minimum map unit size 0.6 - 0.4 hectare) using traditional methods. Currently, this newly-developed technology is leading to the efficient production of a more accurate soil survey for Jasper County, Indiana. This survey may become the prototype for all future SCS directed surveys.

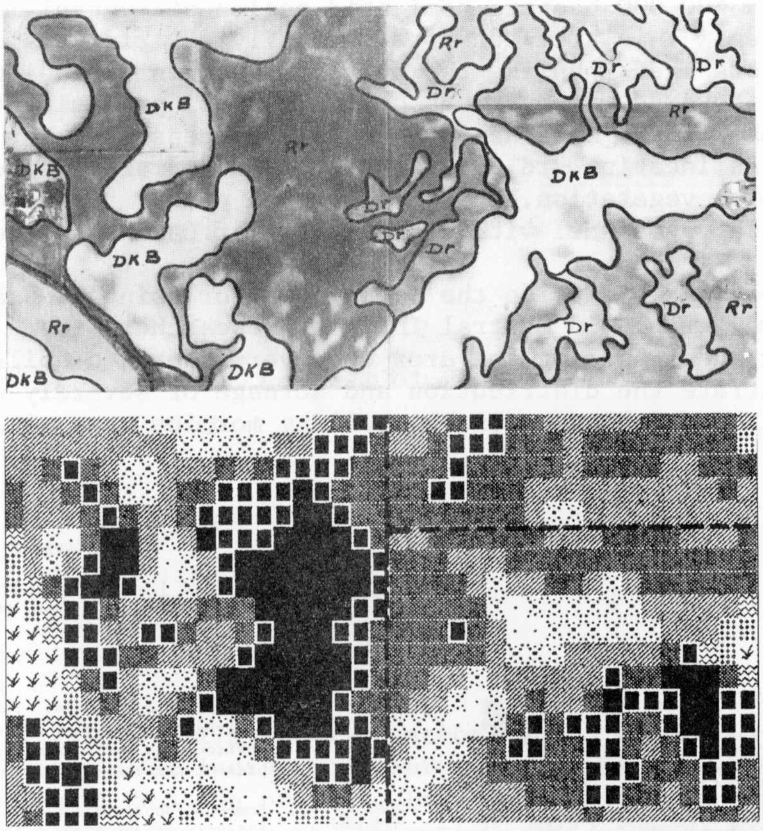


Figure 13. A comparison of map units delineated by soil surveyors in the field (above) and the spectral soil map (below).

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.

Unlike the light/dark pattern of Alfisol (timber)/Mollisol (prairie) soils in Jasper County, Indiana, the soils in Ford County, Illinois, are predominantly very dark Mollisols. However, once again, a meaningful delineation of soils was accomplished. This illustrated the ability of computer-aided analysis of Landsat MSS to separate very similar soils within a humid climate. During this effort researchers introduced the manual interpretation of return beam vidicon (RBV) imagery as a tool for delineating major soil boundaries and preparing general soil maps. This Landsat imagery is available at a scale of 1:125,000 and is geometrically corrected, thus providing an excellent initial overview of the area to be surveyed. The spectral maps for Ford County are in the process of being transferred to the SCS personnel in Illinois for incorporation into the survey effort.

To further explore the application of this technology as an aid to soil survey, the SCS and LARS cooperated in producing spectral maps at a scale of 1:24,000 for a 500,000 hectare semi-arid region of central Idaho known as the Big Desert Area. This area consists primarily of Aridisols dissected by lava flows of various ages. Unlike the cultivated soils in Indiana and Illinois, this area was covered with various desert shrubs, predominantly sagebrush. Preliminary use of the maps has proven very successful. Not only are they a great aid in delineating 3rd order (2.5 to 260 hectare) map units, but, since they also depict vegetation, they have proven useful to range management and wildlife habitat personnel within the Bureau of Land Management.

While working to develop the techniques for using Landsat MSS data to aid the soil survey effort in Central Indiana, researchers found a potential means for surveying and measuring the area of severely eroded soils. Figure 14 and Table 3 illustrate the distribution and acreage of severely eroded soil in a 640 acre (271 hectare) tract in the rolling moraine area of Jasper County, Indiana.

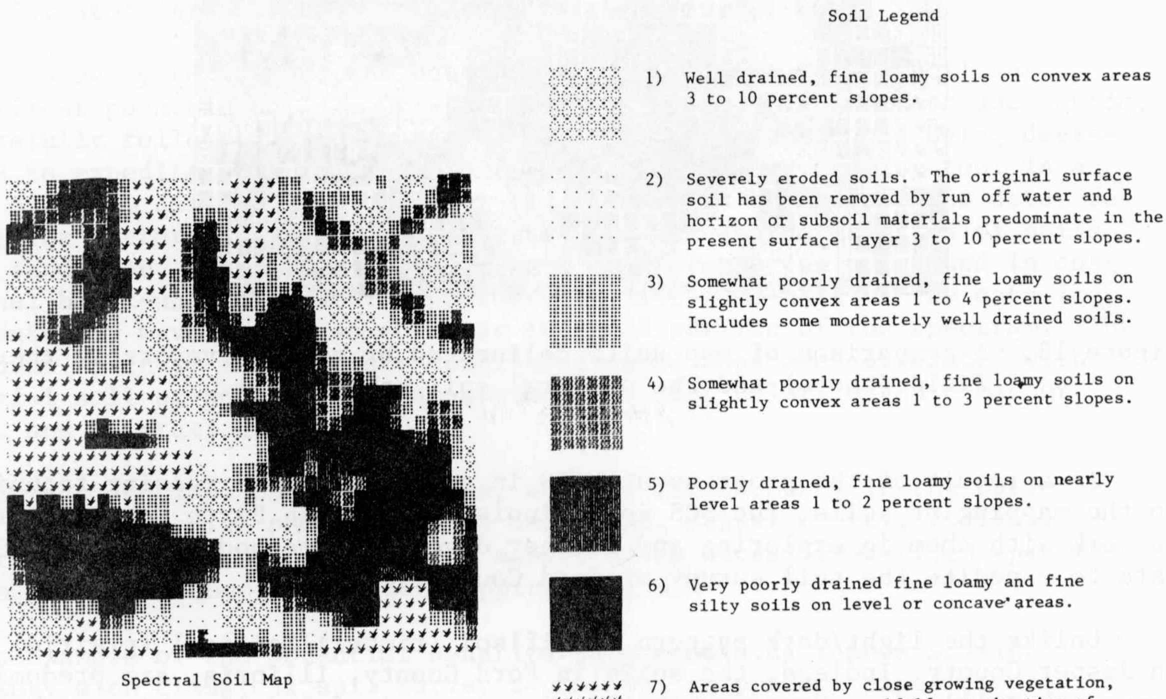


Figure 14. Delineation of severely eroded soils using Landsat MSS data. Each data point represents 0.46 acres or 0.19 hectares.

Table 4. Statistics of severely eroded soils using Landsat MSS data

Area and Extent of Map Units
Jasper County, Indiana
T 29 N R 6 W Sec 10

Group	Points	Acres	Hectares	Percent
1	218	103.8	42.0	16.2
2*	177	84.3	34.1	13.2
3	158	75.2	30.5	11.8
4	144	68.6	27.8	10.7
5	173	82.4	33.4	12.9
6	211	100.5	40.7	15.7
7	263	125.2	50.7	19.6
Total	1344	640.0	259.1	100.0

*Severely eroded class

The separation of eroded soils was also accomplished in Whitley County, Indiana, and in the Ford County, Illinois, soil survey project. Through a continuing Agricultural Experiment Station project, LARS scientists are attempting to relate significant soil properties such as the contents of organic matter, iron oxide, sand, silt and clay and soil color to the spectral characteristics of these eroded soils. Interest in the potential of this promising technique is quite high among such agencies as the USDA/Soil Conservation Service and the Indiana State Soil and Water Conservation Committee. These agencies are primarily responsible for the inventorying, monitoring and control of erosion within the State of Indiana.

This technology has the potential to develop into a powerful tool for maintaining our valuable land resources and helping to reduce sediment loads within our lakes and stream systems.

2. Analysis and Interpretation of Relationships between Physical and Chemical Properties of Soils and their Spectral Properties

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 completed in FY80. 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 have been optimized in the compilation and publication of an "Atlas of Soil Reflectance Properties," AES Research Bulletin 962, May 1980. Graphic display of duplicate spectral curves has been completed for 242 "Benchmark" soil series.

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, as shown, for two common Indiana soils (Figure 15). The spectral data were divided into ten spectral bands to be used in a regression analysis. Correlations for the 481 soils for four soil parameters were found to be much higher when grouped with specific moisture zones or temperature regimes. 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 semi-arid mesic soils.

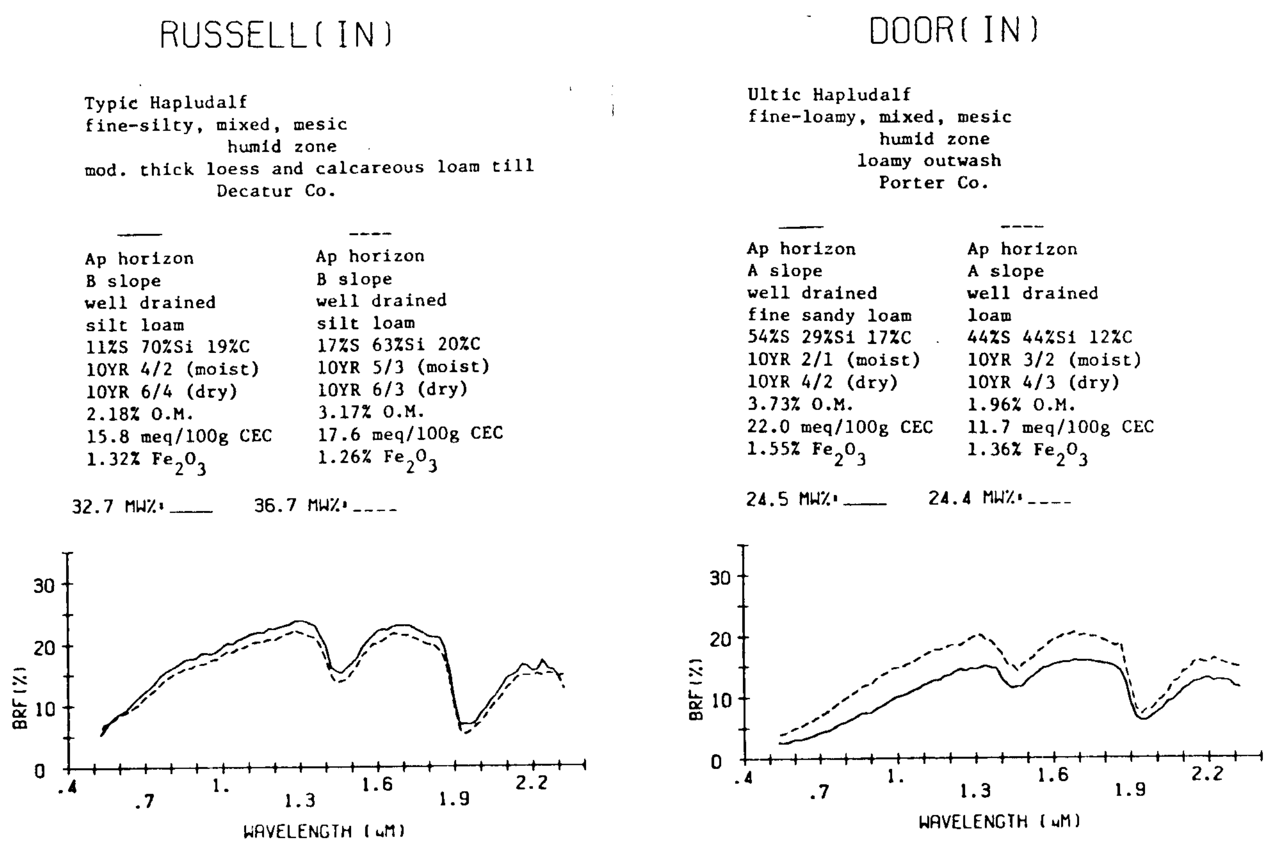


Figure 15. Spectral characteristics of two common Indiana soils.

The spectral characteristics of these 481 soils were found to represent five (5) major types of curves. The shape of these curves tends to be indicative of many of the physical and chemical properties of the individual soils. Two of these curve types have not been previously described. Figure 16 shows a typical Type 1 and Type 2 spectral curve. Type 1 curves exhibit rather low reflectance with a slightly increasing slope which gives them their characteristic concave form from 0.52 to about 1.0μm, seen to be nearly constant. Soil reflectance curves for certain Mollisols and Vertisols are seen to follow this general curve type.

Type 2 curves are characterized by a generally decreasing slope to about 0.6μm, followed by a slight dip from 0.6 to 0.7μm, with continued decreasing slope beyond 0.75μm. The result is a typical convex shaped curve from the visible to 1.3μm. Some soils from the Alfisol soil order and certain Ultisols can be seen to exhibit this curve shape. It has been observed that Type 2 soils tend to be better drained and lower in organic matter content than Type 1 soils.

A continuation of this work should provide valuable insight into the significance of spectral data and aid in their use as a tool in soil investigations.

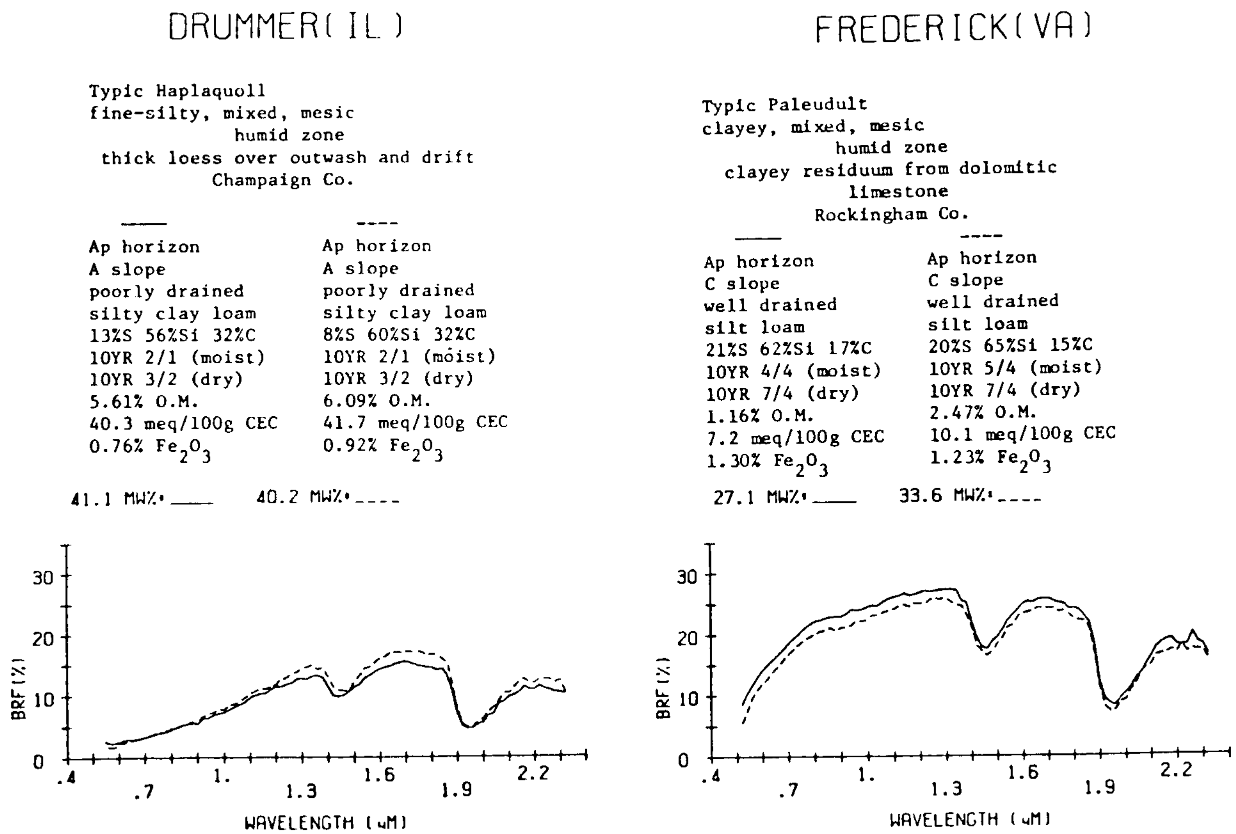


Figure 16. Examples of variation and spectral curve types, type 1 (left) and type 2 (right).

INFLUENCE OF SOIL-MOISTURE ON SOIL REFLECTANCE

Encouraged by the discovery that loss in reflectance from the oven dry state to field capacity for 15 surface soils from central Indiana was related to their oven dry reflectances, the experiment was repeated with surface samples of 57 representative soils from over the United States. The soils were selected to represent a wide range in color, texture, organic matter content and iron content. For all 57 soils an excellent correlation was found at the 1.92-2.02μm wavelength band (Figure 17). It is believed that the smoothness of the curve results from the high absorption of radiant energy characteristic of this band.

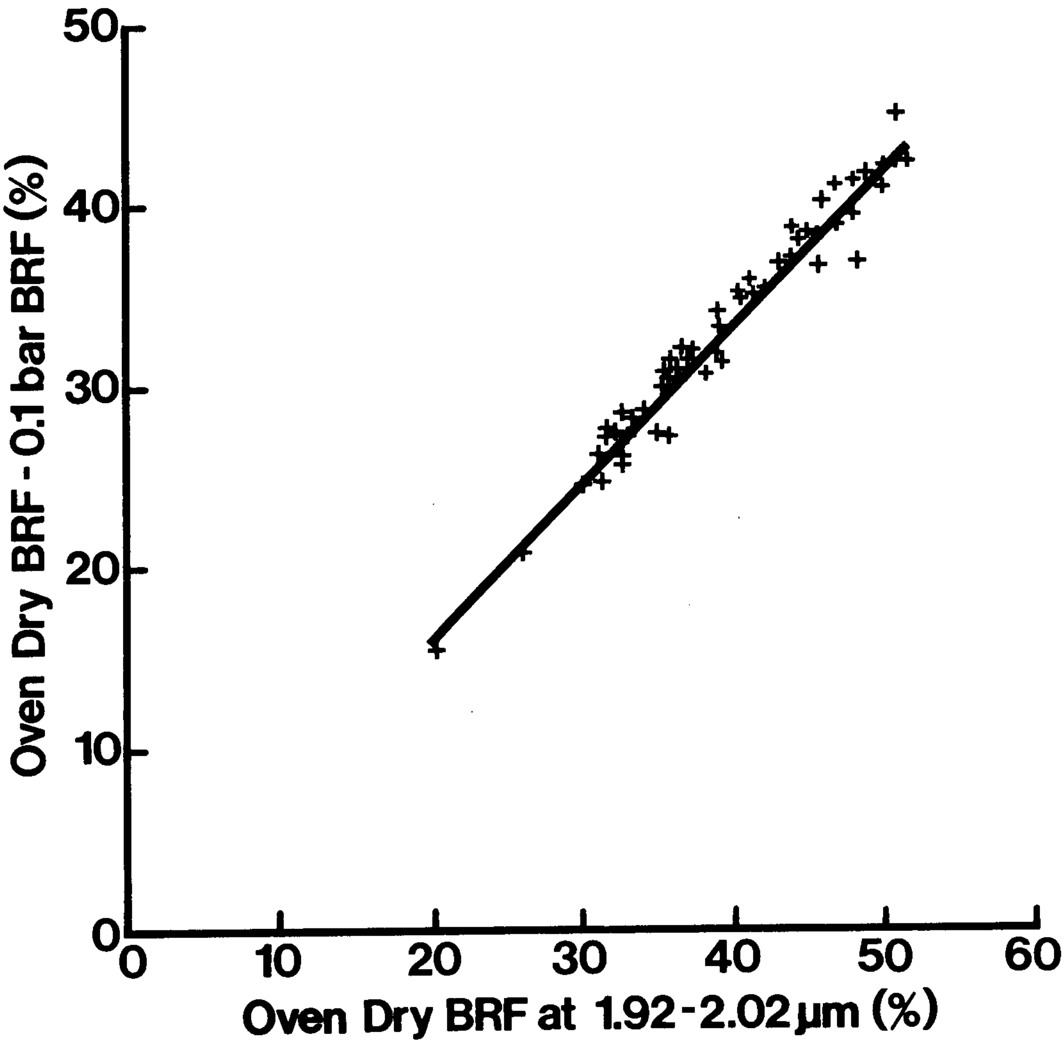


Figure 17. Regression of loss in reflectance (oven dry BRF% - 0.1 Bar BRF%) over oven dry BRF% at 1.92-2.02μm for 57 United States soils representing a wide range of colors, textures, organic matter content and iron content.

Crop Inventory Systems Research Programs

From Biblical times when Joseph convinced the Pharoah of Egypt to store grain during seven years of plenty for seven years of famine, history has recorded large and irregular fluctuations in crop production throughout the world. Even in the past two decades as new, higher yielding crop varieties and improved production practices were being adapted, grain production has varied dramatically. Timely and accurate global crop production forecasts are important inputs to more effective food production, processing, distribution, and marketing decisions. Knowledge of global agricultural conditions is of particular importance to the U.S., the world's largest grain exporter. Lack of accurate, up-to-date information on grain supplies means planting, buying-selling, storage-transportation, and export decisions are made with incomplete information. But relatively few countries have reliable methods for gathering and reporting crop production statistics and the quality and availability of information varies widely from country to country.

During the past decade we have learned that remote sensing from aerospace platforms can provide quantitative, timely information about crop production around the world. However, rigorous research and development is required if the potential of multispectral remote sensing for monitoring and inventorying crop production is to be fully achieved.

The primary mission of the Crop Inventory Research Program is to conduct basic and applied research to accomplish the following goals:

- To increase our quantitative understanding of the radiative properties of crops.

- To research and develop procedures for obtaining crop production information from remotely sensed spectral measurements, together with meteorological, soils and ancillary data.

A secondary mission is to assist in the development and application of remote sensing techniques by:

- Working with various public and private users to assess the effectiveness of remote sensing technology in supplying their crop production information needs.

- Actively participating in the technology transfer and educational programs of Purdue University.

Following the successful completion of the Large Area Crop Inventory Experiment (LACIE) in 1978, a major research and development program, the Agriculture and Resources Inventory Survey Through Aerospace Remote Sensing (AgRISTARS), was initiated by USDA, NASA, and NOAA. We are actively involved in the Supporting Research Project of AgRISTARS conducting tasks on (1) field research of the spectral properties of crops, (2) formulation of crop development and condition models utilizing spectral inputs, and (3) development and evaluation of training, classification, and sampling approaches for use with Landsat MSS data.

The specific tasks and accomplishments of FY80 are described in the following paragraphs.

1. Field Research: Experiment Design, Data Analysis, and Data Acquisition

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. Purdue/LARS is responsible for the technical design and coordination of the AgRISTARS supporting field research and has major roles in the data acquisition and analysis.

During FY80 our primary activity was the acquisition and analysis of spectral and agronomic measurements of corn and soybean canopies. Data were acquired from several experiments at the Purdue Agronomy Farm, where our objectives have been to:

- Determine relationship of spectral response to crop development stage.
- Determine relationship of spectral response to amount of vegetation (LAI, biomass, % cover, etc.)
- Determine effects of stress (moisture, nutrition, disease) on spectral response.
- Determine effects of agronomic treatments (variety, plant population, planting date) on spectral response.
- Determine effects of soil background (color, moisture, roughness) on spectral response of crops.
- Determine effects of view angles and solar illumination angles on reflectance in relation to canopy geometry of soybeans.

Additionally, spectral and agronomic data have been acquired at test sites in Iowa and North Dakota to study the spectral discriminability of corn, soybeans, spring wheat, and barley as a function of crop development and cultural practices.

Key results of analyses conducted during the past year quantify (1) the reflectance characteristics of corn and soybeans as a function of development stage, soil background condition and agronomic practices; (2) the relationship of leaf area index to reflectance of wheat, corn, and soybeans; and (3) the effect of nitrogen deficiency on the spectral response of corn and winter wheat. In addition, a model relating solar illumination angle, row azimuth direction and canopy geometry has been developed. Studies of the polarization properties of crop canopies demonstrate that they may be indicative of development stage and condition (Figure 18).

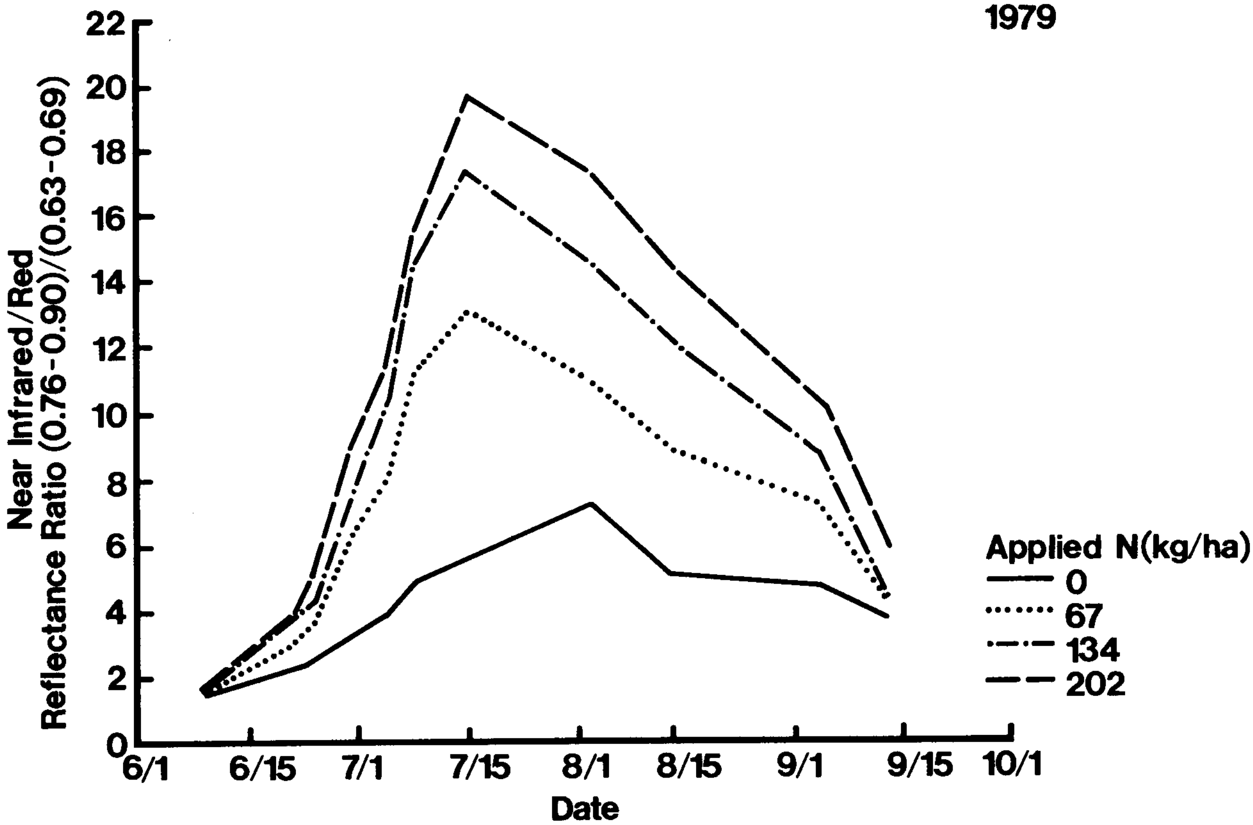
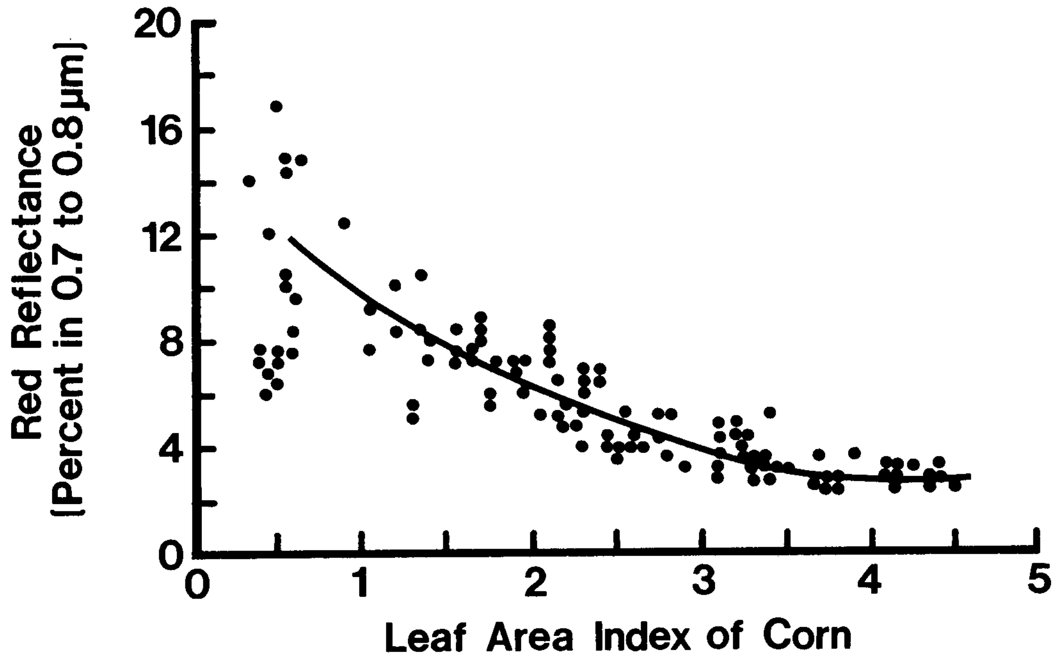


Figure 18. Effect of nitrogen fertilization on the reflectance properties of corn canopies. The changes in reflectance were due to variation in leaf color (chlorophyll concentration) and canopy structure (leaf area and percent soil cover). The results indicate the potential of using multispectral remote sensing to monitor crop condition.

2. Spectral Inputs to Corn and Soybean Yield Models

In a project initiated in 1979, the potential inclusion of spectral data to corn and soybean models is being investigated. It is hypothesized that remotely sensed observations taken 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 (Figure 19).



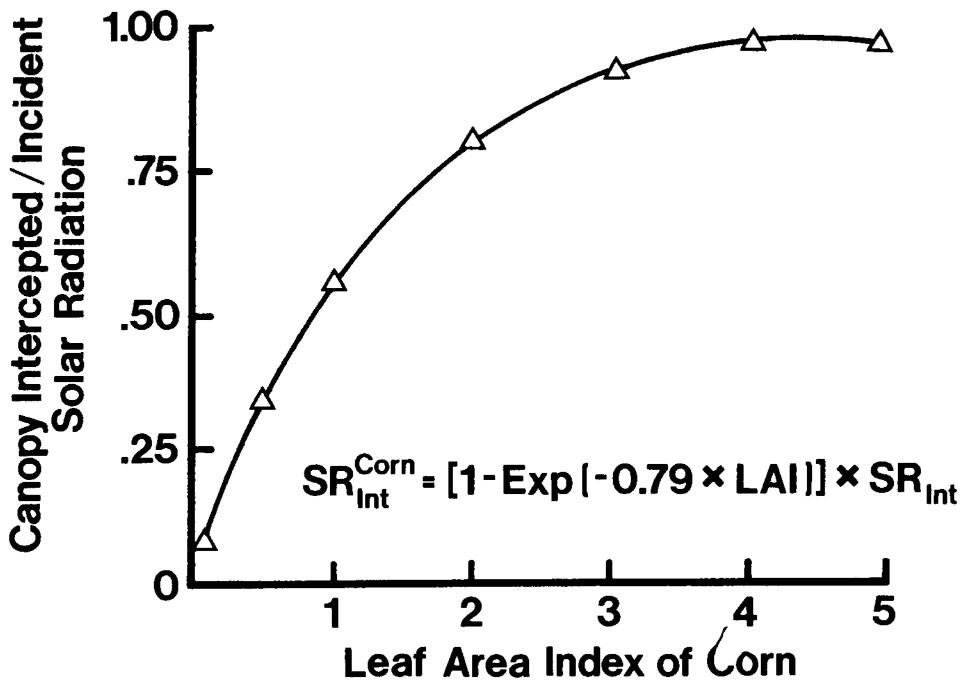


Figure 19. Field studies have shown a strong relationship between leaf area index and spectral reflectance (top). From these measurements it should be possible to predict the amount of radiation intercepted by crop canopies. This capability would for the first time permit sensing of a key agronomic variable for input to crop growth, development and yield models for large areas.

Preliminary results indicate that the percent of solar radiation intercepted by a crop canopy can be estimated from spectral data. This variable has potential usefulness in crop yield models, and evapotranspiration models. A test of the concept is currently being conducted using Landsat MSS and crop data from several Corn Belt test sites (Figure 20).

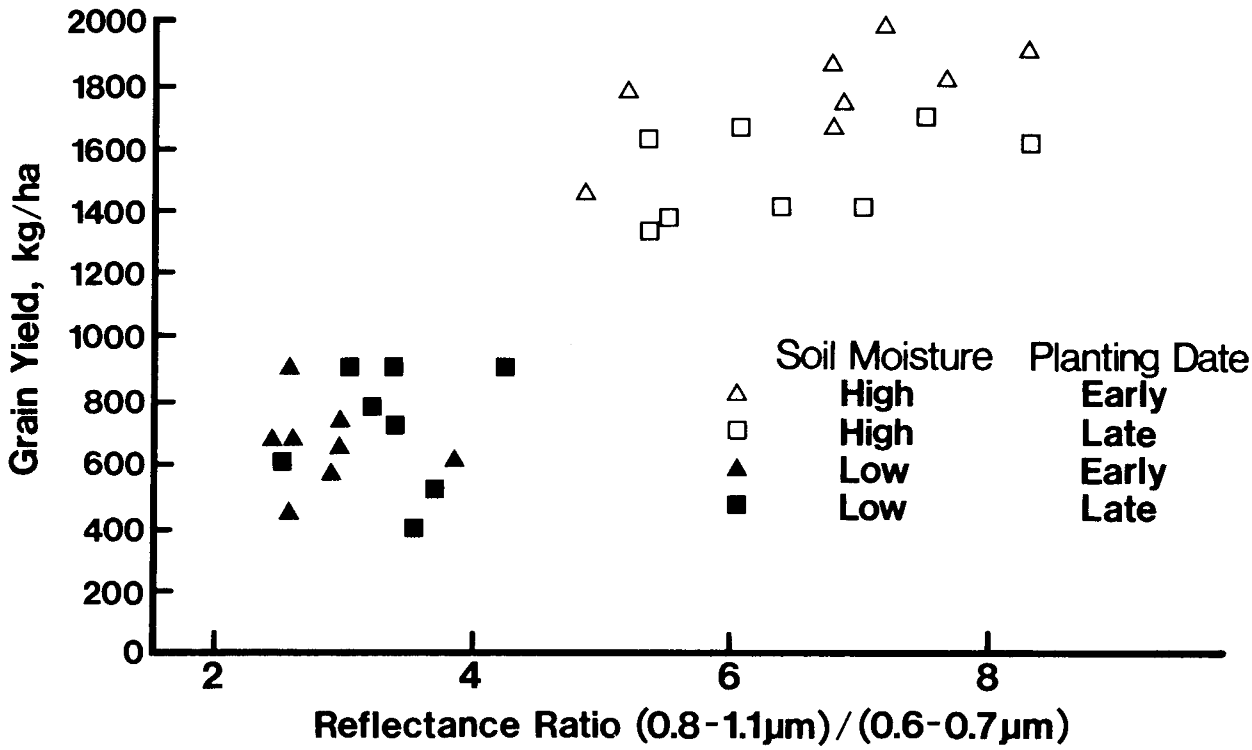


Figure 20. Illustration of the relationship of grain yield to the reflectance properties of spring wheat canopies as influenced by available soil moisture and planting data. The changes in reflectance were associated with variation in leaf area index and development rate. Spectral variables could become a key input to crop growth and yield prediction because the spectral response integrates the effect of many cultural and environmental factors and may be determined on a field by field basis over large geographic regions.

3. Spectral-Meteorological Crop Development State Estimation for Corn and Soybeans

Crop calendars describe the progression of a crop through detectable or agronomically significant events in its life cycle. The major approaches in the literature to estimate crop development are (1) normal or average phenology, (2) meteorologically-based models, and (3) spectrally-based models. Each of these approaches has its own advantages and disadvantages. No one method adequately predicts crop development.

In this project a combination of features from all models is proposed. Meteorological models will provide basic predictions of crop phenology for crop reporting districts, and spectral models will be used for local adjustments. The prediction of crop phenology will be an iterative process using as much information as is available.

The products of this research and development effort will be used by analysts in AgRISTARS to help identify crops from their spectral appearance first in the U.S. and later in foreign areas.

4. Application and Evaluation of Landsat Training, Classification, and Area Estimation Procedures for Crop Inventory

This three-year project resulted from a proposal submitted to NASA. Its overall objective 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. During the past year several significant results have been obtained:

- No significant differences were found in performance of five classifiers evaluated on several agricultural data sets, indicating that training the classifier is relatively more important for obtaining accurate classifications.

- High classification accuracy of corn and soybeans was not achieved until after corn had tasseled. It was further found that two dates of Landsat data, near emergence and after tasseling, provide a minimal set for accurate identification of corn and soybeans.

The current topics under study in this area include: (1) comparison of several methods for obtaining training statistics, (2) relationship of classification performance to scene characteristics, and (3) assessment of several full-frame sampling technologies (Figure 21).

5. Research in Sampling and Aggregation for Landsat Crop Inventories

During FY80, sampling and aggregation work was initiated in support of the AgRISTARS program. In particular, a task was defined to determine the optimal level for combining area and yield estimates to make estimates of production.

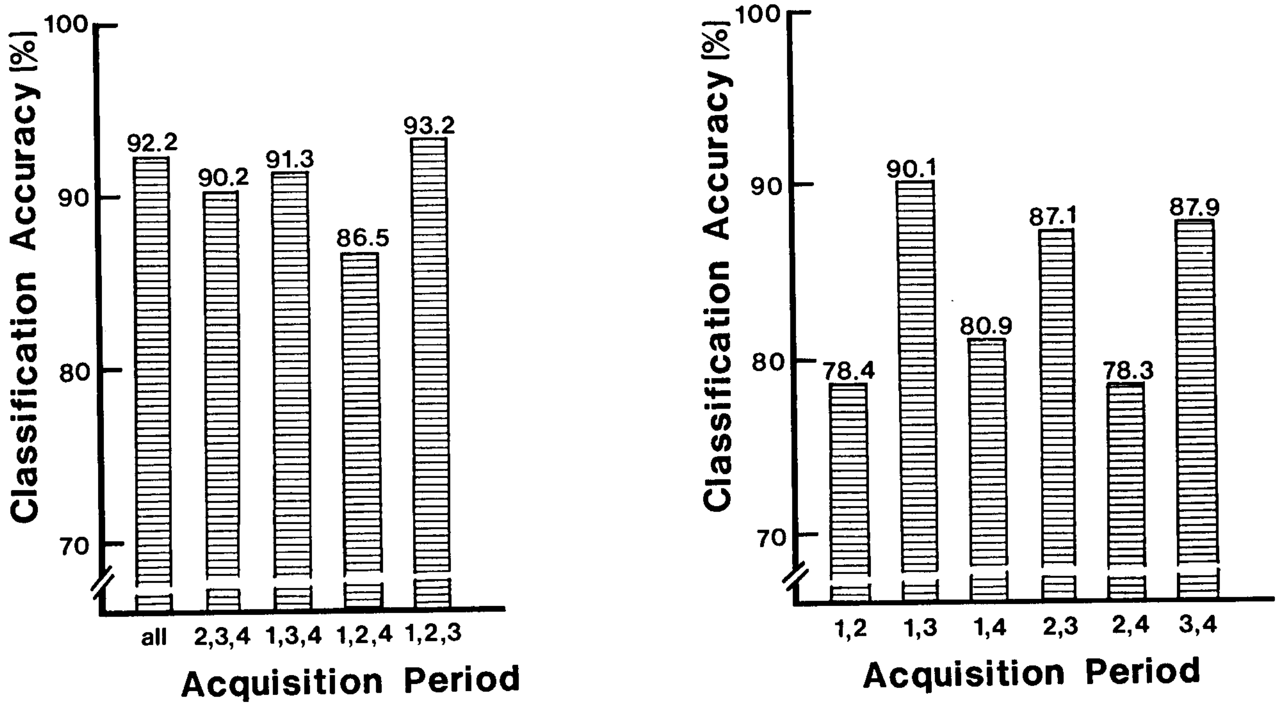


Figure 21. Comparison of accuracy of corn and soybean identification over seven test sites as a function of Landsat data acquisition period (crop development stage) during the growing season. The combination of an early season acquisition near crop emergence and an acquisition after tasseling of corn were required to maximize performance.

The eventual aim of crop inventory studies is production estimation, not area or yield estimates alone. Production estimates can be made only at a level where area and yield strata intersect. The variance of the production estimates is dependent upon the means and variances of both acreage and yield in the stratum. Thus, it is important that the stratifications for area and yield estimation be coordinated and that the levels for aggregation be selected so that acceptable variances are obtained.

6. Remote Sensing Experiments for Analogous Vegetative Areas in the United States and the Soviet Union

This project, sponsored by NASA, called 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 fourth year of a multi-year study and was 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 Kirsk Oblast of Russia were selected and data for three crop years were collected, processed and analyzed. The study, completed in FY80, concentrated on measuring the spectral reflectance of wheat and the agronomic factors affecting its growth and development. Data were exchanged by the two countries and the Soviet data, along with data from the U.S. test site, were analyzed.

Measurements Research Programs

The measurements program area was established at the founding of LARS in 1965 as one of the basic components of a research program in remote sensing. Originally concerned with the relationships between laboratory and field data, the research program has developed a significant data acquisition capability of its own. The emphasis is on field data acquisition, field instrumentation development, basic research, the physical aspect of remote sensing, and spectral data handling and analysis procedural developments. During the LACIE program operated by NASA the measurements program has featured field data acquisition, but more recent research programs have featured a return to the study of basic problems in remote sensing instruments and target characterization. A basic study of such problems is required to support the technological developments in remote sensing during the 1980's.

During FY80 the following activities were pursued in the measurements program area:

1. Field Data Acquisition and Preprocessing

The LARS field data acquisition capability centers around two basic instrument systems, namely, the model 20C wide range spectral radiometer and the model 100 multiband radiometer. Both of these instruments are truck mounted. The model 20C is mounted on a mobile aerial tower, whereas the model 100 is mounted on a specially developed pick-up truck platform. During FY80 special instruments necessary to accurately access proper meteorological conditions for data acquisition were developed for the model 20C system. Also, a special, relatively low cost boom was developed for the model 100 system that permits the acquisition of data at appropriate altitudes over crop canopies of interest. The model 100 system has also been equipped to simultaneously acquire boresighted thermal and photographic data with the multiband radiometer data acquired by the model 100 instrument.

A Tektronix model 4054 graphics computer was obtained by the Laboratory during FY80 and special software is being developed by the measurements program area for the graphics computer to enable it to process field spectral data in a variety of formats. Easy interface with the spectral data by the analyst has been found to be an essential ingredient in the successful analysis of continuous-spectral and multiband-spectral data. Considerable effort has been invested in the continuing development of the LARSPEC software system that is used in the reformatting, preprocessing, and analysis of spectral data. This software system has been modified to allow the convenient inclusion of ancillary data into the spectral-data base. The spectral-data library that is controlled by LARSPEC now contains over 160,000 calibrated, characterized spectra available for analysis by user scientists and engineers.

During the past and current growing season the LARS field data acquisition systems have been deployed at the Purdue University Agronomy Farm while conducting a series of integrated experiments on wheat, corn, and soybeans. Additionally, correlated experiments at test sites located in North Dakota and Iowa are being conducted with a spectroradiometer mounted on a helicopter.

The data from the helicopter are also being included in the LARS spectral-data library. All of the data from all of the instruments (truck-mounted radiometers and the helicopter-mounted spectroradiometers) are calibrated, correlated, and verified before being placed in the spectral-data library. The data in the spectral-data library are available to the remote sensing community by issuing data requests to NASA.

2. Instrument Development

During FY80 an eight-band multiband radiometer was specified by measurements program area engineers, and the instrument (designated Model 12-1000) is being constructed by a commercial vendor. The instrument is scheduled for delivery early in FY81 (Figure 22). The experience obtained with the model 100 multiband radiometer system was a primary motivator for the development of the specifications for the eight-band system. The eight-band radiometer will be mounted on the pick-up truck system mentioned above and will obtain data that are easily correlated with data from the thematic mapper scanner that is to be launched into earth orbit sometime in calendar year 1983. A special data logger that will digitize and store the data produced by the model 12-1000 radiometer has been designed and is being constructed by measurements program area technicians. The data-logger system features a solid state memory that can be detached from the data-logger and will retain its data for a later interface with the digital computer that will be used to reformat and analyze the data. Also, a special camera system that takes and automatically numbers photographs of the scenes under study by the multiband radiometer has been developed along with a controller that integrates the system functions of the multiband radiometer, camera system, and data logger.

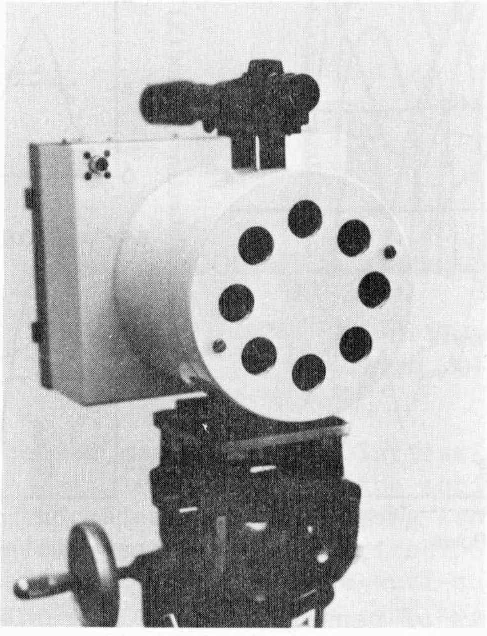


Figure 22. Prototype multiband radiometer for remote sensing field research.

Previously, an instrument had been proposed that would be capable of measuring available soil-moisture profile utilizing a UHF technique without disturbing the soil surface. The available soil-moisture profile, in principle, can be measured to approximately a depth of one meter below the soil surface to a resolution of approximately ± 5 centimeters. This project has been revived and proposals prepared to acquire funding for the development, design, and construction of the instrument. The instrument development project is expected to commence during FY81.

3. Basic Scene Studies

During FY80 a detailed program was continued concerning the relationship between illumination and view angles upon the apparent reflectance of vegetative canopies. A data set acquired over spring wheat at Williston, N.D., in which the reflectance factor at several illumination and viewing angles was measured, has been analyzed in detail. Additional angle data obtained with the model 100 system over winter wheat and soybeans is being studied using similar procedures to those developed for the spring wheat data. Also, the effects of row direction in soybeans is being studied using special plots and scene manipulating devices. The effects of sensor altitude with respect to row separation in soybeans and corn have also been carefully studied and documented (Figure 23).

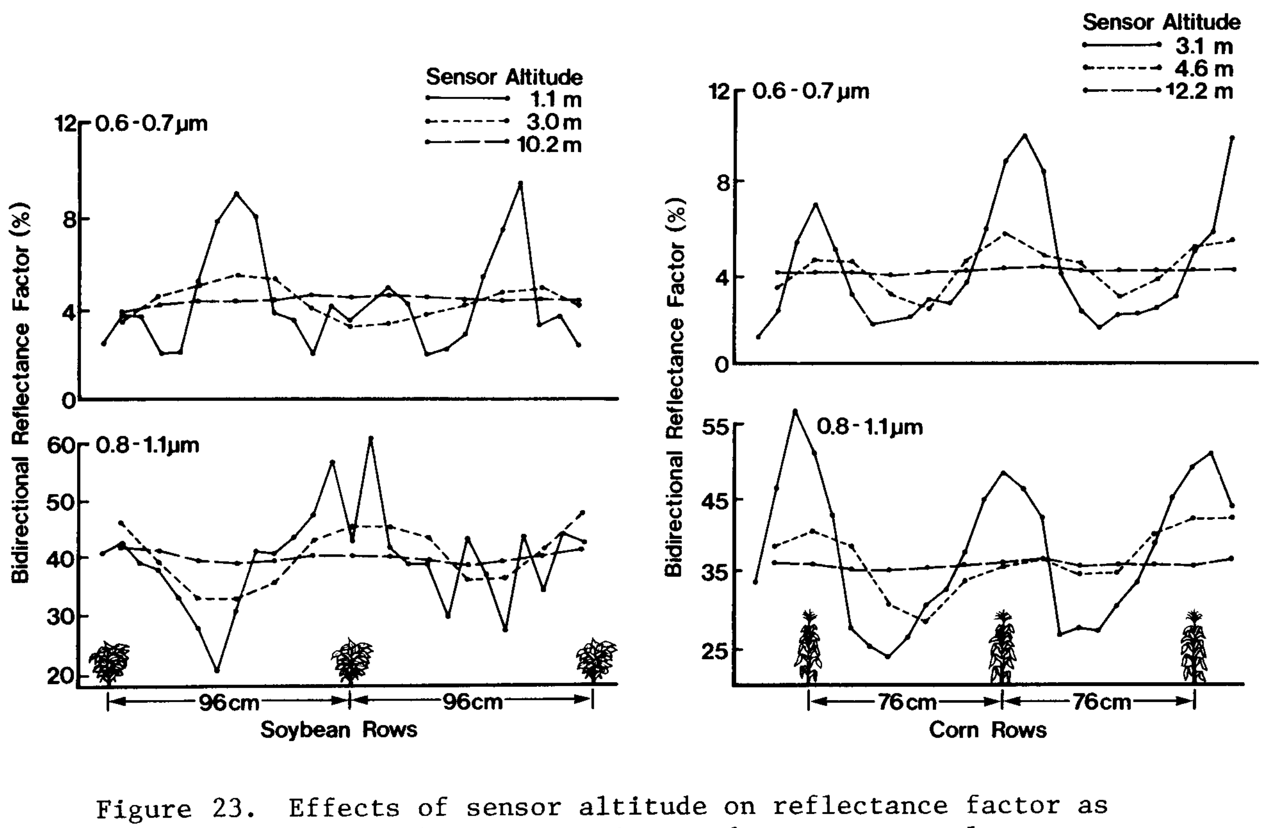


Figure 23. Effects of sensor altitude on reflectance factor as down-looking sensor is moved across several rows.

Theoretical predictions of the effect of canopy geometry upon the polarization of reflected radiation continues. There appears to be a considerable amount of information concerning basic crop status in the polarization of the reflected radiation from the vegetative canopy (Figure 24).

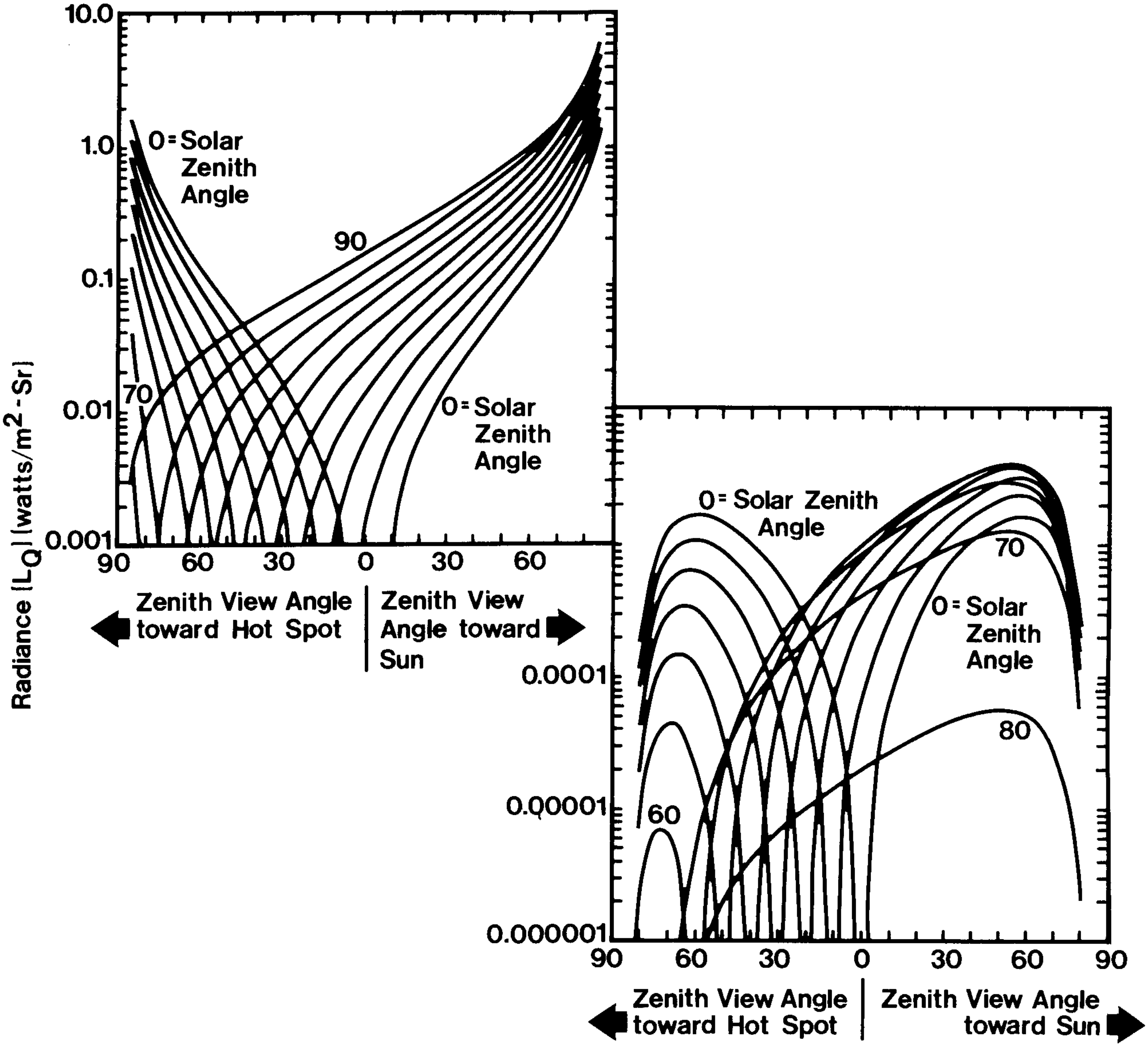


Figure 24. (Left) Preheaded wheat canopy polarization response. Prior to heading the response is zero at the anti-solar point, the "hot spot," and increases with increasing zenith view angle.
(Right) Headed wheat canopy polarization response. After heading the response remains zero at the anti-solar point, is maximum at intermediate zenith view angles, and approaches zero for near-horizontal view directions where heads and stems obstruct view of polarizing flag leaves.

Laboratory spectral-data using the model 20C field spectroradiometer (Figure 25) were obtained over an array of soil samples. These data were used at the source data in the compilation of a soils atlas described elsewhere in this report. The soil spectra along with the reflectance, geometric data described above are being used in scene modeling studies that are essential to deepen the understanding concerning the interaction of incident and reflected radiation with remotely-sensed targets.

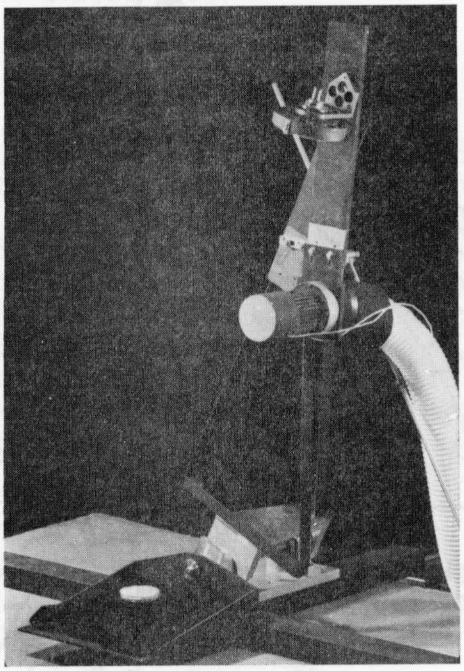


Figure 25. BRF reflectometer positioned for soil sample detection by the Exotech 20C spectroradiometer.

4. 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 in a project done with the cooperation of the biomedical engineering center at Purdue. The technique has been used to definitively establish the unsuitability of ungelled foil dispersive electrodes in electrosurgical applications (Figure 26). The technique utilizes fully calibrated thermal imagery so that quantitative results are available for reporting the performance for various designs of electrosurgical dispersive electrodes. The digital-thermal scanner is also used to check the result of various theoretical models that have been postulated for the operation of dispersive electrodes on human and animal tissue.

One of the results of the research has been the development of improved electrosurgical dispersive electrode designs capable of conducting electrosurgical current with minimal tissue heating.

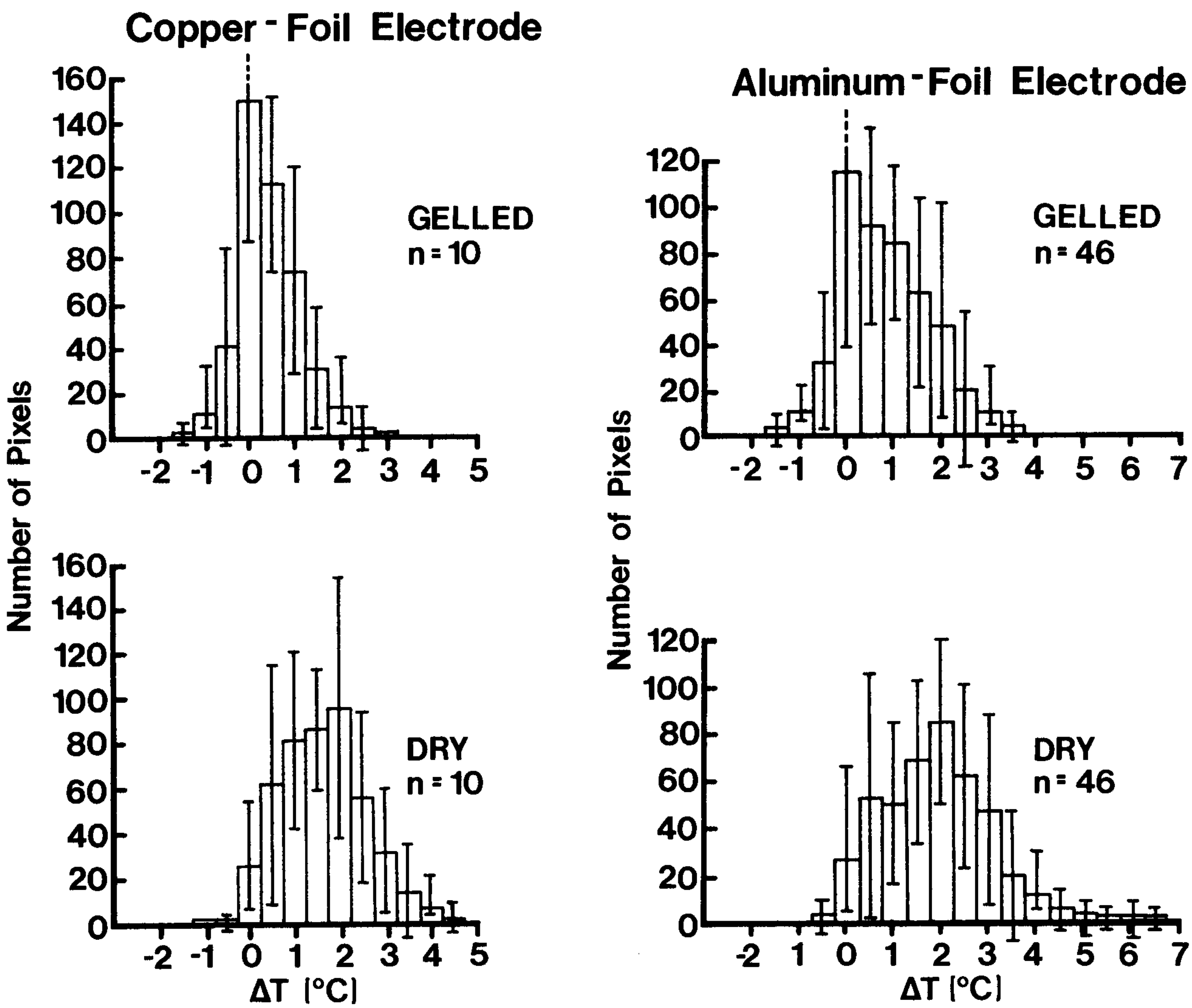


Figure 26. (Left) Histogram showing the number of pixels with different temperature rise classes for gelled and dry copper-foil electrodes. The bars represent the mean values in the temperature class, and the lines on the bars represent ± one standard deviation. (Right) Histogram showing the number of pixels with different temperature rise classes for gelled and dry aluminum-foil electrodes.

Ecosystems Research Programs

1. Mapping Indiana Wetland Cover Types

During the past year, a project to test the feasibility for using computer-aided analysis of Landsat satellite data to map wetlands in Indiana was conducted in cooperation with the Indiana Department of Natural Resources. The project was sponsored by NASA's Office of University Affairs. The test site involved the Pigeon River State Fish and Wildlife area. Landsat data were registered to soils information of the area, and the combined data set was classified using the Layered Classifier. Classification results were compared to type maps prepared from color infrared photography of the test site area. Results indicated that the soils data substantially improved the ability to delineate and identify wetland areas, and that certain cover types could not be effectively identified as wetland habitat without the combined Landsat and soils data. It is anticipated that higher spatial resolutions from future satellite systems will allow even more accurate wetland habitat classification to be obtained.

2. Evaluation of Combined Landsat Data and Topographic Data for Mapping Forest Cover Types

Earlier work with Landsat data had indicated that satellite reflectance measurements could be used to effectively identify and map areas of coniferous and deciduous forest cover but could not be used in areas of mountainous terrain to differentiate between individual forest cover types (e.g., species groups). This led to a research project directed at developing and evaluating different methods for combining Landsat reflectance measurements with topographic data in areas of mountainous terrain in order to more accurately map individual forest cover types. This concept is based upon the knowledge that differences in elevation, aspect and slope will often influence the type and characteristics of vegetation growing in any particular location and regions of mountainous terrain. Therefore, the ability to combine topographic data with the satellite reflectance data provides a potential for mapping individual forest cover types over extensive areas of rugged terrain.

Three different methods for using the combined satellite and topographic data were defined and tested for a region in the San Juan Mountains of southwestern Colorado. The results indicated that a Layered classification procedure was the most effective analysis technique for this particular region. An overall increase in classification performance of approximately 15% was realized through the use of the combined topographic and spectral data as compared to the use of spectral data alone.

The techniques defined for the Colorado test site area were further tested to determine the validity of the approach in a different geographic region having different ecological characteristics. The test site used during the past year was an area in central Washington. The forest cover types in this region again showed a distinct distribution as a function of elevation (Figure 27). Landsat MSS data were registered to elevation data, and aspect and slope were computed.

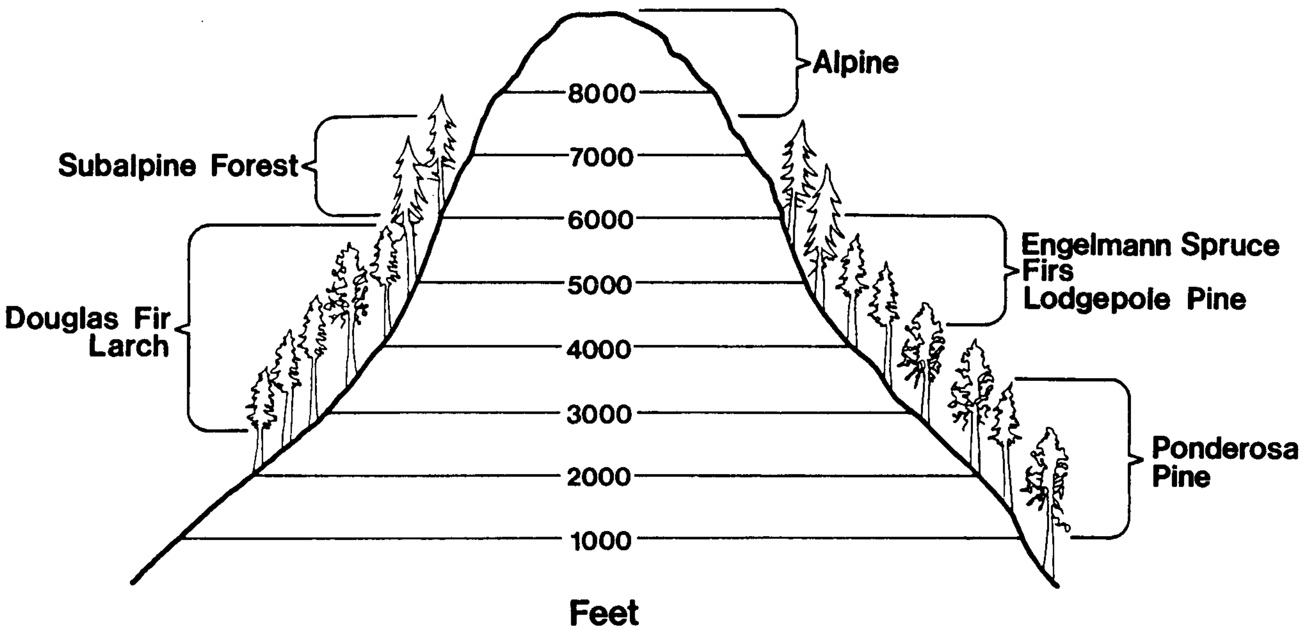


Figure 27. Species distribution in relation to elevation in the central Washington test site area.

In addition to the topographic data, 21 channels of "GRIDS" data were registered to the Landsat data. The GRIDS data were provided by the Washington Department of Natural Resources and contained a variety of data about specific one-acre sample plots, including forest cover type, stand density, species composition, crown closure, and other stand characteristics. The GRIDS data provided an excellent source of information for developing the training statistics and for evaluating the classification results. Figure 28 shows a schematic of the data sets which were registered and used in this study. The results of the analysis of the Washington data are currently being compiled and evaluated.

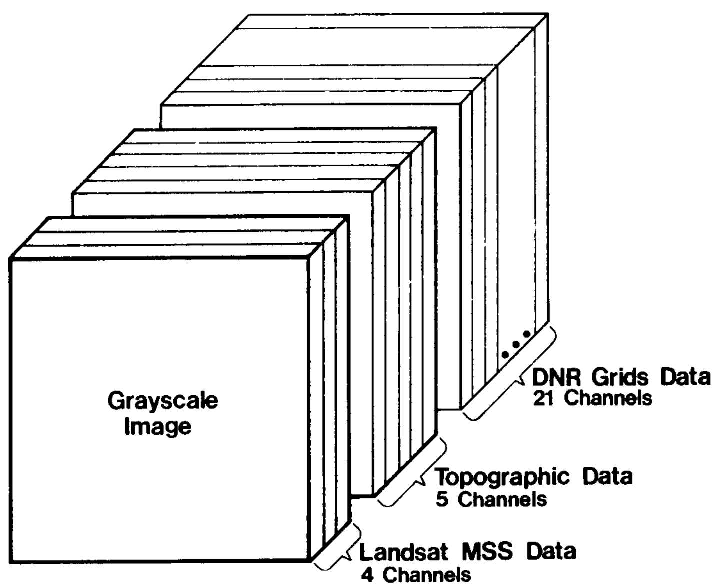


Figure 28. Schematic of the registered Landsat, topographic, and "GRIDS" data sets for the test site in central Washington.

3. Computer-Aided Processing of Landsat MSS Data for Classification of Forest Lands

A third study this past year involved a comparison between two different methods for developing training statistics in order to define the advantages and limitations of each for purposes of classifying forest land using Landsat data and incorporating U.S. Forest Service forest inventory procedures. The results of this study indicate that the P-1 approach requires accurate location of the ground plots in the satellite data as well as an adequate set of ground plot data in order to represent all cover types and the complete range of spectral variability within each cover type, but that this approach does maximize the use that can be made of existing U.S.F.S. forest inventory information. If an adequate set of ground plot data is not available, the Multicluster Blocks approach to developing training statistics is recommended. The study indicated a good potential for combining Forest Survey data with Landsat data to more quickly update Forest Survey information, but additional work is needed to define an effective set of guidelines for incorporating Landsat data and computer processing into normal Forest Survey operations.

4. Evaluation of SLAR and Simulated Thematic Mapper MSS Data for Forest Cover Mapping using Computer-Aided Analysis Techniques

A fourth research project of significance during the past year involved a study to determine the impact of the spectral and spatial characteristics of Thematic Mapper scanner data on the classification of forest cover types using computer-aided analysis techniques. The Thematic Mapper is a new generation multispectral scanner system currently scheduled to be launched into orbit in 1983. It differs from the Landsat systems in that it has more wavelength bands (including portions of the spectrum previously unused) and the spatial resolution will be 30 meters rather than the 80 meters currently obtained with Landsat satellites.

A second objective of this sutdy is to determine the value of radar data in combination with scanner data for identifying various forest cover types and determining differences in density and the condition of the forest cover. However, during the past year, the NASA aircraft were unable to obtain the radar data, so the work concentrated on an evaluation of the multispectral scanner data obtained.

The test site involved an area in South Carolina which was designated as a prime study area by the U.S. Forest Service. Scanner data were obtained by NASA from an altitude of 6000 meters. From this altitude, the resulting spatial resolution is approximately 15 x 15 meters. Spatially degraded data sets were prepared having spatial resolutions of 30 x 30 meters, 60 x 60 meters, and 75 x 90 meters. Analysis of the classification results from the different spatial resolution data sets and spectral evaluation of the various wavelength bands is in progress.

5. Applications of Remote Sensing Technology to Industrial Forest Management Problems in the Southeast

In October 1977, the St. Regis Paper Company and the National Aeronautics and Space Administration joined in a cooperative agreement to develop a Forest Resource Information System (FRIS). NASA contracted LARS to provide the necessary remote sensing expertise to provide technical support for the St. Regis effort.

The St. Regis Project is unusual in that it brings to bear a unique mix of experience from the private, government, and academic sectors on a single, well-defined problem. The project, which finishes in FY81, consists of four phases, as depicted in the chart below (Figure 29).

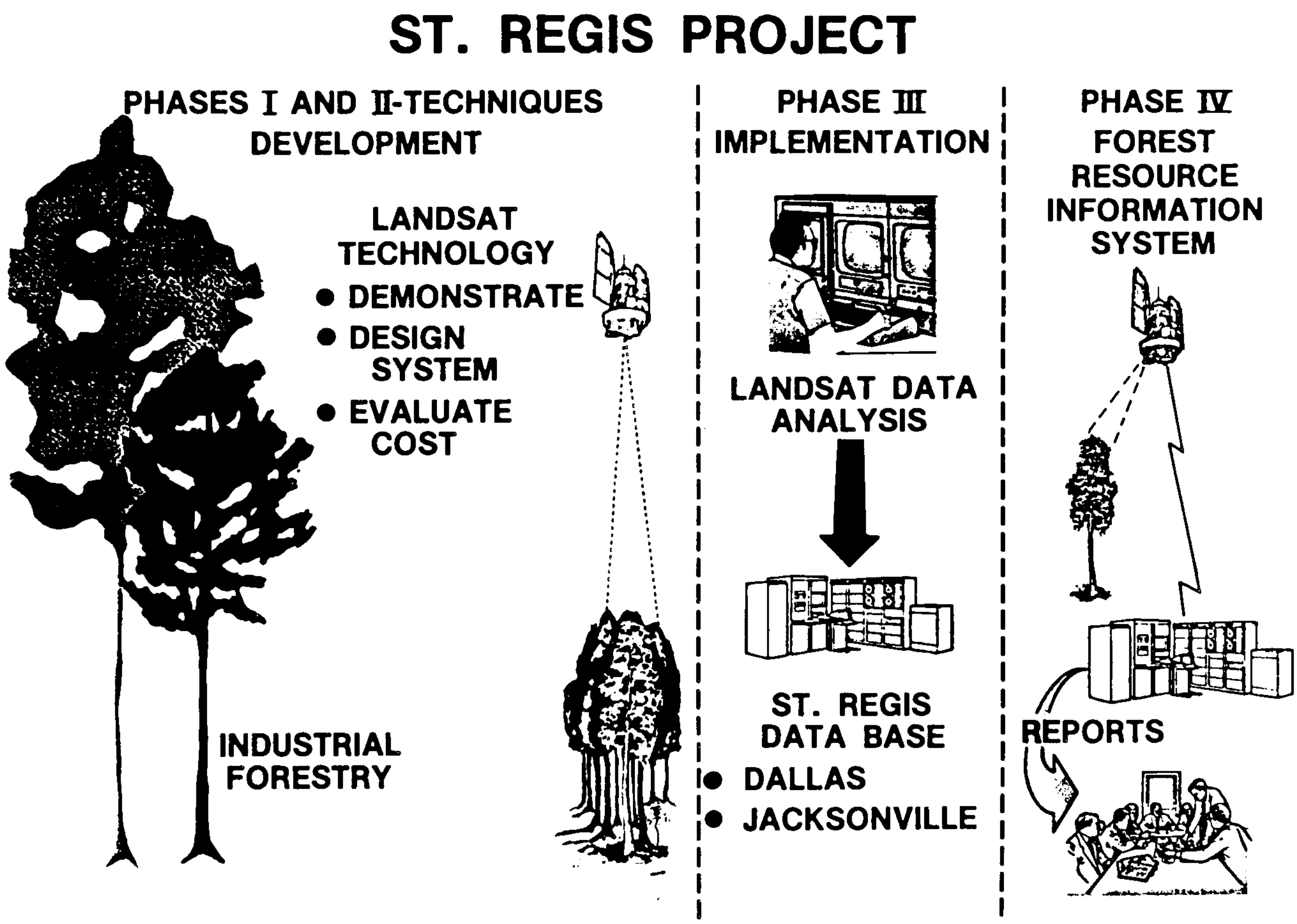


Figure 29. Four phases involved in the St. Regis Project.

LARS staff have made a significant contribution during each phase, specifically:

- The Technique Development Phase demonstrated the applicability of remote sensing data to industrial forest management problems encountered in the southeast.

- The Implementation Phase involved both the transfer of remote sensing technology and software developed at LARS for the analysis of multi-spectral data to St. Regis computational facilities.

- Phase IV represents that stage in the project development where St. Regis assumes complete, independent operational control of the Forest Resource Information System.

A milestone in remote sensing technology will be achieved at the culmination of Phase IV, in that St. Regis will be the first private forest based company to have operational remote sensing capabilities. LARS has played a significant part in this achievement.

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 will lease land under their Save Our Small (S.O.S.) game program. The leased land will be developed for pheasant habitat in order to encourage an increase in bird population.

LARS staff cooperated with personnel from the Division of Fish and Wildlife to produce maps showing various elements of available pheasant habitat. The map shown (Figure 30) is an example of the drainage element map for one township of Benton County. The habitat boundaries, cover type composition, and aerial measurements were all made from aerial photos. State personnel used these maps to identify potential lease sites, and began contacting land owners during the spring of 1980 to request their participation in the S.O.S. program.

DRAINAGE WAYS

UPLAND GAME BIRD HABITAT

Benton County, IN

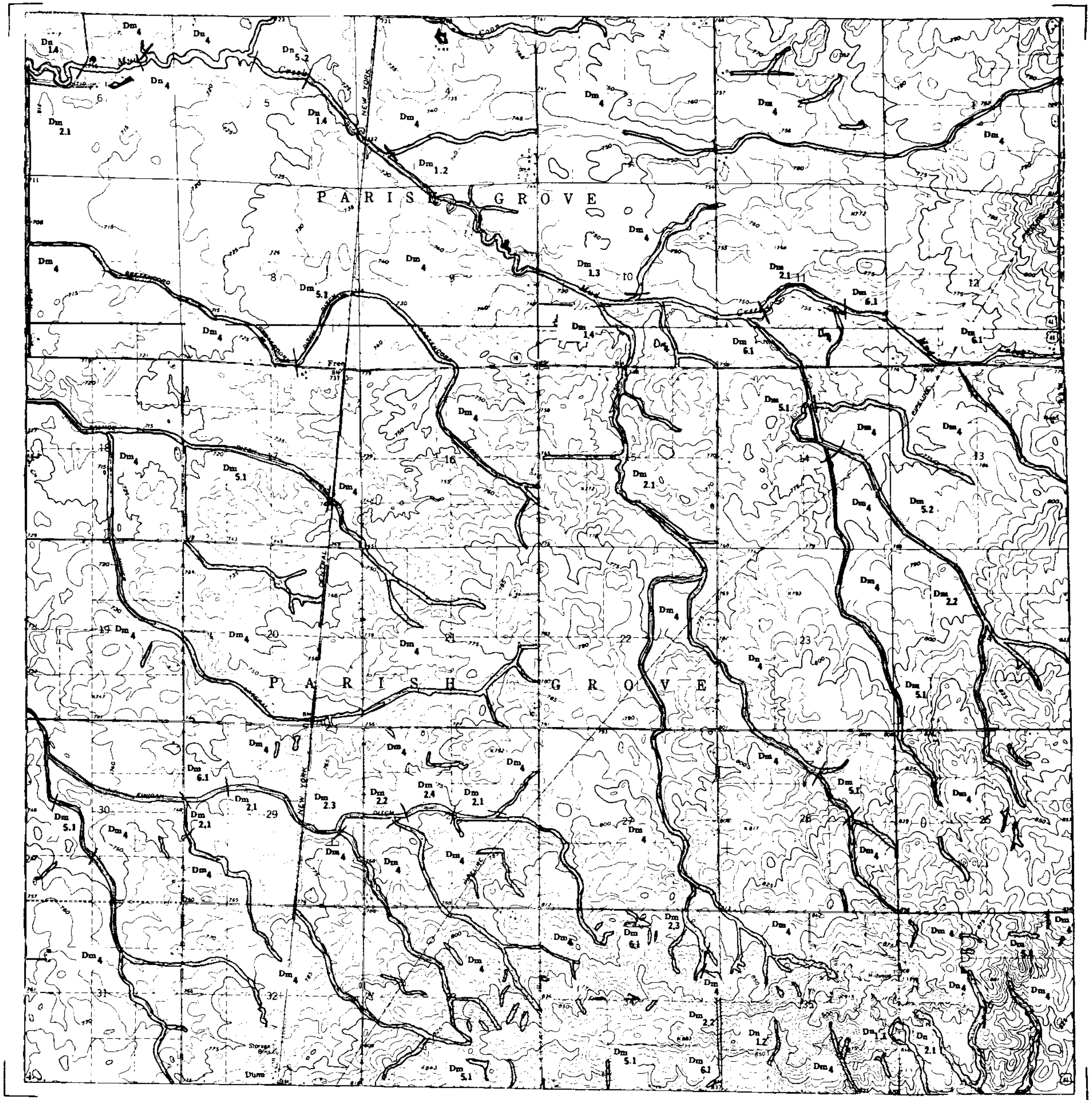
T 25 N R 9 W

Sheet No. 7

1979

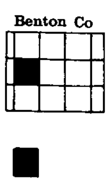
SCALE 1:24000
1 IN = 2000 FEET

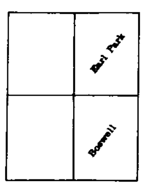
0 MILE 1



LEGEND

Symbol	Class	Linear ft. (1000)	Total Acres
NATURAL DRAINAGEWAYS			
Dn_1	Tree	11.1	31.1
Dn_2	Tree-shrub	5.6	4.1
Dn_3	Shrub	8.8	8.5
Dn_4	Grass	22.5	24.3
Dn_5	Tree-grass	1.3	5.4
MAN-MADE DRAINAGE			
Dm_1	Tree	10.2	12.7
Dm_2	Tree-shrub	45.7	91.1
Dm_4	Grass	251.1	293.7
Dm_5	Tree-grass	18.1	31.1
Dm_6	Shrub-grass	14.9	19.7





Habitat information on this map was developed through interpretation of aerial photography taken by the Indiana State Highway Commission 27 July 1977. This interpretation was supported in part by a NASA Office of University Affairs Grant NGL 15-005-186 and the Indiana Department of Natural Resources Division of Fish and Wildlife. This work was conducted at the Laboratory for Applications of Remote Sensing.

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Figure 30. An example of a product from the Upland Game Bird Habitat Project.

Data Processing and Analysis Research Programs

This area of research has focused on generalizing basic principles and methods of earth resources data processing to cover more extensive and complex forms of data. The characteristics of a remote sensing instrument under development, the Thematic Mapper, were studied; increasingly complex collections of data from multiple sources were constructed and studied; and new methods for incorporating spatial information in scene classification were investigated. Also studied was the implementation of complex data processing tasks on advanced computer systems.

1. Data Processing Research

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 topography, geophysics, soil type, land use, zoning, political boundaries, and others. The multi-image concept was studied in the context of exploration for mineral deposits. In one test area in southeastern Arizona, several prospects were located using a combination of Landsat spectral reflectance data, gamma-ray radiation data, earth magnetic field, and digitized geology data. The prospects were field-checked and several were found to have good potential for copper mineralization. Investigations were also begun in the year into methods of extracting information from seismic exploration data using pattern recognition techniques. Progress in this area will increase to probability of finding new, even smaller and deeper petroleum resources.

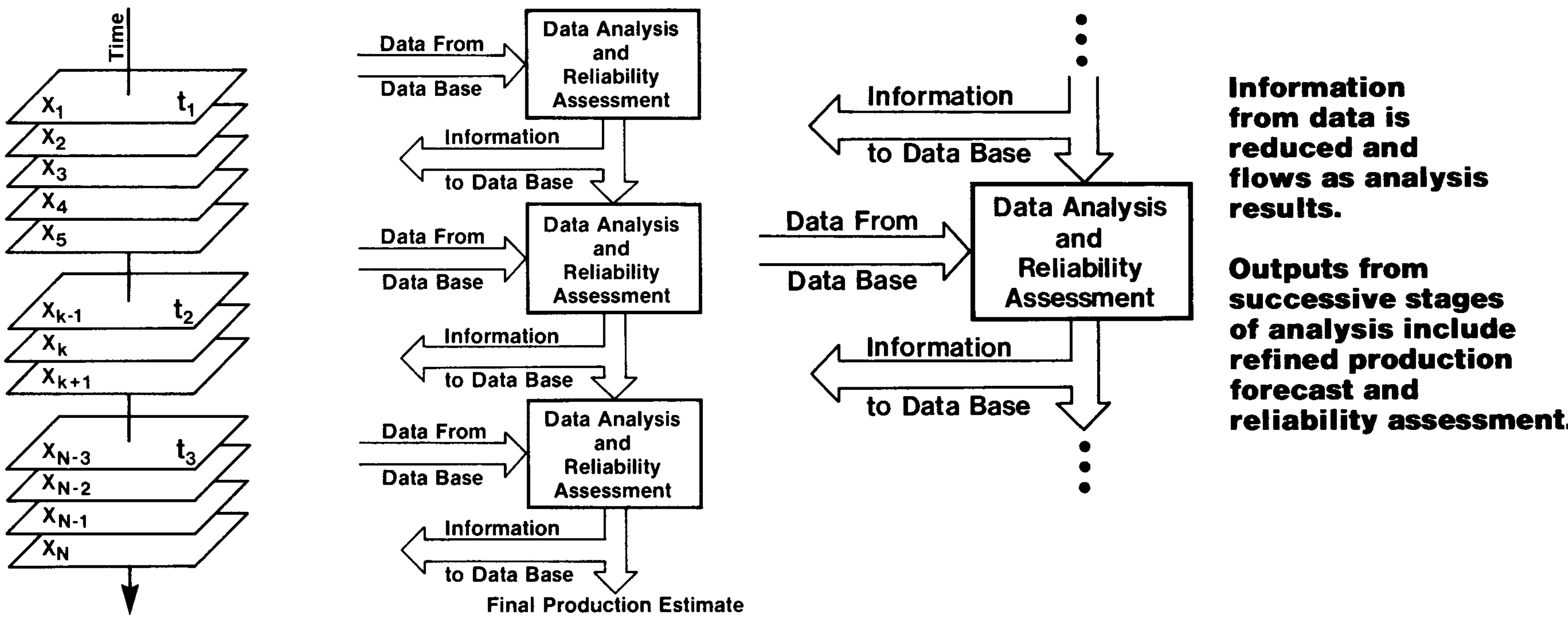

Figure 31. Data storage and analysis concept for complex Earth resources data base.

2. Data Analysis Research

For more than a decade, efforts to extract information from multispectral remote sensing image data have proved increasingly successful. Many of these efforts have focused on the classification of the ground scene one pixel at a time. However, there are many applications for which the classes of interest can be better characterized if the spatial information in the remote sensing data is utilized in addition to the spectral information on a pixel basis. One way to approach spatial information in image data is to recognize that the ground cover associated with a given pixel, i.e., its class, is not independent of the classes of its neighboring pixels. Mathematically, the image can be considered a two-dimensional random process and the characteristics of this process can be incorporated into the classification strategy. This has been the objective of one of the principal research activities during this year. Experimental results have shown this to be a powerful method for improving classification performance.

As increasingly complex forms of data and data analysis methods are employed, the computational requirements tend to become more demanding. Although improvements in the raw speed of digital computer components can be exploited to some extent to meet these requirements, the evolving computer architectures, especially those involving multiple processing elements, have much to offer to alleviate the computational burden. The context classifier described above has computational requirements which are severe and rapidly become more so as the size of the contextual neighborhood under consideration is expanded. It is a natural candidate, therefore, for multiprocessor implementation. A commercial multiprocessor system known as the Cyber-Ikon, developed by the Control Data Corporation, has been the target machine for studying multiprocessor implementations of the contextual classifier. Still more general multiprocessor systems are of interest, however, and these are expected to be the focus of continuing research in the coming years.

The Thematic Mapper, a remote sensing instrument offering characteristics tremendously improved over the multispectral scanner system orbited on Landsat satellites 1, 2, and 3, is under development and expected to be orbited on later Landsat satellites. The specifications for this satellite system have been the topic of an investigation to determine how sensitive typical classification analysis will be to the satellite design parameters. During this year, sensitivity to the accuracy of interband registration has been studied. NASA may use the results of these studies to determine how rigidly the instrument design specifications must be adhered to in order to meet the level of performance anticipated for a particular class of applications.

Contributions of LARS to Professional and Academic Educational Programs

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 32). The major Technology Transfer activities during Fiscal Year 1980 were:

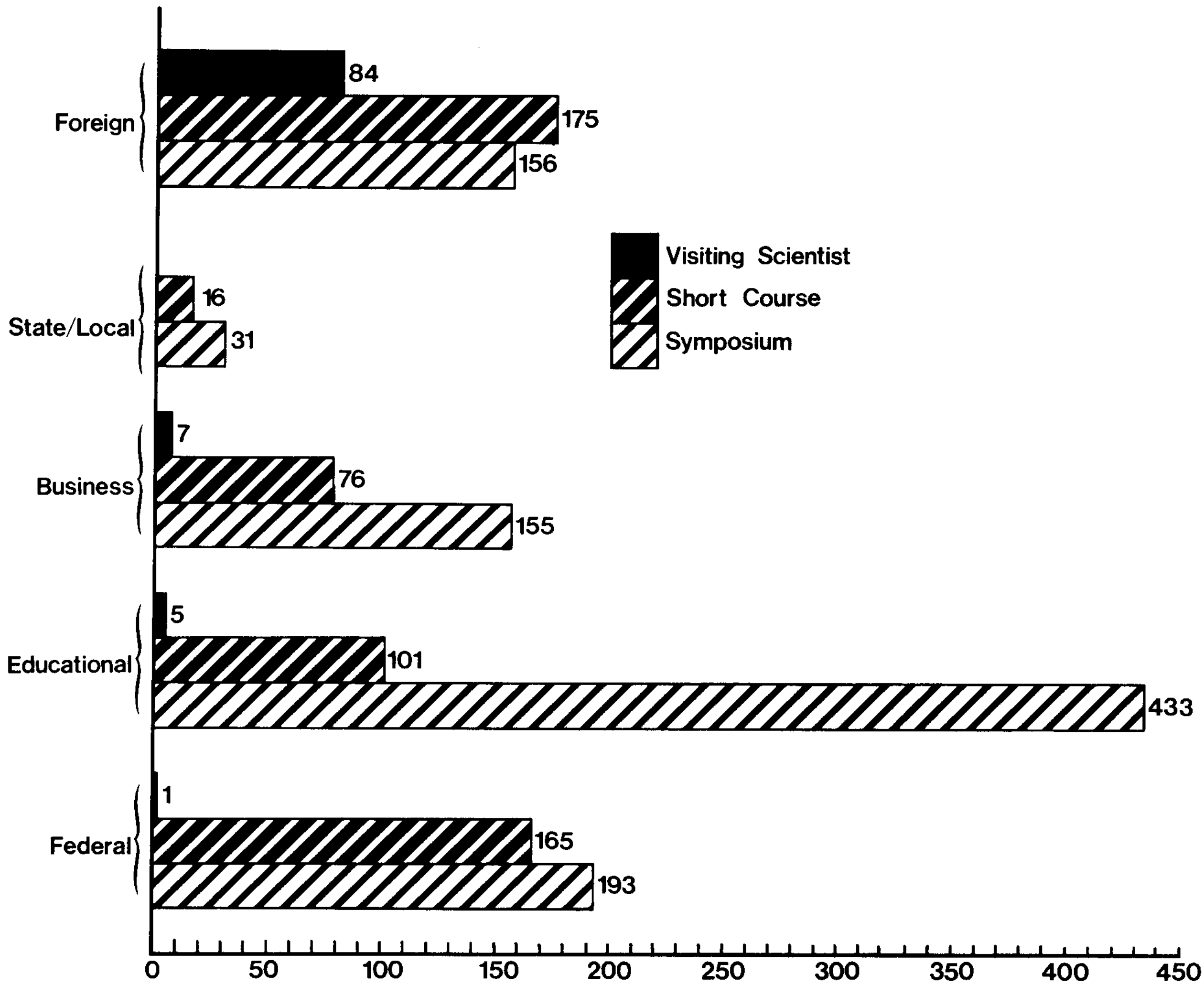

Figure 32. Background of personnel participating through June 1980 in Technology Transfter programs offered by LARS.

Short Courses

Short Courses offered during FY80 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 FY80 with a total of 70 paying attendees, 26 of whom also participated in the "Hands-On" computer exercises option. These 70 included 25 from foreign countries, bringing the total foreign participation to 175, as shown in Figure 33.

As in previous years, the participants were a heterogeneous group coming from federal government agencies (40%), foreign (35%), business and industry (4%), Purdue and other universities (21%).

The five-day "Advanced Topics in the Analysis of Remote Sensing Data" short course has been offered once a year for the past four years with a number of attendees: 10 in 1977, 29 in 1978, 32 in 1979 and 19 in 1980. Both of these short courses are financially self-supporting.

This fiscal year produced a new dimension of the short courses that augurs expansion in the years ahead. The "On-Site" option was exercised in three different instances this year. Fifteen participants were given the regular monthly course at the Johnson Space Center in Houston, Texas rather than here at the Purdue/LARS facilities. Similarly, a modified version of the course was given in Spanish in Panama to 29 participants. (Additional offerings in Spanish are already scheduled subsequently.) A still more modified version of the short course emphasizing applications in geology was presented to 14 participants in the Bureau of Land Management in Denver, Colorado.

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 have been a total of 100 visiting scientists involved in applying remote sensing technology to problems in the 32 different countries which they represented. During FY80 there were 6 visiting scientists from 5 different countries, bringing the total foreign visiting scientist participation to 87, as shown in Figure 34.

Symposium

During FY80 LARS, in cooperation with Purdue's Division of Conferences and the International Soil Science Society sponsored the Sixth Symposium on Machine Processing of Remotely Sensed Data. It was attended by 215 participants, 38 of whom came from 29 different countries, bringing the total foreign symposium participation to 156, as shown in Figure 35.

Figure 33. Foreign short course attendees from 1972 through June 1980 (175 total).

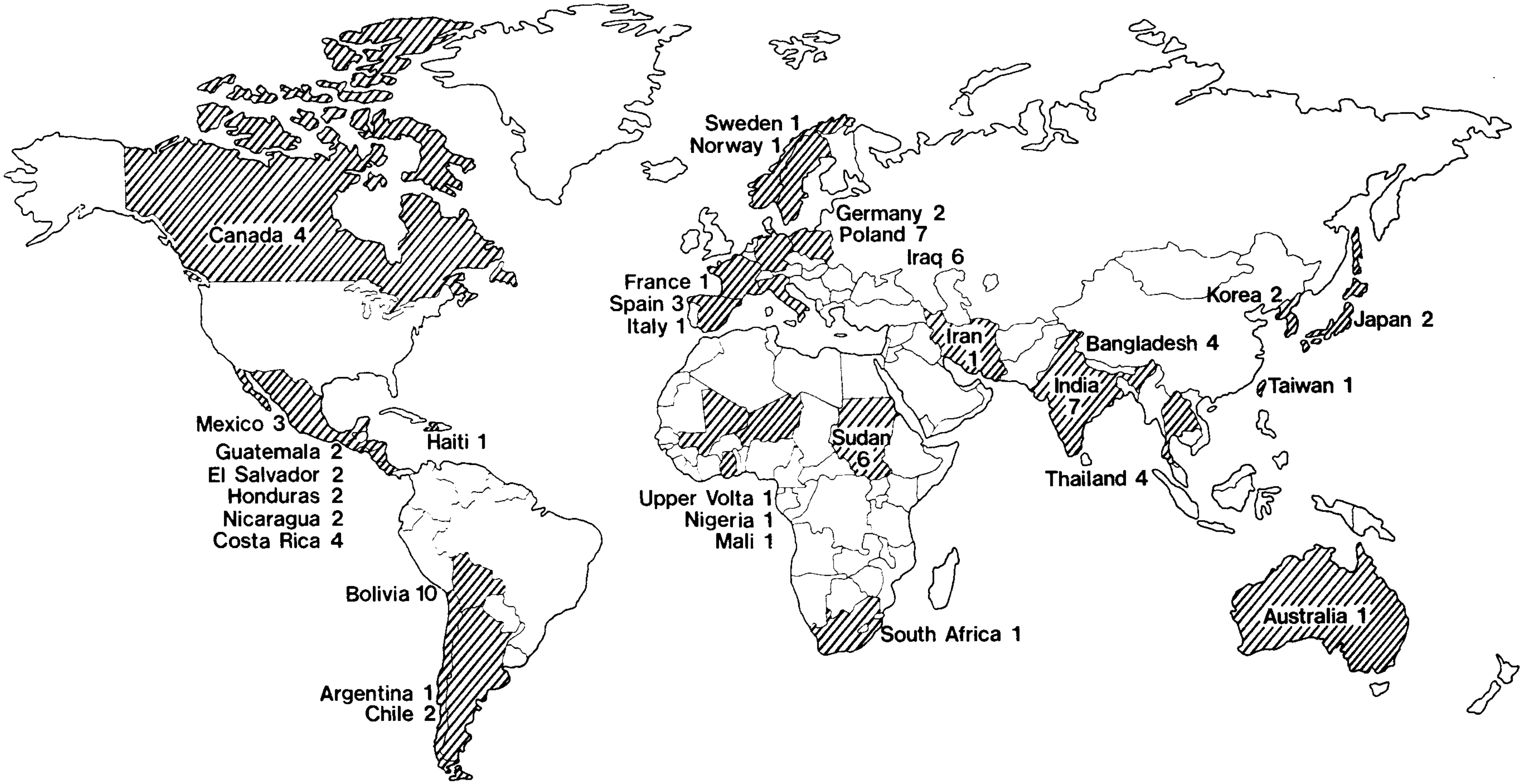

Figure 34. Foreign visiting scientists from 1973 through June 1980 (87 total).

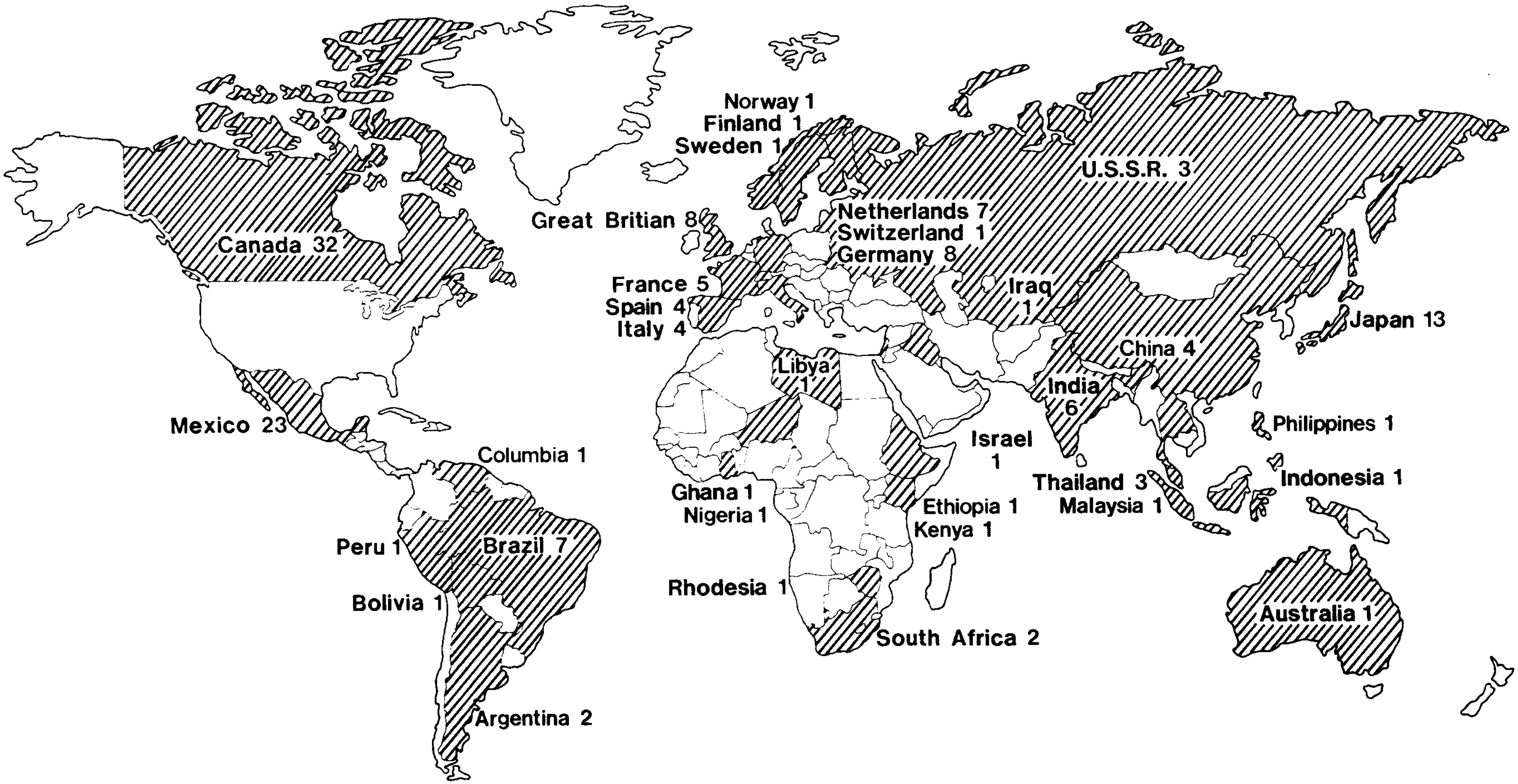

Figure 35. Foreign symposium attendees from 1973 through 1980 (156 total).

Research and Analysis Network

LARS reduces the large personnel and financial commitments required for entry into the remote sensing community by providing to educators and researchers a low-cost, low-risk means of access to a powerful remote sensing technology through a remote terminal network. Access to the remotely sensed data gathered by sensors onboard spacecraft, aircraft and field platforms is provided through the LARS data library. This access provides the latest techniques in remote sensing technology as well as well-maintained and documented software currently implemented on the Purdue/LARS IBM 3031.

Since 1972, remote terminals have been installed at twelve different remote sites (See Figure 5, page 11). Six sites have implemented their own verson of processing capabilities and six continue to support active remote terminals for access to LARS remote sensing and research capabilities. LARS provides specialized training on the use of the processing tools available to members of the remote terminal network.

Educational Materials on Remote Sensing

Since 1974, LARS has been actively involved in the development of educational materials which present fundamental remote sensing concepts and principles in a tutorial manner. During FY80 activities in this area centered on additions to the minicourse series and the development of high-quality videotapes.

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

The minicourses in this series are multi-media educational packages that present the fundamental concepts of remote sensing. They have been developed with funding from Purdue's Division of Conferences and Continuing Education Administration and are available for purchase, either individually or in full sets, from Continuing Education.

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 the first phase of minicourse development, 19 different units were created. Figure 36 shows the rate of sales over the four-year period of their availability, July 1976 - July 1980. At the end of FY80, over 2,800 individual minicourses had been purchased, equivalent to 149 full sets. During the past year, foreign institutions were responsible for making 76% of the purchases (on a single-minicourse basis), with U.S. universities and libraries making 13% of the purchases. Domestic businesses and governmental units accounted for 3% and 8% of the purchases, respectively.

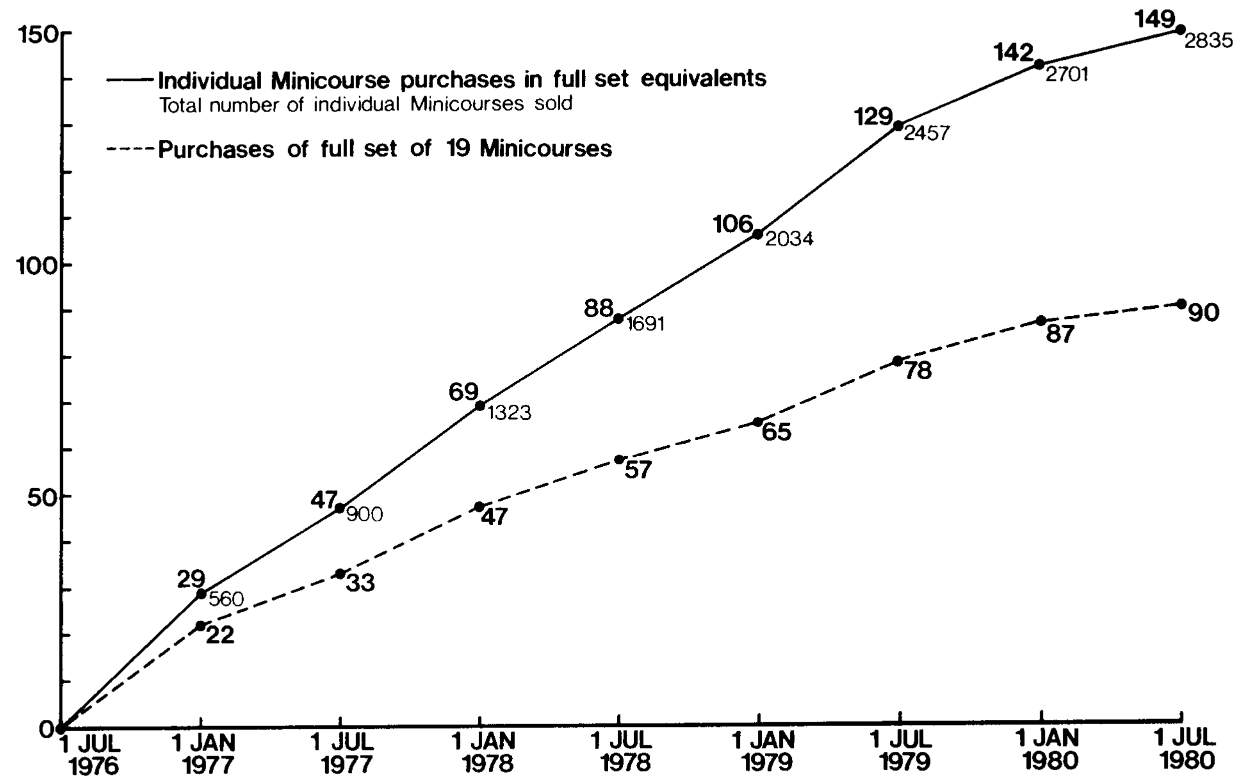

Figure 36. Cumulative purchases (in six-month intervals) of the Fundamentals of Remote Sensing minicourse series, July 1976 to July 1980.

During FY79 and FY80, four additional minicourses have been under preparation and are scheduled for distribution in autumn of 1980. 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.

In addition, arrangements for adding other minicourses to the series have been drawn up by Continuing Education with the International Institute for Aerial Survey and Earth Sciences (ITC), Enschede, The Netherlands, a world-renowned training facility for aerial photointerpretation, photogrammetry, and cartography. Their desire to support the development of two additional minicourses in the format established at Purdue is evidence of their high assessment of the utility of the series for their own students. These two minicourses will be released in autumn of 1980 with the four mentioned above:

"Selected Landsat Imagery" by F. W. Hilwig and S. M. Davis.

"Photogeology" by H. E. C. van der Meer Mohr, J. F. M. Mekel and S. M. Davis.

2. Videotape Series

Currently a videotape development project is being funded by Purdue University's Continuing Education Administration. 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 videotapes in this series "capture" a subject-matter specialist's discussion of a remote sensing topic (Figure 37). 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 the textbook, Remote Sensing: The Quantitative Approach, edited by P. H. Swain and S. M. Davis (McGraw-Hill, 1978).

The videotapes planned for distribution during FY81 are:

"Introduction to Quantitative Analysis" by D. A. Landgrebe.

"Correction and Enhancement of Digital Image Data" by P. E. Anuta.

"The Role of Pattern Recognition in Remote Sensing" by P. H. Swain.

"The Role of Numerical Analysis in Forest Management" by R. M. Hoffer.

"Multispectral Properties of Soils" by M. F. Baumgardner.

Figure 37. Shirley Davis adjusts the color monitor before viewing a new videotape in the series on remote sensing.

3. OTHER EDUCATIONAL MATERIALS

The materials now being developed will make a significant addition to a large body of educational materials which have been developed since 1974. These include:

- Remote Sensing of Agriculture, Earth Resources, and Man's Environment: a color booklet and slide-tape presentation that reveal the role remote sensing has played and will play in monitoring and analyzing the earth's resources.

- The FOCUS Series: two-page printed foldouts each presenting a single concept basic to remote sensing.

- Simulation Exercises: printed materials that lead students through the decision-making processes typical of those required by remote sensing analysts.

- The LARSYS Educational Package: a set of multi-media instructional materials developed to train people to analyze multispectral data using LARSYS, a computer software system developed at LARS.

- Remote Sensing: The Quantitative Approach: a textbook, published by McGraw-Hill International Book Company in 1978 and authored and edited by seven LARS staff members.

University Courses

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 Aerogeology and Remote Sensing
cr. 3 Prof. Levandowski

Courses Related to Remote Sensing

Agronomy

565 Soil Classification and Survey
cr. 3 Prof. Bryant

585 Soils and Land Use
cr. 2 Prof. Yahner

655 Soil Genesis and Classification
cr. 3 Prof. Franzmeier

Civil Engineering

503 Photogrammetry I
cr. 3 Prof. Mikhail

567 Airphoto Interpretation
cr. 3 Prof. Miles

603 Photogrammetry II
cr. 3 Prof. Mikhail

604 Analytical 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

Geosciences

514 Glacial Geology
cr. 3 Prof. Melhorn

523 Geomorphology
cr. 3 Prof. Melhorn

558 Geophysical Exploration for Engineers
cr. 3 Prof. Sexton

Graduate Training with LARS Staff and Facilities

Degree Candidates Funded by LARS Contracts FY80

Azimi, M., M.S., E.E., D. A. Landgrebe, thesis title not yet assigned.

Caruso, P., M.S., M.E., D. P. DeWitt, "Thermoperformance of the Jelled-pad Electrosurgical Dispersive Electrode."

* Crabill, E., M.S., E.E., P. E. Anuta, non-thesis option.

Dean, E., M.S., Forestry, R. M. Hoffer, thesis title not yet assigned.

Dickman, K., M.S., C.S., C. Smith, non-thesis option.

* Ernst, C. L., PhD, Forestry, R. M. Hoffer, "Digital Processing of Remotely Sensed Data for Mapping Wetland Communities."

Fleming, M., PhD, Forestry, R. M. Hoffer, "Computer-Aided Analysis Techniques for an Operational System to Map Forest Lands Utilizing Landsat MSS Data."

Grogan, T., M.S., E.E., P. E. Anuta, non-thesis option.

Hinzman, L., M.S., Agronomy, M. E. Bauer, thesis title not yet assigned.

Huang, K. Y., M.S., E.E., P. E. Anuta, "Geophysical Data Processing."

Hynes, N., M.S., Education, S. M. Davis, non-thesis option.

Ju, Y. T., PhD, E.E., C. Kozlowski, research at LARS not related to thesis.

Kalayeh, H., PhD, E.E., D. A. Landgrebe, thesis title not yet assigned.

Kollenkark, J., PhD, Agronomy, M. E. Bauer, "Influence of Solar Illumination Angle and Cultural Practices on the Reflectance Properties of Soybean Canopies."

Latty, R., M.S., Forestry, R. M. Hoffer, "Forest Cover Classification using Conjunctive Classifiers with Higher Spatial Resolution Data."

Latz, K., M.S., Agronomy, R. A. Weismiller, thesis title not yet assigned.

L'Heureux, D., PhD, Geosciences, P. E. Anuta, "Delineation of Montana Mineral Belt by Satellite and Geophysical Remote Sensors."

Lin, C. S., PhD, E.E., C. Smith, research at LARS not related to thesis.

Maadani, F. S., PhD, Agronomy, R. A. Weismiller, thesis title not yet assigned.

* Degree Granted FY80

Machado, C., PhD, C.S., D. Freeman, research at LARS not related to thesis.

Megivern, S., M.S., Geosciences, L. Bartolucci, "Geographic Information Systems."

* Mills, W., PhD, Forestry, R. P. Mroczynski, research at LARS not related to thesis.

Muasher, M., PhD, E.E., D. A. Landgrebe, "Decision Tree Classification for Multispectral Data."

Nash, L., M.S., Agronomy, M. E. Bauer, "Multispectral Properties of Corn Canopies as Influenced by Soil Background, Cultural Practices and Crop Development Stage."

* Nelson, R., M.S., Forestry, R. M. Hoffer, "Computer-Aided Processing of Landsat MSS Data for Classification of Forestlands."

Pearce, J., PhD, B.M.E., D. P. DeWitt, "Thermoperformance of Electrosurgical Dispersive Electrodes."

Peterson, C., M.S., Stat., R. P. Mroczynski, non-thesis option.

Pollara, V., M.S., Agronomy, M. E. Bauer, "Development of Crop Development Stage Models Utilizing Spectral Measurements."

Ranson, J., PhD, Agronomy, M. E. Bauer, thesis title not yet assigned.

Seubert, C., PhD, Agronomy, C.S.T. Daughtry, "Soil Productivity in the Context of a Crop Yield Model."

* Smith, B., M.S. and PhD, E.E., H. J. Siegel, "A Multiprocessor Implementation of a Contextual Classification Image Processing Algorithm." (M.S.)

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

Stabenfeldt, M., M.S., E.E., L. Silva, non-thesis option.

* Stoner, E., PhD, Agronomy, M.F. Baumgardner, "Physiochemical Site and Bidirectional Reflectance Factor Characteristics of Uniformly Moist Soils."

* Swenson, M., M.S., Stat., M. Hixson, non-thesis option.

* Tsuchida, R., M.S., M.E., B. Robinson, non-thesis option. (Document: non-thesis LARS Technical Report 090879, "Design of Evaluation of a Pick-up Truck Mounted Boom."

Walburg, G., M.S., Agronomy, M. E. Bauer, "Effect of Nitrogen Nutrition on Growth, Yield, and Reflectance of Corn Canopies."

* Degree Granted FY80

Other Graduate Students Advised by LARS Staff

AL-Mahawili, S., M.S., Agronomy, M. F. Baumgardner, "Spectral Separability of Salinized Soils in the Tigris-Euphrates Basin."

Batista, G., PhD, Agronomy, M. E. Bauer, "Relationship of Scene Characteristics and Landsat Classification of Cron and Soybeans."

Tilton, J.. PhD, E.E., P. H. Swain, "Incorporating Spatial Context into Statistical Classification of Multidimensional Image Data."

Appendix I - Publications, Presentations and Professional Activities by LARS Staff

Journal Articles

Bauer, M. E. 1979. LACIE: an experiment in global crop forecasting. Editor's Forum, Crops and Soils Magazine, August/September. p. 5-7. (LARS Publ. 082779.)

Baumgardner, M. F. 1980. Remote sensing provides a new look at the earth and its resources. (publ. in Chinese). Modern Engineering Tech. 4:12-18. Beijing, China. (LARS Tech. Rpt. 042080.)

Chu, N. Y. and P. E. Anuta. 1979. Automatic color map digitization by spectral classification. Photogram. Eng. and Remote Sensing 45:507-515. (LARS Tech. Rpt. 042879.)

Cipra, J. E., D. P. Franzmeier, M. E. Bauer, and R. K. Boyd. 1980. Comparisons of Landsat MSS and spectroradiometer measurements of the multispectral reflectance properties of soils. Soil Sci. Soc. of Amer. J. (In press.)

Daughtry, C. S. T., M. E. Bauer, D. W. Crecelius, and M. M. Hixson. 1980. Effects of management practices on reflectance of spring wheat canopies. To appear in Agron. J. 72. (Agri. Exp. Sta. Bulletin No. 8054.)

Daughtry, C. S. T. and D. A. Holt. 1980. Growth stage and fertilizer on hemicellulose concentration and composition. Submitted to Agron. J. 72. (Agri. Exp. Sta. Bulletin No. 8094.)

Ernst, C. L., R. P. Mroczynski, and R. A. Weismiller. 1980. Using aerial survey techniques to locate abandoned strip mine land. Journal of Environ. Quality. Vol. 9, No. 4.

Geddes, L. A., J. A. Pearce, J. D. Bourland, and L. F. Silva. 1980. Thermal properties of dry metal - foil dispersive electrosurgical electrodes. Journal of Clinical Eng. 5:13-17.

Hanley, E. J., R. K. Boyd, and D. P. DeWitt. 1978. Screening for neonatal jaundice using skin reflectance. Advances in Bio-engineering, Amer. Soc. Mech. Eng. p. 91-94. (LARS Tech. Rpt. 122978.)

Hannemann, R. E., D. P. DeWitt, E. J. Hanley, R. L. Schreiner, and P. Bonderman. 1979. Determination of serum bilirubin by skin reflectance: effect of pigmentation. Pediatric Research 13:1326-1329. (LARS Tech. Rpt. 072179.)

Hannemann, R. E., D. P. DeWitt, and J. F. Wiechel. 1978. Neonatal serum bilirubin from skin reflectance. Pediatric Research 12:207. (LARS Tech. Rpt. 122778.)

Hixson, M. M., B. J. Davis, and M. E. Bauer. 1980. Sampling Landsat classifications for crop area estimation. Accepted by Photogram. Eng. and Remote Sensing.

Hixson, M. M., D. K. Scholz, N. C. Fuhs, and T. Akiyama. 1980. Evaluation of several schemes for classification of remotely sensed data. Accepted by Photogram. Eng. and Remote Sensing. (LARS Tech. Rpt. 041279.)

Hoffer, R. M. 1980. Computer-aided analysis of satellite and aircraft MSS data for mapping snow-cover and water resources. In Remote Sensing Application in Agriculture and Hydrology, 24:373-388. G. Fraysse (ed.), A. A. Balkema, Rotterdam, The Netherlands.

Hoffer, R. M. 1980. Computer-aided analysis techniques for mapping earth surface features. In Remote Sensing Application in Agriculture and Hydrology, 11:133-152. G. Fraysse (ed.), A. A. Balkema, Rotterdam, The Netherlands.

Holt, D. A., C. S. T. Daughtry, H. F. Reetz, and S. E. Hollinger. 1979. Separating soil and weather effects in large area yield prediction. Agron. Abstracts 71:10.

Kollenkark, J. C., C. S. T. Daughtry, M. E. Bauer, G. Walburg, and D. Long. 1979. Soybean canopy reflectance as influenced by cultural practices. Agron. Abstracts 71:13.

Kumar, R., B. F. Robinson, and L. F. Silva. 1979. Calibration of long wavelength Exotech Model 20C spectroradiometer. Applied Optics 18:2334-2341.

Landgrebe, D. A. 1980. The development of a spectral-spatial classifier for earth observational data. Pattern Recognition 12:165-175. (LARS Tech. Rpt. 072180.)

Mobasseri, B. G., P. E. Anuta, and C. D. McGillem. 1980. A parametric model for multispectral scanners. IEEE Trans. on Geoscience and Remote Sensing GE-18:175-179. (LARS Tech. Rpt. 041580.)

Mobasseri, B. G. and C. D. McGillem. 1979. Multiclass Bayes error estimation by a feature space sampling technique. IEEE Trans. on Systems, Man and Cybernetics SMC-9:660-665. (LARS Tech. Rpt. 101679.)

Robinson, B. F., M. E. Bauer, D. P. DeWitt, L. F. Silva, and V. C. Vanderbilt. 1979. Measurements of optical radiations. SPIE 196:8-15. (LARS Tech. Rpt. 082979.)

Schreiner, R. L., R. E. Hannemann, D. P. DeWitt, and H. C. Moorhead. 1979. Relationship of skin reflectance and serum bilirubin: full-term Caucasian infants. Human Biology 51:31-40. (LARS Tech. Rpt. 123079.)

Siegel, H. J. 1979. A model of SIMD machines and a comparison of various interconnection networks. IEEE Trans. on Computers C-28:907-917.

Siegel, H. J., R. J. McMillen, and P. T. Mueller, Jr. 1979. A survey of interconnection methods for reconfigurable parallel processing systems. Nikkei Electronics 228:49-83. (Japanese Publ., translated from 1979 Nat'l. Computer Conf. paper.)

Singh, A. N., S. J. Kristof, and M. F. Baumgardner. 1979. Delineating salt-affected soils in the Ganges Plain by digital analysis of Landsat data. Journal India Soc. Photo-Int. and Remote Sensing VII. (LARS Tech. Rpt. 111477.)

Stoner, E. R. and M. F. Baumgardner. 1979. Data acquisition through remote sensing. Agron. Monograph 21, Planning the Uses and Management of Land, Amer. Soc. of Agron. p. 159-185. (LARS Tech. Rpt. 121579.)

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. Soil Sci. Soc. of Amer. J. 44:572-574.

Swain, P. H. 1980. Pattern recognition techniques for remote sensing applications. Accepted by the Handbook of Statistics, Vol. 2, 1981.

Swain, P. H., H. J. Siegel, and B. W. Smith. 1980. Contextual classification of multispectral remote sensing data using a multiprocessor system. IEEE Trans. of Geoscience Electronics GE-18:197-203. (LARS Tech. Rpt. 042380.)

Walburg, G., C. S. T. Daughtry, M. E. Bauer, J. C. Kollenkark, and S. A. Barber. 1979. Maize canopy reflectance as influenced by nitrogen nutrition. Agron. Abstracts 71:17.

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060580. A model of plant canopy polarization response. V. C. Vanderbilt. (In Proc. Sixth Symp. on Machine Processing of Remotely Sensed Data, Purdue University. p. 98-107.)

060680. A case study of soil erosion detection by digital analysis of the remotely sensed multispectral Landsat scanner data of a semi-arid land in southern India. V. Guruswamy, S. J. Kristof, and M. F. Baumgardner. (In Proc. Sixth Symp. on Machine Processing of Remotely Sensed Data, Purdue University. p. 266-271.)

060780. Development of a digital data base for reflectance-related soil information. E. R. Stoner and L. L. Biehl. (In Proc. Sixth Symp. on Machine Processing of Remotely Sensed Data, Purdue University. p. 273-278.)

060880. Procedure 1 and forestland classification using Landsat data. R. F. Nelson and R. M. Hoffer. (In Proc. Sixth Symp. on Machine Processing of Remotely Sensed Data, Purdue University. p. 319-324.)

072180. The development of a spectral-spatial classifier for earth observational data. D. A. Landgrebe. (In Pattern Recognition 12:165-175.)

Contract Reports

053079. Semi-Annual Status Report for December 1, 1978 - May 31, 1979. R. A. Weismiller and R. P. Mroczynski. The application of remote sensing technology to the solution of problems in the management of resources in Indiana. Grant No. NGL-15-005-186.

062679. Final Report for March 1977 - June 1978. LARS Staff, IBM-FSD, NASA Wallops and Goodyear Aerospace. Synthetic aperture radar/Landsat MSS image registration. Contract No. NAS6-2816.

063079. Quarterly Report for April 1, 1979 - June 30, 1979. R. P. Mroczynski. Forest resource information system. Contract No. NAS9-15325.

071079. Final Report for October 4, 1978 - July 10, 1979. R. B. Castro. Computer-aided analysis of Landsat data taken over Spain. Account No. 01015-5736-65-12805.

071579. Quarterly Report for April 16, 1979 - July 15, 1979. R. M. Hoffer, M. D. Fleming, and L. A. Bartolucci. Digital processing of Landsat MSS and topographic data to improve capabilities for computerized mapping of forest cover types. Contract No. NAS9-15508.

072379. Final Report for November 6, 1978 - July 27, 1979. T. Akiyama. Analysis of ground cover types and grassland condition using Landsat-2 multispectral data in the Tokachi district in Japan. Account No. 01016-5736-65-12805.

081679. Activity Report for November 1975 - August 1979. N. C. Fuhs, M. M. Hixson, L. L. Biehl, and M. E. Bauer. Remote sensing experiments for analogous vegetative areas in the United States and the Soviet Union. Contract No. NAS9-15081. (Not in public domain.)

082879. Final Report for September 5, 1978 - August 28, 1979. W. D. DiPaolo. An analysis of Landsat data for soils investigations on federal lands in southwestern Idaho. Contract No. A551CT836.

083079. Quarterly Report for June 1, 1979 - August 31, 1979. D. A. Landgrebe and staff. Research in remote sensing of agriculture, earth resources, and man's environment. Contract No. NAS9-15466.

083179. Quarterly Report for May 16, 1979 - August 15, 1979. R. S. Latty and R. M. Hoffer. Evaluation of SLAR and Thematic Mapper MSS data for forest cover mapping using computer-aided analysis techniques. Contract No. NAS9-15889.

093079. Quarterly Report for July 1, 1979 - September 30, 1979. R. P. Mroczynski. Forest resource information system. Contract No. NAS9-15325.

101579. Quarterly Report for July 16, 1979 - October 15, 1979. R. M. Hoffer. Digital processing of Landsat MSS and topographic data to improve capabilities for computerized mapping of forest cover types. Contract No. NAS9-15508.

112679. Annual Report to the University. Fiscal Year 1979. D. A. Landgrebe and staff.

112779. Annual Financial Report to the University. Fiscal Year 1979. D. A. Landgrebe and staff.

112879. Final Report for December 1, 1978 - November 30, 1979. M. E. Bauer, L. L. Biehl, C. S. T. Daughtry, B. F. Robinson, and E. R. Stoner. Agricultural scene understanding and supporting field research. Contract No. NAS9-15466.

112979. Final Report for December 1, 1978 - November 30, 1979. C. S. T. Daughtry and M. M. Hixson. Processing techniques development: crop inventory techniques. Contract No. NAS9-15466.

113079. Final Report for December 1, 1978 - November 30, 1979. P. H. Swain, P. E. Anuta, D. A. Landgrebe, and H. J. Siegel. Processing techniques development: data preprocessing and information extraction techniques. Contract No. NAS9-15466.

120179. Final Report for December 1, 1978 - November 30, 1979. J. L. Kast, L. A. Kraemer, B. M. Shelley, S. K. Schwingendorf, and T. L. Phillips. Computer processing support. Contract No. NAS9-15466.

120279. Final Report for December 1, 1978 - November 30, 1979. D. A. Landgrebe. Annual technical summary. Contract No. NAS9-15466.

120379. Quarterly Report for September 1, 1979 - November 30, 1979. R. M. Hoffer and R. S. Latty. Evaluation of SLAR and Thematic Mapper MSS data for forest cover mapping using computer-aided analysis techniques. Contract No. NAS9-15889.

122879. Final Report for October 1979 - December 1979. D. Samake. Computer-aided analysis of land cover types using Landsat-1 data over the District of Diema in Mali. Contract No. AID-it-C-6089.

012080. Quarterly Report for October 1, 1979 - December 31, 1979. R. P. Mroczynski, F. E. Goodrick, S. Schwingendorf, B. M. Shelley, D. Freeman, C. Kozlowski, and C. Peterson. Forest resource information system. Contract No. NAS9-15325.

020180. Monthly Progress Report for January 1, 1980 - January 31, 1980. D. K. Scholz and S. M. Davis. Training course entitled remote sensing for mineral specialists. Award No. YA-553-RFPO-2.

022680. Quarterly Report for December 1, 1979 - February 29, 1980. R. M. Hoffer. Evaluation of SLAR and Thematic Mapper MSS data for forest cover mapping using computer-aided analysis techniques. Contract No. NAS9-15889.

022780. Monthly Progress Report for February 1, 1980 - February 29, 1980. S. M. Davis. Training course entitled remote sensing for mineral specialists. Award No. YA-553-RFPO-2.

022880. Final Report for September 15, 1976 - February 28, 1980. N. C. Fuhs, M. M. Hixson, L. L. Biehl, and M. E. Bauer. Remote sensing experiments for analogous vegetative areas in the United States and the Soviet Union. Contract No. NAS9-15081.

022980. Quarterly Report for December 1, 1979 - February 29, 1980. M. E. Bauer. Research in remote sensing of agriculture, earth resources, and man's environment. Contract No. NAS9-15466.

033080. Interim Report for October 1, 1979 - March 31, 1980. P. H. Swain, V. C. Vanderbilt, C. D. Jobusch, and D. A. Landgrebe. A quantitative Thematic Mapper design specifications. Contract No. NSG-5414.

033180. Monthly Progress Report for March 1, 1980 - March 31, 1980. S. M. Davis. Training course entitled remote sensing for mineral specialists. Award No. YA-553-RFPO-2.

041880. Quarterly Report for January 1, 1980 - March 31, 1980. R. P. Mroczynski, S. Schwingendorf, D. Freeman, C. Kozlowski, C. Smith, and C. Peterson. Forest Resource Information System Phase III. Contract No. NAS9-15325.

043080. Monthly Progress Report for April 1, 1980 - April 30, 1980. S. M. Davis. Training course entitled remote sensing for mineral specialists. Award No. YA-553-RFPO-2.

053180. Quarterly Report for March 1, 1980 - May 31, 1980. M. E. Bauer and staff. Research in remote sensing of agriculture, earth resources, and man's environment. Contract No. NAS9-15466.

060780. Quarterly Report for March 1, 1980 - May 31, 1980. R. M. Hoffer and R. S. Latty. Evaluation of SLAR and Thematic Mapper MSS data for forest cover mapping using computer-aided analysis techniques. Contract No. NAS9-15889.

063080. Final Report for December 21, 1979 - June 30, 1980. S. M. Davis. Training course entitled remote sensing for mineral specialists. Award No. YA-553-RFPO-2.

Internal Reports

071679. M. M. Hixson and C. D. Jobusch. Compatibility programs for LARSYS and EOD-LARSYS.

081579. P. E. Anuta. LARS data handling research group program description and user's guide.

061477. D. P. DeWitt, R. E. Hannemann, and J. F. Wiechel. Method for determining bilirubin concentration from skin reflectance.

Special Professional Activities by LARS Staff

Anuta, P. E. 1980. Honorable mention, Talbert Abrams Award, for paper on "Automatic Color Map Digitization by Spectral Classification." In Photogrammetric Engineering and Remote Sensing, American Society of Photogrammetry. March 9-14, 1980.

Bartolucci, L. A. 1980. Co-chairman, Symposium on Machine Processing of Remotely Sensed Data, Purdue University, West Lafayette, Indiana. June 3-6, 1980.

Bauer, M. E. 1980. Became editor-in-chief, Remote Sensing of Environment journal. June 1980.

Bauer, M. E. 1980. Member, steering committee for planning NASA basic research program in the area of "Scene Radiation Characterization and Atmospheric Effects."

Bauer, M. E. 1979. Chaired session on Crop Stress at Gordon Research Conference on Remote Sensing, Plymouth, New Hampshire. August 20-24, 1979.

Bauer, M. E., C. S. T. Daughtry, M. M. Hixson, and J. K. Kast. 1979. Actively participated in the planning and design of AgRISTARS. Supporting Research Program.

Baumgardner, M. F. 1979-1980. Chairman, Agricultural Research Institute (ARI) Study Panel on Remote Sensing.

Baumgardner, M. F. 1980. Chairman, Symposium on Machine Processing of Remotely Sensed Data, Purdue University, West Lafayette, Indiana. June 3-6, 1980.

Baumgardner, M. F. 1979. Participated in meeting of Space and Terrestrial Applications Advisory Committee, NASA Headquarters, Washington D.C. April 19-20, 1979.

Baumgardner, M. F. 1979. Research Fellow of the East-West Center and Affiliate Professor of Soil Science, University of Hawaii, Honolulu, Hawaii. June 1-July 6, 1979.

Baumgardner, M. F. 1979. Special assignment to Caribbean island of Dominica to assess damage caused by Hurricane David as member of National Board of United Methodist Committee on Relief. November 5-9, 1979.

Baumgardner, M. F. 1980. Represented American Society of Agronomy and Soil Conservation Society of America in discussion of research priorities in the 1980s for USDA's Science and Education Administration (SEA). January 28-29, 1980.

Baumgardner, M. F. 1980. Appointed member of Editorial Advisory Board, International Journal of Remote Sensing, London, England.

Baumgardner, M. F. 1980. Awarded Honorary Degree of Doctor of Science, DePauw University. May 18, 1980.

Daughtry, C. S. T. 1979-1980. Served as second deupty chairman of Plant Science Committee, American Society of Photogrammetry.

Daughtry, C. S. T. 1980-1981. Serving as Vice Chairman of Plant Science Committee, American Society of Photogrammetry.

Daughtry, C. S. T. 1980-1982. Serving as Vice Chairman of Publications Review Board, Remote Sensing Applications Division, American Society of Photogrammetry.

Daughtry, C. S. T. 1979. Participated in Gordon Research Conference on Remote Sensing, Plymouth, New Hampshire. August 20-24, 1979.

Hixson, M. M. 1980-1985. Member, AgRISTARS sampling and aggregation coordination team.

Hoffer, R. M. 1980. Committee on Space Research (COSPAR). Presented invited paper and chaired one session at 23rd annual meeting. Budapest, Hungary. June 9-12, 1980.

Hoffer, R. M. 1979-1980. President (November 1979 - present), Vice President (January 1979-November 1979), Western Great Lakes Region, American Society of Photogrammetry. (Includes Indiana, Illinois, Wisconsin, and part of Michigan.)

Hoffer, R. M. 1980. Asked to serve as Chairman of the National Long Range Planning Committee of the American Society of Photogrammetry.

Hoffer, R. M. 1979. Chairman, Agriculture/Forestry/Range Panel of NASA's ERSAR (Earth Resources Synthetic Aperture Radar) Working Group. Houston, Texas. November 6-9, 1979.

Hoffer, R. M. 1979. Chairman, "Data Acquisition and Information Extraction" Session at Semi-Annual Convention of the American Society of Photogrammetry, Sioux Falls, South Dakota. September 17-21, 1979.

Landgrebe, D. A. 1979. Chairman, session on Spectral Characterization of Organic Matter, Gordon Research Conference, Plymouth, New Hampshire. August 20-24, 1979.

Landgrebe, D. A. 1979. Member, peer review committee, Advance System Verification Test, NASA Headquarters, Washington, D.C. June 25-26, 1979.

Landgrebe, D. A. 1980. Member, review panel of the Advanced System Verification Test, NASA Headquarters, Washington, D.C. February 5, 1980.

Landgrebe, D. A. 1979-1980. Member, IEEE Geoscience and Remote Sensing Administrative Committee.

Landgrebe, D. A. 1980-1981. Member, National Academy of Science Space Science Board Committee on Data Management and Computation.

Landgrebe, D. A. 1980. Guest Editor, Special Issue on Machine Processing of Remotely Sensed Data, IEEE Transactions on Geoscience and Remote Sensing.

Lindenlaub, J. C. 1980. Awarded "Helping Student's Learn" annual award given by Purdue University Alumni Foundation. April 26, 1980.

Morrison, D. B. 1980. Coordinator, Symposium on Machine Processing of Remotely Sensed Data, Purdue University, West Lafayette, Indiana. June 3-6, 1980.

Peterson, J. B. 1980. Member, USDA-Land Grant University review team for Department of Natural Resources and Environmental Studies, Alabama A&M University, Huntsville, Alabama. May 11-15, 1980.

Silva, L. F. 1980. Technical Editor for Visual and Infrared Techniques, IEEE Geosciences and Remote Sensing Society. January 1, 1980 to present.

Swain, P. H. 1979-1980. Member, Working Group for Design of Basic Research Plan in Pattern Recognition and Image Analysis, NASA.

Weismiller, R. A. 1979-1980. Member, Committee-1, Soil Survey, North Central Regional Technical Work-Planning Conference, USDA/SCS.

Weismiller, R. A. 1979-present. Member, ECOP Agriculture, Forestry, and Related Industries Subcommittee task force on Cooperative Extension Services involvement in remote sensing programs.

Weismiller, R. A. 1980. Member, State of Indiana Inter Agency Information and Education Committee on 208 Non-point Source Pollution.

Appendix II - Staff

Staff July 1, 1979 to June 30, 1980

Professorial Staff

1. AGRICULTURE

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

2. ENGINEERING

a) D. P. DeWitt - Associate Professor of Mechanical Engineering
b) D. A. Landgrebe - Professor of Electrical Engineering and Director of LARS
c) J. C. Lindenlaub - Professor of Electrical Engineering and Senior Scientist
d) C. D. McGillem - Professor of Electrical Engineering
e) H. J. Siegel - Assistant Professor of Electrical Engineering
f) L. F. Silva - Professor of Electrical Engineering and LARS Program Leader
g) P. H. Swain - Associate Professor of Electrical Engineering and LARS Program Leader

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

Professional Staff

1. AGRICULTURE

a) L. A. Bartolucci - LARS Program Leader
b) M. E. Bauer - Research Agronomist and LARS Program Leader
c) C. S. T. 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) R. K. Boyd - Data Analyst and Training Specialist
d) G. M. Brammer - Software Analyst
e) J. S. Buis - Systems Analyst I
f) R. Chung - Coordinator for Computer Systems
g) J. C. Cochran - Applications Programmer I
h) M. D. Collins - Computer Operations Supervisor
i) S. M. Davis - Education and Training Specialist
j) J. B. Etheridge - Manager of Systems Analysis
k) S. L. Ferringer - Visual Designer
l) D. M. Freeman - Manager of Data Reformatting
m) N. C. Fuhs - Applications Programmer
n) R. A. Garmoe - Manager of Basic Systems
o) M. C. Hodge - Administrative Assistant
p) S. K. Hunt - Systems Analyst I
q) P. L. Jobusch - Senior Computer Analyst
r) P. K. Johnson - Business Office Administrative Assistant
s) J. K. Kast - Program Developer
t) B. C. Kozlowski - Applications Programmer
u) L. A. Kraemer - Applications Programmer
v) G. E. Majkowski - Systems Analyst I
w) D. E. Parks - Publications Coordinator
x) T. L. Phillips - Deputy Director of LARS
y) M. E. Pierson - Shift Supervisor
z) B. J. Pratt - Administrative Assistant
aa) B. F. Robinson - Research Engineer and LARS Associate Program Leader
bb) S. K. Schwingendorf - Applications Programmer
cc) B. M. Shelley - Reformatting Operations Assistant
dd) C. R. Smith - Reformatting Operations Assistant
ee) M. L. Tang - Software Analyst
ff) V. C. Vanderbilt - Research Engineer

3. Humanities, Social Science and Education

a) D. B. Morrison - Education and Training Coordinator

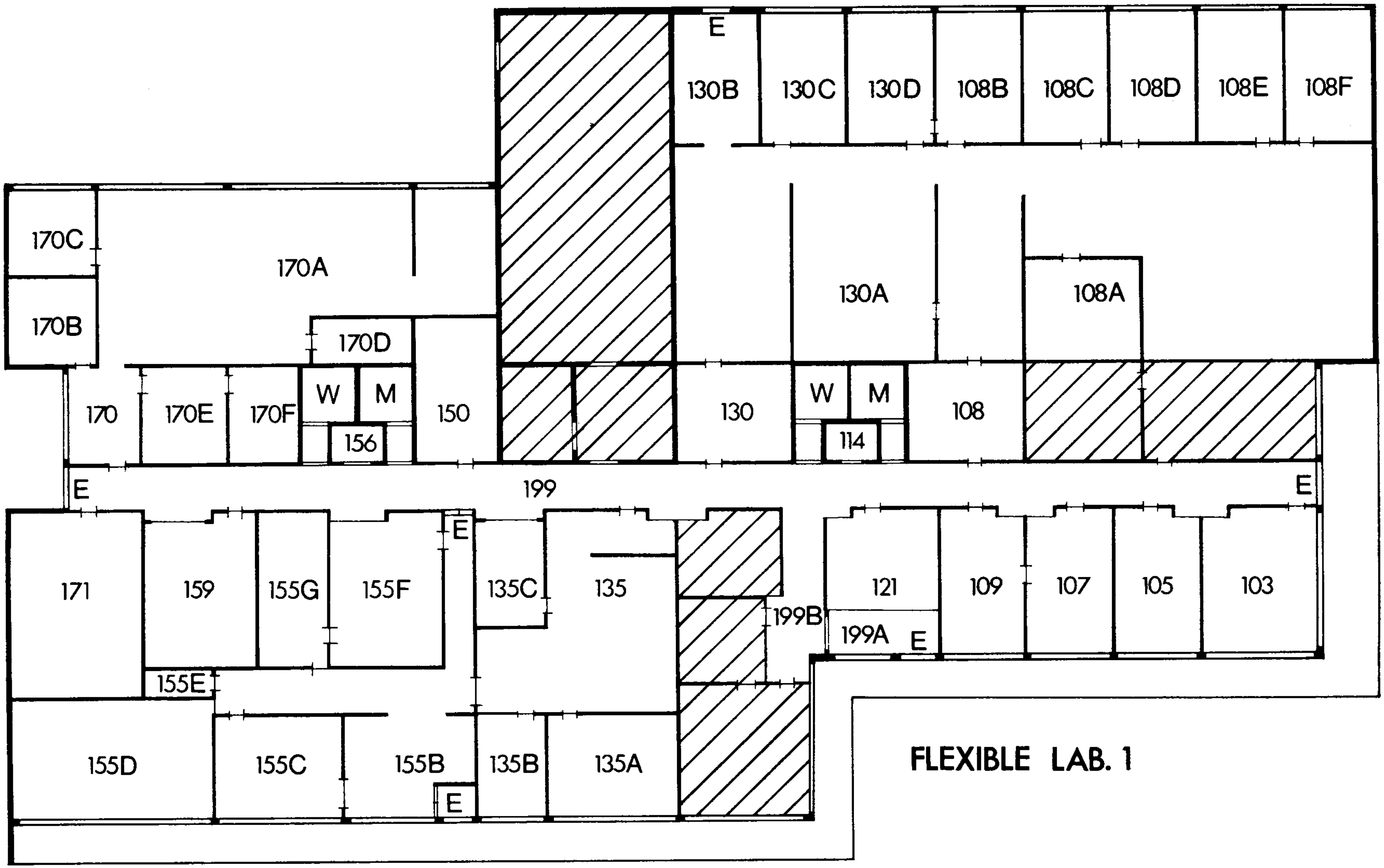
4. Science

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

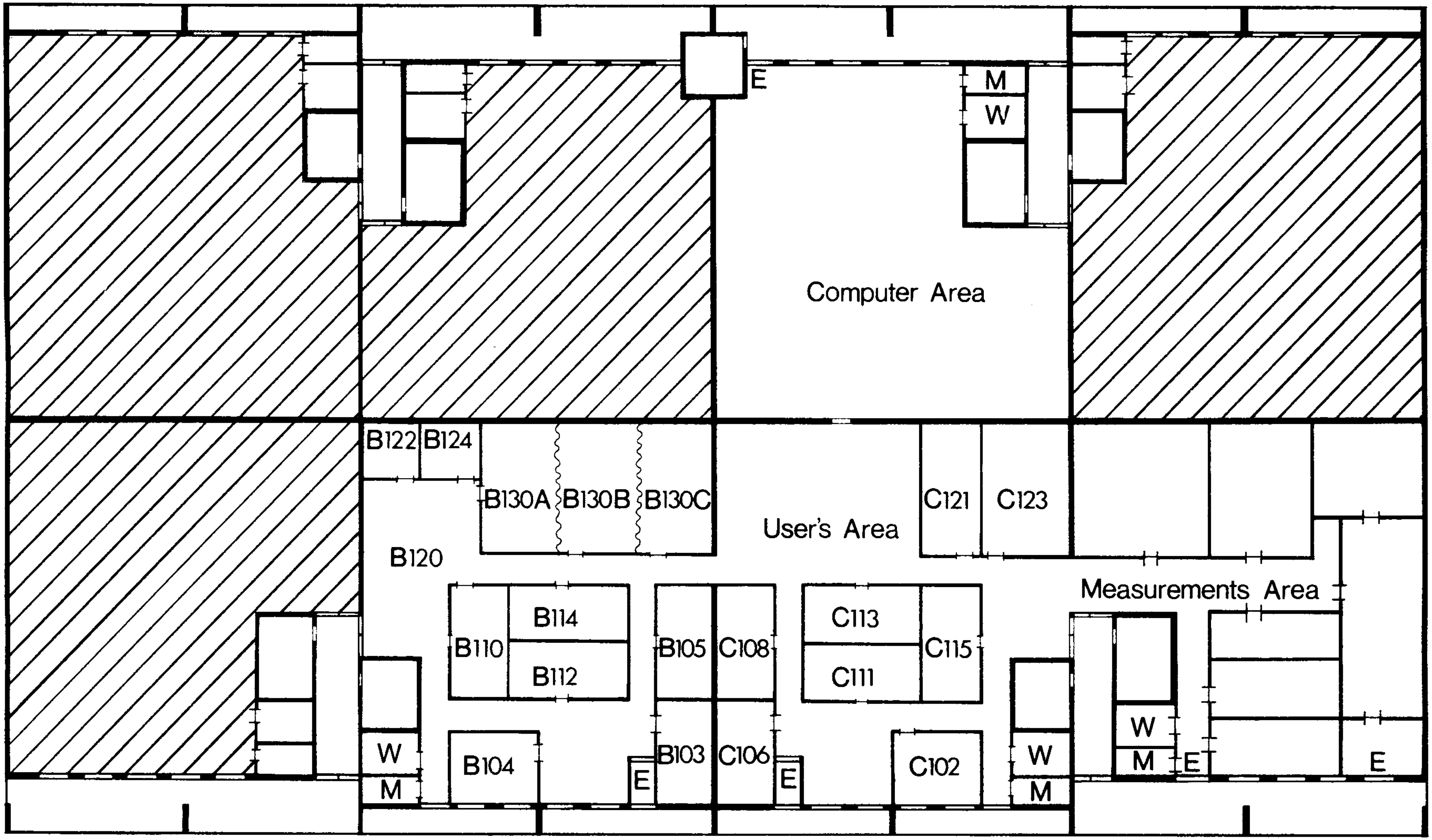
Table 5. Staff involvement at LARS by department and classification.

Department	Faculty (Page 87)	Professional (Page 88)	Graduate Students (Page 61)	Undergraduate Students	Service	Clerical
Agriculture						
Agronomy	4	6	11	10	1	
Forestry	1	2	6	1		
Engineering						
Bio-Medical	1		1			
Electrical	6	3	12	1		
Experiment Station		29	1	70	5	17
Mechanical	1		3			1
HSEE						
Education	1		1			
Communications		1				
Science						
Computer Science			1			
Geoscience	1		1			
Statistics	3	2	2			
TOTAL	18	43	39	82	6	18

Appendix III - Floor Plans



FLEXIBLE LAB. 1



FLEXIBLE LAB. 2