LABORATORY FOR APPLICATIONS OF REMOTE SENSING

Annual Report to the University

Fiscal 1976

Purdue/LARS
1220 Potter Drive
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1975-76 Report to the University
The Laboratory for Applications of Remote Sensing

This report covers the period July 1, 1975 through June 30, 1976. It provides a summary of research and development activities and the training functions carried out with contract funds. It also documents the amount of staff and student involvement and the manner in which funds were expended as a function of academic unit.

This year has been characterized by increased interest both in devising the tools of remote sensing and in using them. The demand for educational activities showed a marked increase this year. This is evidenced not only by participation in our short course which is now offered every month, and the visiting scientist program where participation nearly tripled over the previous year, but also in graduate student participation. There were 53 graduate students participating this year as compared to 42 last.

The plans to launch LANDSAT-C in 1977 with its more advanced capabilities and the design and launch of LANDSAT-D in 1981 with its even greater capabilities are already having their impact on the field. Not only are the opportunities for research going to be enhanced but the demand will increase for well-trained graduates to staff the many operational programs now forming in government and industry.

We are pleased to transmit this report to you and look forward to another year of contribution to the several disciplines involved in the remote sensing field.

David A. Landgrebe
Director

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ANNUAL REPORT TO THE UNIVERSITY

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RESEARCH ACCOMPLISHMENTS

I. INFLUENCE OF LARS ON REMOTE SENSING TECHNOLOGY, PATTERNS OF INTERDISCIPLINARY RESEARCH, AND PURDUE'S RESEARCH AND EDUCATIONAL PROGRAMS

A. LARS CONTRIBUTIONS TO REMOTE SENSING TECHNOLOGY

Much of the innovative research which has spearheaded the rapid development of today's sophisticated remote sensing technology has been produced by Purdue scientists working at LARS. Paralleling the inception of LARS and its growth the science and technology of remote sensing has advanced from an image oriented endeavor using photo interpretation as its basic technique to a numerically oriented one depending on mechanical analysis of electronically sensed data. This evolution has been made possible to a great extent by the research of Purdue scientists working in the LARS organization. That the scientific community is aware of LARS' role is evidenced by the remarks of Russell R. Schweickart, astronaut and top NASA official, in his keynote address for the 1975 NASA Earth Resources Survey Symposium, Houston, Texas. He stated that the first major milestone in the development of remote sensing technology was the demonstrated successful application of pattern recognition theory to classifying agricultural crops by scientists at LARS, Purdue.

In 1964 with the encouragement of Dr. Ralph Shay, then head of the Purdue Department of Botany and Plant Pathology, Purdue was selected by NASA as the location for a research center to develop and test the feasibility of using multispectral data to inventory agricultural features. The early research was so successful it led to a grant from NASA in 1966 to establish the Purdue Laboratory for Agricultural Remote Sensing, later to become the Laboratory for Applications of Remote Sensing (LARS), a title to fit its expanding role.

The major achievements by LARS people over the following decade may be listed as milestones outlined in the following pages:

MAJOR REMOTE SENSING MILESTONES

MAJOR THRUST	DATA COLLECTION	DATA PROCESSING	APPLICATIONS
	1964		
Feasibility Studies	Multispectral Cameras DK-2 Laboratory	Photo Interpretation* of Spatial Patterns	
	Successful relating of multispectral imagery to crop characteristics.		
	1965		
	Scanner System Definition		Laboratory Spectral Responses
	Superiority of multispectral scanner over photographic systems proposed.		
	1966		
Definition of Approach	A/C Scanner Slow Scan Spectrometer Adapted to Field Conditions	Multiband Level Slicing, Multivariant Pattern Recognition	Crop Classification (5 square mile)
	NASA begins financial support of Purdue proposal to establish center to develop remote sensing technology for agriculture, Laboratory for Agricultural Remote Sensing (LARS). LARS introduced broad-based interdisciplinary approach, featuring close cooperation among natural scientists, data analysts and engineers. Promising results achieved with application of multivariant pattern recognition to analysis of multispectral scanner (MSS) data. Successful identification of several crops by LARS staff with airborne MSS data encourages development of the digital approach.		
	1967		
Development of Approach For Increasing •Areas •Disciplines •Techniques		Image Registration (small areas)	
	Further tests of pattern recognition theory to MSS data greatly advanced by LARS.		

*Underlined activities were initiated by LARS staff members.

MAJOR THRUST	DATA COLLECTION	DATA PROCESSING	APPLICATIONS

1968

	Image Registration (large areas), Feature Selection	First Machine Implemented Soil Classification and Water Quality and Forest Classification

Effective computer software package, LARSYS, produced by LARS staff.
This and later editions were to become a principal system used the world over for analyzing MSS data.
Successful registration of large areas of multitemporal image data.

1969

Apollo IX	Per Field Classification	Satellite Crop and Geologic Classification (10,000 square miles)

LARS becomes Laboratory for Applications of Remote Sensing in recognition of expanding role of interest including such additional areas as geology, geography and hydrology.
First successful machine analysis of satellite data using scanned Apollo IX photography and computer image registration system.

1970

	Clustering, Data Compression, First Multitemporal Analysis	Corn Blight Watch

Machine-implemented multitemporal analysis first demonstrated.
Marked improvement made at LARS in use of MSS data and machine analysis to identify features of the landscape.
LARS scientists successfully identified southern corn leaf blight damage.
Installation of dedicated IBM 360/67 made possible researching possibilities of exporting technology by a remote terminal system.

Test of Technology

1971

	Quasi-operational System	Corn Blight Watch

LARS at request of NASA and USDA coordinated and managed Southern Corn Leaf Blight Experiment, the largest ever experiment in agriculture, involving 1,000 people from 17 federal and state agencies and covering seven corn belt states.

*Underlined activities were initiated by LARS staff members.

MAJOR THRUST	DATA COLLECTION	DATA PROCESSING	APPLICATIONS
	1972		
Program Broadening User Community Contact	ERTS-1 Fast Scan Field Instrument	Spatial-Spectral Classifier	Tests for many Disciplines (5,000 square miles)

LARS staff at request of NASA makes first successful classification of earth's landscape with MSS data from the ERTS-1 satellite.
Continued successful development by LARS staff of applications of remote sensing to agriculture, forestry, hydrology, land use, and geology.
First test of classifier algorithm using both multispectral and spatial scene variations which used machine implemented scene regimentation.

	1973		
	Skylab	Remote Terminal System in Operation, Geometric Correction, Multitemporal Analysis of Satellite Data	

LARS played a leading role at the invitation of NASA in the experiment, Crop Identification Technology Assessment for Remote Sensing (CITARS).
LARS begins successful inventory of use of United States land in the Great Lakes Watershed in response to request from the Land Use Reference Group of the International Joint Commission.

	1974		
		Education Materials	LACIE

Decision tree approach applied to multivariate and multiclass classification of MSS data.
At the invitation of NASA, LARS assumed leading role in the Field Measurement Experiment, in support of the Large Area Crop Inventory Experiment (LACIE), a "quasi-operational" experiment on a world-wide scale to explore the feasibility of large scale crop inventories using MSS data from satellites.

	1975		
Rapid Improvement in Applications of Technology	International Field Measurements Experiment	Registration of Ancillary Data with LANDSAT Data, Thematic Mapper Simulation	LACIE

LARS cooperates with the Soil Conservation Service (SCS) in developing potentially effective techniques for expediting the making of soil surveys; continues leadership in the international field measurements experiment.

*Underlined activities were initiated by LARS staff members.

MAJOR THRUST	DATA COLLECTION	DATA PROCESSING	APPLICATIONS

Becomes recognized world wide as center for education in applications of remote sensing offering a symposium attended by 250 scientists from many countries, 11 one-week short courses serving 90 people and on-the-job training for 20 visiting scientists from eight foreign countries.

Conducted simulation of parameters for Thematic Mapper, an advanced scanner system to be in orbit in 1981.

*Underlined activities were initiated by LARS staff members.

B. LARS CONTRIBUTIONS TO DEVELOPMENT OF EFFECTIVE PATTERN OF INTERDISCIPLINARY RESEARCH

A truly interdisciplinary research program has been achieved within the framework of a large university with few of the constraints associated with a university department. This has been accomplished through maximizing the freedom permitted LARS by Purdue to innovate, test and improve management, structure, and policy.

Significant steps in the evolution of the Laboratory's present structure include:

First, an early decision to avoid the constraints inherent in a departmental type structure by creating a research organization without fixed disciplinary boundaries, with a flexible arrangement for participation in the projects by academic staff members and with enough autonomy and authority to insure a planned and effective operation. To accomplish this a management structure has evolved from one based on a co-director pattern to that of a single director. The director is supported by an associate director, deputy director and business manager, and participates in a managerial committee consisting of the director of LARS, and the directors of the Agricultural Experiment Station, and the Engineering Experiment Station. He receives advice and consent for major policy decisions from a policy committee consisting of the Vice President for Research, the Deans of Agriculture, Engineering and Science, and the university Business Manager, subject to approval by the Provost. This structure has effectively insured the multidisciplinary operation of the Laboratory but provides a more tortuous path for policy decision than is adapted to quick expediting of major changes.

Second, the creation of a real and effective interdisciplinary approach to research within the Laboratory. This has evolved from several things:

1) A staff structure which provides for academic staff members to receive certain perquisites from the Laboratory while working on research projects involving remote sensing. Included among the possible privileges are:

A. Proportional funding of the professor's salary according to his share of effort on a project, funded by budget transfer to the professor's home department from LARS contract funds.

B. Graduate student support to the professor, funded in the same manner.

C. Availability to the professor and his students of computer services and other Laboratory services on a cost basis, recoverable from the particular research project involved.

D. Technical support from LARS professional staff members, also on a cost recovery basis from project funds.

E. Privilege of presenting proposals to funding agencies for research projects in the areas of overall interest to the Laboratory following proper clearance with LARS administration regarding availability of space, computer services and other resources.

These arrangements make it possible for academic staff members and graduate assistants to work on research projects at LARS as much and as long as the appropriate contract funds are available. They also provide them with the opportunity to capitalize on the stimulation and support to be gained in working in the midst of a creative group of scientists and to make use of the other resources available at the Laboratory.

Third, an intralaboratory management structure which provides orderly management of funds and of resources while offering decentralized management and policy making procedures. This is accomplished through the organization of six program areas each headed by a director and associate director who participate once a week with the laboratory director and his staff in a policy making and management meeting. The program area directors are responsible for the activities in their program areas.

Fourth, the development of a project oriented managerial procedure to implement each grant or contractual arrangement under the direction of a principal investigator with responsibility for management under the contract of both fiscal affairs and research.

In a sense, if the program area organizational plan can be considered as a vertical plotting of intralaboratory responsibility, the project arrangement can be plotted horizontally across the appropriate program area boundaries.

Over time the research program areas have become quite stable, continuing operational units, whereas the projects exist as temporary units depending on contractual arrangements for time and funds. The arrangement provides great flexibility in the grouping of multidisciplinary teams on problems of common interest and in the dissolution of the teams and possible regrouping of the team members with other scientists on new projects as objectives are fulfilled.

Fifth, development of stability of tenure on the part of professional and administrative staff although tenure is not guaranteed. Professional employees, usually on a fulltime basis, provide continuity to the laboratory research. By design the F.T.E. of professional employees is kept at approximately the same as that of the academic employees to insure a strong academic program involving graduate students and insuring close coordination with the academic program of the University. The Laboratory has been successful in employing and holding highly qualified professional staff people.

These staff members enjoy in general all the benefits of academic personnel with the exception of tenure. The managerial staff consisting of the director, associate director, and deputy director have held their positions for the last five years.

These five steps in the history of the Laboratory have resulted in a dynamic, evolving structure. The policies and operational procedures which have evolved have created an environment in which scientists from various disciplines but with common interests are able to work together well in a well-organized but flexible pattern. Such a pattern has been found to permit the elasticity essential to keeping a research program relevant and timely while at the same time permitting the individual scientists to maintain their identities as members of specific disciplines.

C. INFLUENCE OF LARS ON SPACE-ORIENTED EDUCATIONAL AND RESEARCH ACTIVITIES AT PURDUE

Through the Laboratory a significant contribution has been made to space-science activities at Purdue in research, formal education, and the transfer of technology. LARS makes available to Purdue staff members a well-equipped multidisciplinary laboratory so organized and managed that it provides a truly interdisciplinary environment. A large proportion of the support for the Laboratory's activities in FY76 was provided by grant and contract money totalling $2,121,059.

The resources of the Laboratory directly supported the educational activities for approximately 20 academic staff members who directed graduate thesis research in problems involving remote sensing in FY76. In the spring semester the Laboratory contributed to the salaries, fringe benefits and overhead of 19 academic staff members at an annual rate of $333,066 and supported the same costs for graduate assistants at an annual rate of $182,698. There were 53 graduate degree candidates, 12 of whom were granted an advanced degree, who were advised by LARS staff members in FY76. Five formal university courses dealing with remote sensing are offered in three different schools by professors who gained their expertise at LARS. In addition, the content of several other courses in Agronomy, Forestry, Civil Engineering, and Electrical Engineering include parts dealing with current remote sensing technology.

Many noted scientists from over the world have been attracted to the campus by the remote sensing program, thus adding greatly to the total academic atmosphere of the campus. These people attend symposia, short courses and seminars offered by the Laboratory; participate in the visiting scientists program or come by as interested short-time visitors. The Laboratory helps undergraduate students by providing many jobs which in addition to salary benefits provide excellent technical training and expose capable students to a scientific atmosphere.

The greatest activity of the Laboratory is research based largely on graduate thesis programs guided by professorial staff people and supported by full time professional staff members. The Laboratory's flexible arrangements utilizing Purdue staff members in its active, interdisciplinary programs provide a favorable atmosphere for creative work seldom matched. Through this facility many professors have found support for an active and rewarding career in research.

D. NATIONAL AND INTERNATIONAL RECOGNITION OF LARS STAFF

1967 Chairman of Sensor and Data Systems Panel of National Academy of Sciences Study of Peaceful Uses of Earth Oriented Satellites.

Provided major input to NASA in 1969 for the specifications of the ERTS scanner design.

Software system, LARSYS, was developed, now used totally or in part by many governmental and university groups who analyze MSS data.

Selection of LARS by The Land Use Reference Group of the International Joint Commission to make land use inventory of 33,000,000 hectares of Great Lakes Watershed.

Choice of LARS to provide technical leadership of the Field Measurements project, an important phase of the world wide LACIE.

Awarding of the NASA Scientific Achievement Medal to D. A. Landgrebe in 1973 for scientific leadership as director of LARS.

Consultant for workshop for U. S. National Committee for Geochemistry, Division of Earth Sciences, National Research Council, Fort Myers, Florida, 1974.

Chairmanship in 1975 of NASA selected panel of experts assigned the task of defining specifications for the thematic mapper, a scanner to be mounted on LANDSAT D in approximately 1981. Four other LARS personnel were among the 40 panel participants.

Other significant assignments held by members of the LARS staff include membership in the NASA Headquarters ERTS selection panel; on the committee of scientists and engineers to make recommendations to NASA on specifications of the next generation of satellite sensors; on the Biology and Data Management Panels of the Committee on Remote Sensing of Programs for Earth Resource Surveys (CORSPERS), National Academy of Sciences; and on the Executive Committee on Remote Sensing, The International Society of Soil Science.

Further significant activities of LARS staff members include:

Resource participant, two week study, Snowmass, Colorado, sponsored by National Academy of Engineering to advise U.S. government to nation's need for operational space applications in 1990.

Consultant to Food and Agriculture Organization of the United Nations, the government of Sudan and the International Development Research Center of Canada on using remote sensing to inventory natural resources of Sudan.

Invitational witness to testify before U.S. Senate Subcommittee on Aeronautical and Space Science.

Selection of D. A. Landgrebe and Terry Phillips for citation by NASA for creative development of an evolving method of data analyses, LARSYS III.

Director of Remote Sensing and Interpretation Division of American Society of Photogrammetry.

II. WORK IN PROGRESS

A. DATA PROCESSING AND ANALYSIS RESEARCH

Progress continued during 1975-76 in the development and application of quantitative methods for remote sensing data processing and analysis.

1. Data Analysis Research

NASA's Large Area Crop Inventory Experiment, in which NASA is demonstrating the use of the remote sensing technology in a very significant application, provided motivation for much of our data analysis research activity during 1975-76. In addition to evaluating the impact of the current technology, this experiment will provide an assessment of where many of the greatest needs are with respect to future technological advancements.

To make crop inventory by remote sensing most cost-effective requires analysis of large geographical areas. This presents a serious challenge in terms of adequately characterizing the ground scene and extrapolating that characterization over as large an area as possible -- with minimal use of ground observations, which are very expensive to obtain. Research has therefore been directed toward determining the maximum area over which a set of classifier training statistics can validly be applied.

The use of multitemporal data -- the variation of the scene over a succession of temporally spaced observations -- has been shown of value for accurately identifying crops as well as other types of ground cover. In fact, detection and measurement of the amount of change itself is of value in monitoring the state and predicting the evolution of our environment. Thus another data analysis research objective has been the development of effective means for incorporating multitemporal information in the analysis process. The problem is more difficult than simply extending the "conventional" analysis methods to the multitemporal data sets. Classifiers which use layered decision logic have been shown to provide a promising approach to this problem.

Research support from the U.S. Geological Survey's Census Cities program has provided an opportunity to investigate the characterization of spatial information in the remote sensing data. Various measures of spatial frequency variation and texture have been applied in the context of land-use classification. Further exploration of an automated method for delineating and classifying objects (homogeneous regions) in the scene has also been pursued.

Statistical design and statistical evaluation of results have become of increasing importance as the technology matures. Sampling techniques, for collection of "ground truth," selection of areas to be analyzed, and extrapolation of sampled results to inferences about large areas, have proved a vital tool in the practical application of the technology. Support of the laboratory-wide application of statistical techniques has become a substantial component of the data analysis research effort.

2. Data Handling Research

Registration of Ancillary Data

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 the registration concept has been broadened from image-to-image registration to encompass the registration of map and tabular data of many types to support the analysis of remote sensor data. These other data types can be considered "ground truth" or reference data and include variables such as topographic elevation and slope, soil type, land use, zoning, political boundaries and others. Research has been conducted on methods of converting maps to digital image form and several applications have been investigated. In one case the effects of slope, elevation and direction of slope on spectral response was studied in the San Juan Mountain area of Colorado using topographic map data registered with LANDSAT data. In another experiment geophysical data recorded on contour maps as well as topographic map data were registered with LANDSAT data to aid in exploration for minerals using remote sensing techniques. This research is expected to lead to a wide range of applications of computer-based methods where many remote sensing and ground-collected data variables must be analyzed together to obtain maximum return from the remote sensing data.

B. MEASUREMENTS RESEARCH

Shortly after the establishment of LARS the measurements program area was concerned chiefly with the study of available remote sensing instruments and a study of the characteristics of remotely sensed spectral data. The original work was concerned chiefly with the investigation of signal characteristics of multispectral scanners as a function of the available scanner descriptive parameters. Subsequent work centered chiefly around the acquisition of spectral data from natural materials using available laboratory instruments. The limitations of these available laboratory instruments and their effect upon the quality of the spectral data were carefully studied and specifications for instruments more closely suited to field acquisition of spectral data were drafted.

A truck instrumentation system was designed, constructed and equipped with an interferometer instrumentation system that was used to acquire spectral data over the 1.5 micrometer to 15 micrometer wavelength range. Several instruments were evaluated using the truck system and a complete set of specifications for a more suitable field spectral system were derived based upon the experience gained with the truck system and associated instruments. Several laboratory and field experiments were designed and executed in which the reflectance characteristics of natural material components were related to the reflectance characteristics of the scenes that might be encountered in a typical remote sensing problem.

Based upon prior laboratory and field experience, a field spectral data acquisition system was designed, developed and constructed. The system was especially suited for acquiring spectral data under field conditions in a natural environment as opposed to a laboratory environment. Over the years the system has been continually developed and improved to a point where it is now considered by the remote sensing community to represent the state of the art in field remote sensing spectral data acquisition systems.

Continuing experience with the aforementioned field system led to practical solutions of the extremely difficult problem of establishing standards and calibration procedures for such a field system. LARS developed a coordinated laboratory field calibration procedure which has been accepted by several laboratories involved in field spectral data research as a standard procedure for field calibration. Research into this extremely important facet of remote sensing research continues.

Additionally, several pieces of specialized laboratory and field apparatus have been developed at LARS in the measurements program area. These include specialized calibration equipment, laboratory or directional reflectance measuring apparatus, specialized field reflectance measuring apparatus, unique thermal imaging equipment, and data logging and test apparatus.

During FY1976 the following activities have been pursued in the measurements program area:

1. Field Spectral Data Acquisition

During the past year the LARS spectral data acquisition system was deployed at the North Dakota State University Agricultural Experiment at Williston, North Dakota. The system acquired spectral data as part of a Field Measurements research project described elsewhere in this report. The data that were acquired by the system were deposited in a special data library that was developed for the project. The data from several other sensors used in the project were also deposited in the data library. The data already have been used to calibrate the output from a multispectral scanner operated by NASA. If the calibration data produced by the spectral system had not been available it would have been impossible to use the data produced by the NASA scanner system. Additionally, the data produced by a field data acquisition system operated by NASA at Finney County, Kansas was verified and corrected using a specially developed calibration procedure that was applied in the field at the Williston, North Dakota test site. The NASA system was moved from the Kansas test site to the North Dakota test site for the purpose of data verification and correction. The field system has been deployed again for a year of data acquisition during the 1976 growing scene at the Williston, North Dakota test site.

2. Vegetative Canopy Modelling

A problem of current interest in remote sensing concerns the establishment of the correlations between vegetative canopy reflectance and the geometric characteristics of that canopy. If this correlation can be established, one can relate those features of the canopy which are directly or indirectly relatable to the geometric characteristics of the vegetative canopy to that canopy's spectral reflectance. Many investigators feel that the crop yield of a cultivated vegetative canopy can usually be related to that canopy's geometric characteristics. If true, it would be possible ultimately to relate an important agronomic variable such as yield to a canopy's spectral characteristics. A vigorous activity in the measurements program area has been concerned with a study of a number of currently available canopy models. The emphasis has not been upon the derivation of a new canopy model since the ones already in existence appear to be satisfactory for the purpose. The emphasis has been, however, upon the accurate determination of the important parameters of vegetative canopies, particularly wheat, in a field situation. The utilization of canopy models in a study of the canopy's characteristics can be consumated with these parameters. One such experiment has been a measurement of the optical depth of a wheat canopy and a corn canopy utilizing a laser as a probing device. The data from these experiments have been used to establish the numerical values in the parameters of several important canopy models. The results will ultimately be used to establish the experimental correlations between the spectral reflective and emissive characteristics of the corn and wheat canopies. In addition, the spectral reflectance of a wheat

canopy has been measured as a function of view angle, solar angle and polarization characteristics and the results analyzed to establish the correlation between geometric characteristics and spectral reflectance.

3. Thermal (Emmisive) Characteristics of Vegetative Canopies

Previous research has indicated that the thermal characteristics of vegetative canopies are important indicators of canopy vigor and are often useful in the delineation of canopies. As a consequence, a continuing research effort in the study of thermal characteristics of vegetative canopies has been instituted and will be continued during the current research period. Spectral-thermal data over corn canopies and wheat canopies have been acquired and analyzed and the results correlated with the geometric characteristics of the canopy. A thermal imaging system, that was acquired in the past with year-end funds, has been specially modified so that it is capable of obtaining radiant temperature profiles in vegetative canopies as well as thermal imaging in a vertical view of the canopy. A unique series of experiments which relate radiant temperature profiles to air temperature profiles and the spectral thermal characteristics and radiant temperatures of the top of the canopy have been instituted and are proceeding. This research shows great promise to deepen the understanding of the thermal properties of canopies and their relationship to other important agronomic variables and the spectral reflectance of the canopy. Future earth resource satellites will be equipped with thermal channels, thereby, establishing the importance of a fundamental understanding of the thermal characteristics of natural materials on the earth's surface.

4. Non-Earth Resource Applications

A new project has been established and funded in the measurements program area which utilizes the thermal imaging system mentioned above. This is a project which is being jointly executed by the Biomedical Engineering Center at Purdue and LARS. It involves the use of rapid scan thermographic images to study the heating effects around electrosurgical dispersive electrodes. The results of this study will be used to improve the design of such dispersive electrodes and to aid regulatory agencies in establishing realistic standards for the design and application of such an electrode. Many of the techniques that have been used to analyze earth resource data will be applied directly in the analysis of the multispectral data produced by color infrared film and the thermographic data from the thermal scanner. This project represents the first time in which a non-earth resource application of remote sensing technology has been established and pursued in the measurements program area. The thermal imaging system was also used in a recent effort to aid the law enforcement agencies of South Bend, Indiana and Niles, Michigan in a search for the bodies of suspected murder victims in the Niles, Michigan area. A search of an area in which the victims were suspected to be buried was instituted with a thermal imager mounted on a helicopter.

Several possible sites were located in which recent excavation had been suspected due to the changing thermal characteristics between disturbed and undisturbed soil. The bodies were not located but a suspicion that a burial had taken place in the past was confirmed.

Current and future activity in the measurements program area is centered around the establishment of a firm theoretical foundation to the observed characteristics of natural materials in field situations. This activity is important in view of the fact future earth resource satellites will be acquiring and transmitting more complex data than in the past. It is essential that the characteristics of these data be thoroughly understood in order to maximize the utilization of the data in earth resource information systems. It is anticipated that an important future segment of the measurements research at LARS will constitute the application of powerful multispectral analysis techniques and data acquisition to non-earth resource applications. Future work will be concerned with the classification of burns in animals and humans using thermographic and spectral analytical techniques. A project involving the application of multispectral pattern recognition techniques to the detection of breast cancer in human females is also being proposed.

C. CROP INVENTORY SYSTEMS RESEARCH

In response to the current great need for timely and accurate information on world food production, scientists at LARS continued to concentrate a major part of their research on developing a remote sensing capability to obtain crop production information. Remote sensing is a potentially useful tool for obtaining both area and yield estimates, the two basic kinds of information required to estimate crop production.

During FY76, the Crop Inventory Systems Research program area continued to work with other program areas of the laboratory, particularly Data Processing and Analysis Research and Measurements Research on the spectral stratification and field measurements projects. These projects are in support of the Large Area Crop Inventory Experiment (LACIE) currently being conducted by USDA, NASA, and NOAA. The LACIE is to develop, test, and demonstrate the feasibility of global crop inventories, with multispectral remote sensing data acquired by LANDSAT as one of the major inputs. The large-scale experiment is expected to lead to an operational remote sensing-based crop inventory system.

1. Stratification of LANDSAT Data by Clustering

Full realization of the potential advantages of the synoptic coverage provided by LANDSAT will require the development and use of data analysis techniques which take into account the large variation and diversity of patterns found over many LANDSAT scenes. Stratification of the scene into units which are internally homogeneous is recommended as a first step in the analysis of whole or multiple frames of LANDSAT data. During FY76 computer-implemented clustering procedures for dynamic stratification were developed and tested over several LANDSAT scenes of Kansas. The initial results indicate that the technique can be used to determine the similarity of sample units and that the strata produced agree with major crop, soil, and climatological features of the scene.

2. Agricultural Field Measurements

There is a continuing requirement for calibrated, comprehensive data sets to pursue a wide variety of remote sensing problems. The overall objective of the agricultural field measurements project is to obtain fully annotated and calibrated multitemporal sets of spectral measurements over the wavelength range of 0.4 to 15μm and supporting agronomic and meteorological data which will serve as a data base for: (1) quantitatively determining the temporal-spectral characteristics of spring and winter wheat, the soil background, and surrounding confusion crops in support of the LACIE, (2) defining future multispectral sensor systems, and (3) developing advanced data processing and analysis techniques.

Data is being acquired for test sites in Kansas, South Dakota, and North Dakota. The remote sensing data includes measurements made from truck-mounted spectrometers, a helicopter-borne spectrometer, an aircraft multispectral scanner, and the LANDSAT multispectral scanner. High resolution aerial photography, detailed measurements and observations of the crops and soils, and meteorological measurements are acquired simultaneously as part of each remote sensing mission. An important aspect of the remote sensing data is that it is calibrated so that data from the various sensors, sites, and dates can be readily compared.

LARS role in the project is to provide technical leadership and coordination, acquire data at the North Dakota test site, process and reformat data to standard and comparable formats, evaluate and verify data quality, maintain a data library and distribute data to other users, and data analysis.

3. Crop Identification and Area Estimation Over Large Geographic Areas Using LANDSAT Data

This project which is nearing completion is using advanced data analysis techniques to identify and make area estimates for the major crops in Indiana and Kansas. The Kansas results show that wheat can be accurately identified using the LANDSAT data and that the area estimates compare well with those made by the USDA. An important feature of the approach is that by classifying entire LANDSAT frames using the computer, the sampling error of the estimates is neglible.

4. Large Area Crop Inventory Design

The technology currently being used by the LACIE was largely developed prior to 1972. While our present data acquisition and analysis capabilities offer many potential advantages over alternative information gathering systems, the full potential of the technology has definitely not been achieved. The objective of this project, sponsored by NASA, is to produce plans for the research and development required to develop the second generation of technology. The project will define where the technology should be five years from now and how to get there. The advanced system plans will be for a multi-crop inventory system.

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

A proposal to NASA for LARS to provide the technical implementation of the remote sensing experiments of analygous vegetative areas in the United States and the Soviet Union has been approved and is to start on July 1, 1976. This is the first year of a multi-year study and is one of several U.S./U.S.S.R. studies on remote sensing of the natural environment. Test sites in South Dakota and the Kursk Oblast of Russia have been selected and the first year's data collection initiated. Several remote sensing systems ranging from ground-level to satellite altitudes will be used. Initially, the study will concentrate on the spectral reflectance of wheat and the agronomic factors affecting its growth and development. The project plan calls for exchange of data between the two countries; and the U.S. will have an opportunity to analyze the Soviet data.

D. ECOSYSTEMS RESEARCH PROGRAMS

During the past year, the Ecosystems research group has been working on a number of projects involving forestry, water resources, and land use applications. LANDSAT satellite data from a variety of locations and terrain conditions have been utilized in these studies, including such areas as the Arctic in northern Alaska; Bolivia, South America; rugged mountain terrain in Colorado; and flat and gently rolling terrain in Texas and Indiana. Much of the thrust this year involved work with various users groups to evaluate better the value of applications of computer-aided analyses of remotely sensed data in meeting needs for information necessary in resource management decisions. Some of the more significant results and the current status of the individual projects are described in the following paragraphs.

1. Land Use Mapping Around Lake Wawasee

Professor Anne Spacie of the Department of Forestry and Natural Resources has been working with several state and local agencies in the Lake Wawasee area. Dr. Spacie's work involves developing long range strategies for water quality preservation and aquatic weed control in the lakes. During this work she found that the local administrative bodies lack basic information on land use and urban development in the watershed. The population in the area is increasing extremely rapidly. Recent man-made alterations to the lake shore and surrounding areas have not been documented. The alterations, such as housing development and channelization, have a direct impact on the lake itself, and on the wetland areas near the lake which the Indiana Department of Natural Resources manages. As a consequence, during the spring of 1976 a project was initiated as part of the NASA/PY program to work with the town of Syracuse Planning Commission and the Indiana Department of Natural Resources Division of Fish and Wildlife to obtain the information required to make sound, knowledgeable management decisions. Color infrared photography flown over a large portion of Turkey Creek Township in Kosciusko County is in the process of being interpreted. Work with the various agencies will be continuing throughout 1976.

2. Land Use Mapping in Mountainous Terrain

LANDSAT and SKYLAB multispectral scanner data have been utilized to map Level I and Level II land use in the San Juan Mountains of Southwest Colorado. This area of rugged terrain contains a complex mixture of forest types, rangeland, alpine tundra, agricultural area, water bodies, geologic features and various man-made features. In one of the more significant analysis sequences, an area of 2,456,000 acres was classified into deciduous forest, coniferous forest, grassland, water, and barren (exposed rock outcrops, soil, and sparsely vegetated tundra). To quantitatively evaluate the classification performance, 16,170 data points were used as test areas. An overall accuracy of 91.2 percent resulted. Next, a series of 7½' USGS quadrangles were randomly selected and the acreage of each of the major cover types within each quadrangle was calculated (each resolution element of the satellite data equal 1.1 acres). These acreage figures, based upon computer analysis of satellite data, were then compared to acreage estimates obtained by manual interpretation of aerial photographs for the same quadrangles.

Comparisons between the two estimates showed a correlation coefficient of 0.929.

Both of these results indicate that reasonably accurate classification performance of major land use classes can be achieved, using satellite data and computer-aided analysis techniques even for areas of mountainous terrain and complex cover types.

3. Effective Man-Machine Interface

During the past several years, several different procedures have been developed for analyzing multispectral scanner data. Although the software is available, we are finding that guidelines for effective utilization of the various techniques under different situations have not been well defined. Work with LANDSAT satellite data in an area of mountainous terrain in Colorado indicated that neither the standard supervised or clustering classification techniques could be used effectively. A new approach which combines supervised and clustering capabilities has been developed and is referred to as the "modified clustering" technique. Work during this past year has involved the definition of procedures to allow the data analyst to interface with the computer in an effective, economical manner. The procedures are currently being tested and a detailed description of an optimized analysis interface procedure will be developed during the next six months.

4. Forestry Applications

a. Forest Cover Mapping in Mountainous Terrain

Both LANDSAT and SKYLAB satellite data were utilized to map forest cover for a test site in the San Juan mountains. The forest cover types involved in this analysis included Ponderosa Pine, Spruce/Fir, Oak, Aspen, Grassland, Water, and Barren. An area of approximately 57,000 acres was classified using the modified cluster analysis technique. A classification performance of 76.5 percent was obtained. Acreage estimates for the computer analysis of satellite data were again compared to acreage estimates obtained by manual interpretation of aerial photos. In this particular study, a correlation coefficient of 0.98 was shown between the two data sets. In another study involving an area of extensive alpine tundra, a similar correlation coefficient was found for the estimates but in this case the classification performance was 88.8 percent for the 35,000 acre area. These results indicate a reasonable potential for applying these techniques to mapping of forest cover in remote, inaccessible areas. This project has been completed and the results were published in the Agriculture Experiment Station Research Bulletin 919 entitled Natural Resource Mapping in Mountainous Terrain by Computer Analysis of ERTS-1 Satellite Data, by Roger M. Hoffer and Staff.

b. Forest Cover Mapping in the Central Hardwood Region

A series of analysis activities were carried out in conjunction with the U. S. Forest Service for an area in the Hoosier National Forest in Central Indiana. The Forest Service had been involved in obtaining basic resource data on the Hoosier National Forest using manual interpretation of standard black and white aerial photos. At the request of Forest Service personnel, LARS attempted to map the same cover types using satellite data and computer analysis techniques. A comparison of the results surfaced the need to define what is meant by brush land. A factor in this definition is the decision as to the percent of crown cover which would justify identifying an area as forest land rather than as brush land. Results indicated the separation of brush land from forest land using satellite data versus manual techniques was complicated by the 40 acre minimum mapping unit used in the latter. Additional work is being carried out with Forest Service personnel to evaluate the effectiveness of the computer analysis approach. The Forest Service is particularly pleased with the development by LARS during the past year, of an ability to produce the classification output map in CALCOMP plotter format. Using CALCOMP plotter output format one can change the scale of an output map to whatever is needed by the user agency.

c. Digital Forest Cover and Topographic Combination Maps

One of the most significant results achieved during the past year involved the ability to overlay satellite data onto digital topographic data. Programs were generated to interpolate slope and aspect using topographic elevation data available in digital format for the San Juan Mountains in Colorado. LANDSAT data were then classified into forest cover types. Various combinations of cover types and topographic parameters were generated at the request of U. S. Forest Service personnel from the Carson, Rio Grande, and San Juan National Forest in Colorado. For example, in one sequence, Spruce/Fir cover on 0-30 percent slope for an elevation range from 9,500 to 12,000 feet was obtained. These maps were then used by some of the district foresters for such on-going work as timber inventory, silvicultural prescriptions, timber sale reconnaissance, and planning timber access roads. Response by the user agency personnel to this type of combined data output has been good. This appears to be a major step in acceptance of Remote Sensing Technology by the user community.

d. Wavelength Band Evaluation

As part of the SKYLAB research activity, the 13 wavelength bands of SKYLAB data were analyzed extensively to determine various combinations of wavelength bands and the key portions of the electromagnetic spectrum that could be most effectively used for identifying and mapping forest cover types.

This work has resulted in a series of recommendations to NASA concerning future satellite systems. These results, among others were also published in LARS Information Note 121275 entitled Computer-Aided Analysis of SKYLAB Multispectral Scanner Data in Mountainous Terrain for Land-Use, Forestry, Water Resource and Geology Applications.

Water Resources Projects

1. Inventory of Surface Water Bodies

The empirical and analytical acreage correction procedures were developed to compensate for the area estimation errors caused by the relatively coarse spatial resolutions of the LANDSAT and SKYLAB multispectral scanners. Both correction procedures yield acreage estimations of surface water bodies that are not significantly different from the actual (reference) acreages at a 99 percent statistical confidence level. In addition, the analytically derived acreage correction method has a broader range of validity than the empirically derived correction function. That is, the performance of the analytically derived method is not affected by the particular geometry (shape) of the water body.

2. Snowcover Mapping

In this part of the water resources studies, accurate measurements of the areal extent of snowcover over large geographical areas and over individual watersheds have been accomplished using SKYLAB S-192 multispectral data. This type of data allowed the reliable differentiation of snow and clouds based on the spectral information content of the data. In addition, five different spectral classes of snowcover were mapped. These snowcover classes were found to be related to (1) the different proportions of snow and forest included within each individual ground resolution element, and to (2) the melting conditions of the snowpack.

Important information on the areal extent of the five different snowcover classes as a function of elevational zones was obtained using a registered multichannel set of SKYLAB MSS data and digital topographic data in conjunction with a layered classification procedure.

3. Water Surface Temperatures Determined from Satellite Altitudes

Accurate temperature measurements of water bodies were obtained using the SKYLAB S-192 thermal data and an appropriate non-linear calibration function. Reference information was not necessary in obtaining this accuracy.

4. Thermal Plume Modelling

For monitoring and estimating the nature of thermal discharges into bodies of water it is necessary to know the three dimensional temperature distributions that develop as a result of thermal outfalls. To accomplish

this a computer program called THRM3D5 (3-Dimensional Thermal Simulation Program Version 5) has been written. With this program remotely-sensed water surface temperature data have been successfully combined with information on the velocity field of the out fall. From these data it was possible to produce three dimensional temperature fields. The demonstrations were performed on two electrical generating stations, Cane Run and Gallagher, located on the Ohio River near Louisville, Kentucky. THRM3D5 solves the partial differential equation which characterizes the conservation of heat in bodies of water in free surface turbulent flow subject to the boundary conditions of remotely sensed water surface temperatures.

The next step is to test the model on a lake and then to use the model as an initial condition for a time dependent thermal plume model which will estimate changes in the 3-dimensional nature of plumes under varying flow and thermal loading conditions.

Geological Applications

1. SKYLAB Geological Study

Results from the multispectral classification of SKYLAB S-192 data have indicated that this analysis method provides an adequate approach for delineating alteration areas, provided a representative amount of training samples are available.

Results have also shown that ratioing of properly pre-processed SKYLAB S-192 data, i.e., contrast stretching and the production of ratio color composite images, enhances the response of alteration zones.

E. EARTH SCIENCES RESEARCH

1. Spectral Properties of Soils

Further research confirmed that the multispectral reflectance from surface soils may be related to a broad array of chemical and physical properties of both surface soils and subsoils. Research completed during FY76 indicated, that, of the spectral range (0.5 to 2.37μm) examined, reflectance in the middle infrared (1.80 - 2.37μm) gives higher correlation with soil organic matter, silt and clay content, cation exchange capacity, iron oxides, and interactions between these variables, than do other areas of reflectance. These results provide an excellent argument for including one or more spectral bands in the 1.80 to 2.50μm range on future satellite scanner systems.

2. Soil Classification and Survey

a. Program in Indiana

In FY76 the Soil Conservation Service (SCS) continued its cooperation with LARS in the development of a program to utilize computer-aided analysis of LANDSAT data as a tool in soil survey. During the year significant progress was made in utilizing satellite data in Clinton, Jasper and White counties.

In brief, the most promising procedures are based on using the computer to cluster the satellite data to find significant spectral groups representing different soil groups and to establish relationships useful in identifying and delineating significant soil entities. These methods have been used successfully to separate soils derived from different parent materials, including outwash, till, lacustrine deposits, and alluvium. Separation of soils with different internal drainage characteristics have also been accomplished by spectral analysis.

The significance of this work to SCS is evident by the assignment by SCS of one of their experienced soil scientists to continue full time research at LARS.

b. Program in Missouri

A cooperative program initiated in FY75 was continued with the SCS in Missouri through FY76. The project included the spectral analysis of a frame (34,000 km^2) of LANDSAT data to use in soil survey and land use inventory. One of the significant contributions of this project was the use of digitized data from other sources (topographic data, watershed boundaries, township boundaries) to overlay onto LANDSAT multispectral data. This combination of digitized data sources made possible the separation and mapping of features and soil characteristics which could not have been done with any single data source.

3. Mapping Geology and Soils in Boliva

Under a contract between the Government of Bolivia and Purdue University three Bolivian scientists were trained at LARS. In cooperation with LARS scientists LANDSAT data obtained over different regions of Bolivia were analyzed and interpreted to delineate and map soils and geologic features. Significant results were: (a) spectral separation of LANDSAT data to map soils having different levels of salinity in the Altiplano; (b) extension of geologic mapping in the Bolivian Andes at a scale of 1:25,000 (c) implementation of LARSYS subroutines on Bolivian computer systems.

4. Inventory of Natural Resources in Sudan

Six Sudanese scientists were trained at LARS under a contract funded by Canada's International Development Research Centre. One of the objectives of this project was to produce a series of maps at various scales (1:25,000; 1:100,000, 1:250,000) by computer-implemented analysis of LANDSAT data obtained over an area in Kardofan Province, located west of the White Nile. The three-month training program was completed during FY76. The Sudanese scientists are completing the maps and documentation in Sudan. Evaluation of the results will be made in FY77.

5. Mapping Geology Soils and Land Use in Iraq

A contract between the Government of Iraq and Purdue University provided for the training of six Iraqi scientists at LARS for a period of six months. After initial training in the use of LARSYS the Iraqi scientists, in cooperation with LARS personnel, analyzed LANDSAT data obtained in two regions (environs of Baghdad, Zagros Mountains) and produced geology maps, forest inventory in the mountains, soils maps, and a land use inventory in the Tigris-Euphrates Plain. Completion of this project and evaluation of the results will extend into FY77.

6. Use of Satellite Data in Mineral Exploration

In FY76 the project to study mineral exploration with the use of data from several sensors was continued. Emphasis was placed on the application of digital preprocessing and analysis techniques to the quantitative correlation between various types of remote sensors, geophysical and geological data. The most significant results were the development and refinement of techniques to digitize and overlay to a common scale various data sources. It was found that images or composites produced by combining various data sources provided information superior to that of any single data source or image.

EDUCATIONAL ACTIVITIES

I. INTRODUCTION

While the primary activity of LARS is to provide an interdisciplinary research facility for the analysis and application of remote sensing data; an increasingly important secondary activity is the transfer of technology developed to the user community. This "user community" is broad based, ranging from Purdue University personnel on outward to other universities, state and federal agencies, business and industry, and foreign personnel. In addition to the specific programs described in detail in the following pages of this report, the Laboratory also:

A. Provides a funded research program and facility for 21 academic and 36 professional staff of the University who add to their teaching the knowledge gained in their remote sensing activities.

B. Provides funding for salaries, equipment, operational expenses and thesis research for graduate students from many areas of the University.

C. Provides an experienced, capable staff for offering seminars, symposia, workshops, training programs, short courses, etc. for interested scientists.

D. Attracts scientists as visitors from many parts of the world who seek advice from the LARS staff members.

E. Provides a local facility for those in diverse University courses to learn about the current aspects of the technology and applications of remote sensing. Resources are also available in such related activities as photointerpretation, data acquisition, and processing and data analysis and interpretation.

F. Develops educational aids and teaching materials on remote sensing for use of the University staff.

G. Provides job training and salaried part-time jobs of a technical nature for many undergraduate students.

II. GRADUATE TRAINING WITH LARS STAFF AND FACILITIES

A. DEGREE CANDIDATES FY76

Adams, Dennis, M.S., CS, Non-thesis option.

Adams, James, M.S., Atmos. Sci., Prof. G. M. Jurica, Thesis title not yet assigned.

Ahlrichs, John, M.S., Agron., M. E. Bauer, Thesis title not yet assigned.

Berkebile, John, Ph.D., For. and Nat. Resources, Prof. R. M. Hoffer, Thesis title not yet assigned.

Bohac, Frank, M.S., EE, Prof. L. F. Silva, Non-thesis option.

Brayer, John, Ph.D., EE, Prof. K. S. Fu, "Web Grammars and Their Application to Pattern Recognition".

Burch, Randy, M.S., ME, Prof. D. P. DeWitt, "Thermal and Radiometric Characteristics of Crop Canopies for Remote Sensing Applications".

Clevenger, John W., Ph.D., EE, Prof. L. F. Silva, "A Low Cost Field Spectroradiometer".

Crecelius, Donald, M.S., Agron., M. E. Bauer, Thesis title not yet assigned.

Chu, Nim, Ph.D., EE, Prof. C. D. McGillem, Thesis title not yet assigned.

Ernst, Lisette, M.S., For. and Nat. Resources, Prof. R. M. Hoffer, Thesis title not yet assigned.

Fleming, Mike, M.S., For. and Nat. Resources, Prof. R. M. Hoffer, "Computer-Aided Analysis Techniques for an Operational System to Map Forest Lands Utilizing LANDSAT MSS Data".

Fralick, Terry N., M.S., Geosc., Prof. D. W. Levandowski, "A Computer-Aided Spectral Classification of Saline Products, Gypsiferous Diapirs and the Totora Formation, Rio Desaguadero Region, Bolivia".

Greene, Herbert, M.S., EE, Prof. P. H. Swain, Non-thesis option.

Hason, Syed E., Ph.D., Geosc., Prof. T. R. West, "Boone County, Indiana, Study of Size of Cells Versus Value of Output".

Hawkins, Bob, M.S., EE, Prof. P. H. Swain, Non-thesis option.

Hebeisen, Cheryl, M.S., CS, Non-thesis option.

Horvath, Emilio, M.S., Agron., M. E. Bauer, "Correlation of Multi-spectral Reflectance, Dry Matter Production and Grain Yield of Corn".

Hsu, Kuo-Shih, Ph.D., For. and Nat. Resources, Prof. R. M. Hoffer, Thesis title not yet assigned.

Jo, Soochul, Ph.D., EE, Prof. L. F. Silva, Non-thesis option.

Jordon, Steven, M.S., Geosc., Prof. T. R. West, Non-thesis option.

Kaminski, Sue, M.S., Agron., R. A. Weismiller and Prof. B. O. Blair, Thesis title not yet assigned.

Kardos, Kris, M.S.N.E., NE, Prof. R. E. Bailey, Non-thesis option.

Kaser, Michael, M.S., ME, Prof. D. P. DeWitt, Thesis title not yet assigned.

Lehman, Terry, Ph.D., Geosc., Prof. D. W. Levandowski, Non-thesis option.

Lube, B., Ph.D., Instr. Dev., Prof. J. D. Russell, Thesis title not yet assigned.

McDonald, Ellen, M.S., CS, Non-thesis option.

Mobasseri, Bijan, Ph.D., EE, Prof. C. D. McGillem, Thesis title not yet assigned.

Mundy, Steve, M.S.C.E., CE, Prof. K. S. Curtis, Non-thesis option.

Noyer, Stephen, M.S., For. and Nat. Resources, Prof. R. M. Hoffer, Thesis title not yet assigned.

Pfaff, William, Ph.D., EE, Prof. P. H. Swain, Thesis title not yet assigned.

Schenck, Brett, M.S., For. and Nat. Resources, Prof. R. M. Hoffer, Non-thesis option.

Seberger, Lewis J., Ph.D., EE, Prof. C. D. McGillem, Thesis title not yet assigned.

Selzer, Gary, M.S., C.S., Non-thesis option.

Steva, Kieth, Ph.D., EE, Prof. L. F. Silva, Thesis title not yet assigned.

Stoneburner, Ronald, M.S., EE, Prof. P. H. Swain, Non-thesis option.

Svedlow, Martin, Ph.D., EE, P. E. Anuta, and Prof. C. D. McGillem, "Design of an Optimal Image Registration Processor".

Whitsitt, Stephen J., Ph.D., EE, Prof. D. A. Landgrebe, "Predicting Performance in Multiclass Statistical Pattern Recognition".

Wiersma, Daniel J., Ph.D., EE, Prof. D. A. Landgrebe, "Optimal Representation of a Non-Stationary Random Process by Orthogonal Basis Functions".

Wiswell, Eric, Ph.D., EE, Prof. G. F. Cooper, "Analytical Study of Multispectral Scanner Design".

Yu, T. S., Ph.D., EE, Prof. K. S. Fu, Thesis title not yet assigned.

B. DEGREES GRANTED FY76

Bartolucci-Castado, Luis A., Ph.D., Geosc., Prof. R. M. Hoffer and D. W. Levandowski, "Applications of Spectral Signature Mixing to Water Resources".

Borger, Robert L., M.S., Geosc., Prof. D. W. Levandowski, Non-thesis option.

Cochran, Jeffery K., M.S., NE, Prof. R. E. Bailey, "Three-Dimensional Time Invariant Computer Simulation of Thermal Discharges as a Remote Sensing Boundary Value Problem".

Grady, Louann, M.S., C.S., Non-thesis option.

Hanley, E. J., M.S., ME, Prof. D. P. DeWitt, "Thermal Diffusivity of Eight Well Characterized Rocks at High Temperatures".

Hixon, Marilyn, M.S., Stat., Prof. J. Yackel, Non-thesis option.

Kast, Jim, M.S., Ind. Mgmt., Non-thesis option.

Montgomery, Oscar, Ph.D., Agron., Prof. M. F. Baumgardner, "An Investigation of the Relationship Between Spectral Reflectance and the Chemical, Physical and Genetic Characteristics of Soils".

Roepke, Harlan, M.S., Geosc., Prof. T. R. West, Non-thesis option.

Richardson, G. R., M.S., Geosc., Prof. T. R. West, "Environmental Geologic Mapping of West Lafayette Related to Indiana 43 Route Relocation".

Singer, Michael F., M.S., CS, Non-thesis option.

Walker, Carl, M.S., Agron., Prof. J. E. Yahner, "A Model to Estimate Corn Yields for Indiana Soil".

III. SPECIFIC EDUCATIONAL PROGRAMS

Since its initiation in FY74 the Technology Transfer Program has grown rapidly in scope under Professor John C. Lindenlaub. In response to growing awareness of and demand for up-to-date information in remote sensing. The major components of Technology Transfer activities in FY76 were:

A. Remote Terminal Project

In 1970 NASA approved and funded at LARS the establishment of a computer network dedicated to the analysis of remote sensing data. The aim of this project is in part education:

> to provide a training facility to potential remote sensing researchers and users
>
> to facilitate the communication of new remote sensing technology to remote sensing researchers and users

During FY76 remote terminals were in operation at seven locations: two locations at LARS; one location each at NASA/Goddard Space Flight Center, Maryland; NASA/Wallops Island, Virginia; NASA/Johnson Space Flight Center, Houston, Texas; Indiana State University, Terre Haute, Indiana; and EROS Data Center, Sioux Falls, South Dakota.

B. Visiting Scientist Program

The Visiting Scientist Program at the Laboratory for Applications of Remote Sensing, Purdue University, 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 at the Laboratory during a period of residence of length determined on a case-by-case basis.

A scientist wishing to participate in the Visiting Scientist Program must be accepted in advance by a LARS staff member who will serve as his sponsor. Applicants are carefully screened for adequacy of background and ability to work with the sponsor on some phase of a definite research project. The research projects are chosen so as to be good training vehicles in the trainee's area of interest while contributing to the ongoing research of the Laboratory.

The trainee or his sponsoring agency is expected to pay the cost of his 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 for travel and subsistence expenses. The program is under the direction of Professor John C. Lindenlaub.

Since FY73 there have been a total of 33 visiting scientists from 14 countries. During FY76 the number of Visiting Scientists nearly tripled over that of FY75. There were twenty visiting scientists involved in applying remote sensing technology to problems in the eight different foreign countries which they represented.

C. Symposia

Although the interval between the FY75 and the FY76 symposia was only twelve months--verses an interim of eighteen months between the FY74-75--the shorter interval still resulted in more papers (both long and short). This was not as a result of lowering the standards. That the quality of papers remained high even though the quantity increased, may be attested to by the fact that there were many more papers rejected in FY76 than previously. The seventy accepted papers represented a 10 percent increase over the preceding year's symposium. These papers were presented in three plenary sessions and the following technical sessions:

a. Systems

b. Natural Resources

c. Data Analysis I and II

d. Research Forum: Data Processing and Applications

e. Preprocessing

f. Agriculture/Forestry.

The central themes of the symposium were theory, implementation, and applications of machine processing of remotely sensed data. The symposium was designed to provide an opportunity for researchers in the field of data processing and data utilization to present recent results and describe new technological development and techniques. There were three plenary sessions, four technical sessions divided into two concurrent meetings each, a luncheon, and a banquet.

The continuing and growing interest in remote sensing has prompted selection of the dates of June 21-23, 1977 for the fourth LARS Symposium.

D. Short Courses

The success of prior LARS short courses prompted the initiation of a monthly short course beginning in July of 1975 and extending through the fiscal year ending with two June offerings of this course.

In addition to the seventy-eight paid participants from literally around the world, there were nine additional Purdue personnel who participated in this training. Sixteen foreign countries were represented, fourteen different federal agencies, five different state or local government agencies, eight different businesses and industries and ten other universities. Over twenty LARS staff members participated in the instruction throughout the year.

During this intensive week's training, participants studied the fundamentals of remote sensing. They learned the principles of pattern recognition based on reflectance data and their application to providing useful resource information to decision makers. Examples were provided of the use of such data in seeking solutions to problems in such areas as agriculture, land use planning, environmental monitoring, mineral exploration and forest assessment.

The nucleus of the course was a series of workshops on the analysis of multispectral data obtained from a LANDSAT satellite using the LARS software system as a prototype of digital remote sensing processing systems. Nearly one-third of the participants exercised the additional "Hands-On" option which gave them interactive experience in utilizing the computer in analyzing a data set in a selected project.

E. Matrix of Remote Sensing Educational Materials

Remote sensing educational and training materials of various types and at different technical depths have been developed by members of the Technology Transfer program. These materials have now been organized in a matrix format, useful for showing in a concise manner the subject matter content, prerequisite requirements and level of presentation of each of the instructional modules in the matrix. The matrix organization has proven useful for the design of training programs to meet the specific needs of individual students, staff and visiting scientists.

The matrix of education and training materials developed at LARS under NASA and Purdue sponsorship appears on the next page. Individual units are designated by a letter and a number. The letter designates the series as follows:

F FOCUS
M Minicourses
E LARSYS Educational Package
S Simulations
V Videotapes

While the number designates which member of the series. The general prerequisite level for materials in the matrix can be judged by the number of asterisks following the letter-number designation. For instance V3** indicates the third member of the videotape series and two asterisks indicates that a considerable amount of prerequisite material is recommended. An entry such as F4 designates the fourth member of the FOCUS series and the lack of an asterisk means that no prerequisites are required. A brief description and list of titles in each series is given in the paragraphs below.

1. The FOCUS Series

Each FOCUS is a two-page foldout consisting of a diagram or photograph and an extended caption of three to four hundred words treating a single concept, A student typically spends 10 to 20 minutes studying these materials. He may chose from 14 titles. The series is especially useful for general briefings or introductory treatments of remote sensing topics.

List of FOCUS Titles -

F1 The Multispectral Scanner

F2 Cover Type Classification

F3 Pattern Recognition

F4 Mapping Soil Characteristics

F5 Sample Classification

F6 Earth Resources Data Processing System

F7 Remote Sensing

F8 LANDSAT: An Earth Resources Data Collection System

F9 Role of Images in Numerical Data Analysis

F10 Crop Species Identification

MATRIX OF INSTRUCTIONAL MATERIALS IN REMOTE SENSING

Background Needed: **Extensive *Moderate None

TOPICS				INSTRUCTIONAL MATERIALS: FOCUS (10-20 minutes)	Minicourses (45-75 minutes)	Videotapes (30-60 minutes)	Simulations (3-4 hours)	Case Studies (20-40 hours)
			Introductory, Basic Concepts	F7	M1, E1	V1		
	Physical Basis		Electromagnetic Spectrum	F10, F14	M2	V9, V10*, V11*		
			Atmospheric Effects		M2			
			Spectral Reflectance		M2, M3*, M4*			
			Emittance		M2	V11*		
	Data Collection	Instruments	Photographic	F1	M9*	V2, V9, V10*		E6**, E7**
			Multispectral Scanners		M8*	V2, V9, V10*		
			Radar		M10*			
			Spectrometers			V12**		
		Systems	Mission Planning		M5*	V3**		
			Airborne			V2		E6**
			Satellite	F8, F12	M6*, M7*	V2		E7**
	Data Analysis Techniques	Images	Photography	F9, F12	M13*			
			Scanner Images		M15*			
			Radar Images		M14*			
		Computer-Aided	Pattern Recognition	F2, F3, F5, F13	E1, M11*, M12**	V4, V5*, V6**, V7**, V8**	L2*	E6**, E7**
			LARSYS	F6, F11	E4*, E5**	V7**, V8**	E2*, E3*	E6**, E7**
	Applications		Agronomy	F4, F10	M18*			E6**
			Forestry		M16*	V13	S1**	E7**
			Geography					E7**
			Geology		M17*			
			Land Use				S2**	E7**
			Hydrology		M19*			E7**

F11 What is LARSYS?

F12 LANDSAT Multispectral Scanner Data

F13 Clustering

F14 How the Earth Reflects

2. The Fundamentals of Remote Sensing, A Minicourse Series

Instructional units in this series consist of printed study guides, a set of 35mm color slides and an audio tape. In addition, several of the units include tangible items which the student uses as he progresses through the minicourses. The series is aimed at the introductory or fundamental principle level. Persons with a background in elementary biology, physics and mathematics can understand and work with the basic concepts and ideas presented in the series. A 35mm slide projector and audio casette player are required special aids for use with the minicourses. The minicourse series is funded by the Division of Conferences and Continuing Education Administration and presently marketed by them.

List of Minicourse Titles -

M1 Remote Sensing: What is it?

M2 The Physical Basis of Remote Sensing

M3 Spectral Reflectance Characteristics of Vegetation

M4 Spectral Reflectance Characteristics of Earth Surface Features

M5 Mission Planning: Considerations and Requirements

M6 LANDSAT: An Earth Resources Satellite System

M7 SKYLAB: Earth Resources Experiment

M8 Multispectral Scanners

M9 Photographic Sensors

M10 Side-Looking Airborne Radar

M11 Pattern Recognition in Remote Sensing

M12 Typical Steps in Numerical Analysis

M13 Interpretation of Color Infrared Photography

M14 Interpretation of Radar Imagery

M15 Interpretation of Multispectral Scanner Images

M16 Applications of Remote Sensing in Forestry

M17 Applications of Remote Sensing in Geology

M18 Crop Surveys Through Remote Sensing

M19 Temperature Mapping of Water by Remote Sensing

3. The LARSYS Educational Package

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

List of Educational Package Units -

E1 An Introduction to Quantitative Remote Sensing

E2 LARSYS Software System - An Overview

E3 Demonstration of LARSYS on the 2780 Remote Terminal

E4 The 2780 Remote Terminal: A "Hands-On" Experience

E5 LARSYS Exercises

E6 Guide to Multispectral Data Analysis Using LARSYS

E7 A Case Study Using LARSYS for Analysis of LANDSAT Data

4. Simulation Exercises

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

List of Simulation Exercise Titles -

S1 A Forestry Applications Simulation of Man-Machine Techniques for Analyzing Remotely Sensed Data

S2 Determining Land Use Patterns through Man-Machine Analysis of LANDSAT Data

5. The Videotape Series

The videotapes in this series "capture" a subject matter specialist discussing a remote sensing topic. The tapes are a refinement of a seminar or series of lectures given by the authors. Each tape runs about thirty minutes. Student viewing notes have been written for some of the videotapes.

List of Videotape Titles -

V1 Introduction to Quantitative Remote Sensing

V2 Duality of System Types and the Multivariant Approach

V3 System Parameters Fundamental to Information Extraction

V4 Introduction to Pattern Recognition for Remote Sensing Applications

V5 Statistical Characterization of Pattern Classes

V6 Derivation of Discriminant Functions

V7 Feature Selection

V8 Cluster Analysis and Sample Classification

V9 Introduction to Radiation in Remote Sensing

V10 Reflectance in Remote Sensing

V11 Emission in Remote Sensing

V12 Fundamentals of Remote Sensing Instrumentation

V13 Mapping Sudan's Resources from Space

IV. FORMAL UNIVERSITY COURSES DEALING WITH PHASES OF REMOTE SENSING

A. Courses With Definite Emphasis on Remote Sensing

Electrical Engineering
577 Engineering Aspects of Remote Sensing
cr. 3. Prof. Lindenlaub

Forestry
291 Introduction to Remote Sensing
cr. 1. Prof. Hoffer

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

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

Geosciences
591R Aerology and Remote Sensing
cr. 3. Prof. Levandowski

B. Courses Related to Remote Sensing

Agronomy
565 Soil Classification and Survey
cr. 2. Prof. Zachary

585 Soils and Land Use
cr. 2. Prof. Yahner

655 Soil Genesis and Classification
cr. 3. Prof. Franzmeir

Civil Engineering
503 Photogrammetry
cr. 3. Prof. Mikhail

567 Airphoto Interpretation
cr. 3. Prof. Miles

603 Advanced Photogrammetry
cr. 3. Prof. Mikhail

667 Advanced Airphoto Interpretation
cr. 3. Prof. Miles

Electrical Engineering
644 Communications I
cr. 3. Communications Sciences Area Staff

645 Communications II
cr. 3. Communications Sciences Area Staff

661 Image Processing
cr. 3. Prof. Huang

662 Introduction to Artificial Intelligence and Pattern
cr. 3. Prof. Funkunaga

Forestry
557 Aerial Photo Interpretation
cr. 3. Prof. Miller

MISCELLANEOUS

I. Visitors Summary 1975-1976

A. Overall Summary

1.	Federal Agencies	47
2.	State and Local Agencies	12
3.	Purdue	20
4.	Other American Universities	14
5.	Foreign	26
6.	Industry	31
7.	Miscellaneous	1

B. Visitors by Affiliation

1. Federal Agencies

a.	Bureau of Census	1
b.	USDA/Federal Crop Insurance Corp.	2
c.	USDA/SCS	8
d.	U. S. Forest Service	1
e.	NASA	26
f.	USDA/Agriculture Stabilization and Conservation Service	1
g.	USA/ETL	1
h.	USDA/Statistical Reporting Serv.	2
i.	Environmental Protec. Agency.	1
j.	U. S. Geological Society	1
k.	U. S. Defense Dept.	2
l.	U. S. Energy Research & Dev. Admin.	1

2. Regional Agencies

a.	Wabash Valley Assoc.	20
b.	Indiana Heartland Coordinating Comm.	3

3. Indiana State and Local Agencies

a.	Department of Natural Resources	3

4. Other State and Local Agencies

a.	Maryland Sanitary Comm.	1
b.	North Carolina	1
c.	Michigan	4

5. American Universities

a.	Purdue	20
b.	Other Universities	14

6.	Industry	26
7.	Foreign	
	a. Bolivia	7
	b. Egypt	1
	c. Iran	1
	d. Japan	5
	e. Canada	2
	f. Netherlands	1
	g. Singapore	1
	h. China	1
	i. Italy	2
	j. Yugoslavia	1
	k. Bangladesh	1
	l. Czechoslovakia	1
	m. Venezuela	5
	n. West Germany	1
	o. Kenya	1
8.	Miscellaneous	1

II. PUBLICATIONS AND TALKS BY LARS STAFF

A. LARS Information Note Series*

122073 Bartolucci, L.A., R.M. Hoffer and J.R. Gammon, Effects of Altitude and Wavelength Band Selection on Remote Measurements of Water Temperature*. In pursuing the objectives of further developing computer processing techniques for obtaining accurate radiant temperature measurements from remote platforms, it was found that aircraft altitude and atmospheric window selection had significant effects on the results. However, as demonstrated in this study involving the influence of the Cayuga power plant on the Wabash River, proper selection of atmospheric window and detector band-width, coupled with adequate calibration procedures, allows temperatures to be obtained with an accuracy of about 0.2° C at altitudes of at least 1500 meters. This figure is based upon the correspondence between the remotely measured temperatures and temperature measurements obtained on the river at the time of the overflight.

090174 Wu, C.L., D.A. Landgrebe and P.H. Swain, A Decision Tree Approach to Classification. A logical direction for remote sensing data analysis development to move is toward more complex decision logic, since this should make possible better clssification accuracy. In this work a layered decision logic is proposed and tested. The results indicate possible improvement in both classification accuracy and computational efficiency.

103174 Anuta, P.E., Spline Function Approximation Techniques for Image Geometric Distortion Representations. Registration and geometric correction of multispectral scanner imagery from aircraft and satellite systems requires a mathematical representation to interpolate the image distortion between control points. For certain cases the distortions are severe and high order (eg., fourth, fifth or sixth order) polynomials are required which are difficult to handle computationally. In the work reported here, spline function approximation techniques which use a set of two-dimensional cubic polynomials joined with continuity in value and derivative are explored. Basic theory is presented and development of a two-dimensional cubic spline algorithm is discussed.

110575 Lindenlaub, J.C. and S.M. Davis, LARSYS Educational Package: Instructor's Notes. The Instructor's Notes includes a "Surveys of the LARSYS Educational Package" along with a flowchart showing the relationship of the seven units in the series. Relevant instructor information for all the units is contained along with copies of the student notes for Units II, III, IV and V.

*All LARS Information Notes listed in this series were published in FY75-76. Number indicates date of acceptance of title by LARS.

*Also in Proceedings First Panamerican Symposium on Remote Sensing, Panama City, Panama, p. 147-160, April 27-May 2, 1973.

112174 Silva, L. F., F. V. Schultz and J. T. Zalusky, Electrical Methods of Determining Soil Moisture Content. The relationship between available soil moisture and electrical properties of soils and related instrumentation is studied. A laboratory procedure was developed that produces accurate results on field soil samples. Data for several samples are presented. The conceptual design of a surface mounted instrument for measuring soil moisture profile is presented.

121874 Moore, D. S., S. J. Whitsitt, D. A. Landgrebe, Variance Comparisons for Unbiased Estimators of Probability of Correct Classification. Variance relationships among certain count estimators and posterior probability estimators of probability of correct classification are investigated. An estimator using posterior probabilities is presented for use in stratified sampling designs. A test case involving three normal classes is examined.

This work was supported in part by the Air Force Office of Scientific Research, Air Force Systems Command, under Grant AFOSR-72-2350B and in part by NASA under Grant NGL 15-005-112.

022675 Wilson, L. L., Purdue/LARS Digital Display User's Guide. To acquaint new users with the digital display system, as well as to refresh and enhance the knowledge of those already familiar with its usage, the Purdue/LARS Digital Display User's Guide was created. It is a comprehensive manual incorporating all the information needed to control and to make efficient use of the 4507 digital display and its associated hardware. Included in the text is a description of the digital display system and its capabilities, utilization of the display (both hardware and software), advanced theory and techniques, as well as a comprehensive photographic operations manual. This publication supersedes the Digital Display Photographic Operations Manual, LARS Information Note 101574.

This work was sponsored by Purdue University/LARS Computer Facility.

040775 Stockton, J. G., M. E. Bauer, B. O. Blair and M. F. Baumgardner, The Use of ERTS-1 Multispectral Imagery for Crop Identification in a Semi-Arid Climate. Crop identification using multispectral satellite imagery and multivariate pattern recognition is a relatively new technique enabling rapid evaluation of large areas. The accuracy of this process is examined in this study in a semi-arid climate. Multispectral reflectance data was collected by the Earth Resources Technology Satellite (ERTS-1) over the semi-arid regions of western Kansas and Texas during the 1973 growing season.

Multivariate pattern recognition was used to identify wheat accurately in Greeley County, Kansas. A classification accuracy of 97% was found for wheat and the wheat estimate in hectares was within 5% of the USDA's Statistical Reporting Service estimate for 1973.

The multispectral response of cotton and sorghum in Texas was not unique enough to distinguish between them nor to separate them from other cultivated crops, either singly or multitemporally. The test site of Lubbock County, Texas was deemed too heterogeneous in agriculture practices for correct identification of cotton and sorghum using ERTS-1 imagery.

050575 Cary, T. K. and J. C. Lindenlaub, A Case Study Using LARSYS for Analysis of LANDSAT Data. This material was designed to be a component of the LARSYS Educational Package, teaching new users the sequence of steps comprising an analysis. For each step of the sequence, concepts and theory are presented, an example using LANDSAT data is shown and discussed, and instructions are included directing the student to perform an analysis of another LANDSAT data set.

050975 Kettig, R. L. and D. A. Landgrebe, Computer Classification of Remotely Sensed Multispectral Image Data by Extraction and Classification of Homogeneous Objects. A method of classification of digitized multispectral images is developed and experimentally evaluated on actual earth resources data collected by aircraft and satellite. The method is designed to exploit the characteristic dependence between adjacent states of nature that is neglected by the more conventional simple-symmetric decision rule. The principle reason for doing this is to improve the accuracy of the classification, but it is shown that the speed of the classification can also be increased.

051975 Lindenlaub, J. C., S. M. Davis and D. B. Morrison, Bringing Remote Sensing Technology to the User Community. This paper discusses the procedures and services available for educating and training potential users of remote sensing technology and describes approaches for achieving an in-house capability for the analysis of remotely sensed data using numerical techniques based on pattern recognition principles. The hierarchy of educational steps includes self-study of the literature, attending conferences and symposia, participating in intensive short courses and in residence programs. Remote terminal computer networks and the implementation of analysis software are presented as ways to obtain an in-house capability for numerical analysis. Cost estimates are provided where appropriate.

052075 DeWitt, D. P. and B. F. Robinson, Description and Operation of a Field Rated ERTS-Band Transmissometer. This report describes a field rated instrument for the measurement of normal hemispherical transmittance at four wavelength bands: 0.5-0.6μm, 0.6-0.7μm, 0.7-0.8μm, and 0.8-1.0μm. The instrument consists of a detector system and a transmittance attachment comprised of an integrating sphere with collimator. The principle of measurement permits direct comparison of field results with a laboratory spectrophotometer such as a Bechman DK-2A Spectrophotometer with integrating sphere attachment.

The work reported in this paper was supported by the National Aeronautics and Space Administration under NASA Contract NAS9-14016.

052175 Svedlow, M., C. D. McGillem and P. E. Anuta, Experimental Examination of Similarity Measures and Preprocessing Methods Used for Image Registration. A variety of image registration algorithms have been developed over the past several years by various authors. This study examines the applicability of several of these to the temporal registration problem of LANDSAT data. The results indicate that most methods work well for highly correlated images but only a few are effective for the low correlation case. The magnitude of the gradient enhancement method coupled with a magnitude of the difference correlator is observed to produce the best results.
This report was done under Contract NAS9-14016.

052375 Landgrebe, D. A. and LARS Staff, A Study of the Utilization of ERTS-1 Data from the Wabash River Basin - Final Report. Nine projects were defined for the study; five ERTS data applications experiments and four supporting technology tasks. 1., The Identification and Area Estimation of Crops experiment tested the usefulness of ERTS data for crop survey and produced results indicating that crop statistics could be obtained from ERTS data. 2., Soil Associations Mapping. Results showed that strong relationships exist between ERTS data derived maps and conventional soil maps. 3., Urban Land Use Analysis experiment results indicate potential for accurate gross land use mapping from ERTS data. 4., Water Resources mapping demonstrated the feasibility of mapping water bodies from ERTS data. 5., Earth Surface Features Identification demonstrated feasibility for deriving large area land use data from ERTS. The four supporting technology tasks provided technique development, reformatting and temporal overlay, atmospheric modeling, and scene-processed ERTS data evaluation.

052775 Biehl, L. L. and L. F. Silva, Machine Aided Multispectral Analysis Utilizing SKYLAB Thermal Data for Land Use Mapping. Eight channel SKYLAB multispectral scanner data obtained in January, 1974, were used in a level two land-use analysis of Allen County, Indiana. The data set which includes one visible channel, four near infrared channels, two middle infrared channels, and one far infrared channel was from the X-5 detector array of the S-192 experiment in the Earth Resources Experiment Package on board the SKYLAB space station. The results indicate that a good quality far infrared (thermal) channel is very valuable for land use mapping during the winter months.

052875 Baker, J. R. and E. M. Mikhail, Geometric Analysis and Restitution of Digital Multispectral Scanner Data Arrays. This thesis contains the results of an investigation performed in order to define causes of geometric defects within digital multispectral scanner (MSS) data arrays, to analyze the nature of the resulting geometric errors, and to investigate restitution methods to correct or reduce such geometric errors.

The introduction of geometric transformation relationships for scanned data, from which collinearity equations for MSS may be derived, serves as the basis of parametric methods of analysis and restitution of MSS digital data arrays. The linearization of these collinearity equations is presented, including consideration of the functional assumptions made in order to model the stochastic changes in the exterior orientation of the sensor down the flight line.

A proposed system for the geometric analysis and restitution of MSS digital data arrays is introduced. This procedure is used to test the methods of analysis and restitution, utilizing actual MSS data arrays from two aircraft flights. The results of these tests indicate that the collinearity equations can yield acceptable results when utilized for the analysis and restitution of such arrays.

052975 Davis, S. M., The FOCUS Series 1975: A Collection of Single-Concept Remote Sensing Educational Materials. The FOCUS Series has been developed to present basic remote sensing concepts in a simple, concise way. Issues currently available are collected here so that more people may know of their existance.

061275 Swain, P. H., C. L. Wu, D. A. Landgrebe and H. Hauska, Layered Classification Techniques for Remote Sensing Applications. Layered classification offers several advantages over the very familiar single-stage approach. The single-stage method of pattern classification utilizes all available features in a single test which assigns the "unknown" to a category according to a specific decision strategy (such as the maximum likelihood strategy). The layered classifier classifies the "unknown" through a sequence of tests, each of which may be dependent on the outcome of previous tests. Although the layered classifier was originally investigated as a means of improving classification accuracy and efficiency, it has become apparent that in the context of remote sensing data analysis, other advantages also accrue due to many of the special characteristics of both the data and the applications pursued. This paper outlines the layered classifier method and discusses several of the diverse applications to which this approach is well suited.

061575 Hoffer, R. M. and Staff, Natural Resource Mapping in Mountainous Terrain by Computer Analysis of ERTS-1 Satellite Data. This report describes the significant results of a two year interdisciplinary study involving the use of computer-aided analysis techniques applied to ERTS/MSS data collected over rugged mountainous terrain in south-western and central Colorado. These results involve five specific areas of research, including: 1) Ecological Inventory, with emphasis on the utilization of ERTS data and computer-aided analysis techniques for forest cover mapping and acreage estimates; the results also include a cost analysis; 2) Hydrological Features Survey involving the capability for utilizing ERTS to monitor the change in snow cover and inventory water bodies; 3) Geomorphological Features Survey, with a discussion on the utilization of ERTS data in combination with ancillary information;

4) Interpretation Techniques, discussing the concepts of modeling topographic relief in order to be able to develop better analysis procedures; and 5) Data Collection Platform, a review of the operations of a DCP under adverse climatic conditions.

A section is devoted to a large number of specific results and conclusions of significance, and recommendations for future earth observational systems.

This report was prepared under Contract No. NAS5-21880.

061875 Parsons, C. L., Jr., and G. M. Jurica, Correction of Earth Resources Technology Satellite Multi-Spectral Scanner Data for the Effect of the Atmosphere. A physically-based series of computer programs is used to numerically compute the intensity of the scattered upward-traveling radiation at the top of a plane-parallel in homogeneous atmosphere containing specified vertical distributions of ozone and water vapor concentration and aerosol number density. The study indicates that all of the meteorological parameters affecting the propagation of electromagnetic radiation, water vapor concentration is one of the most variable and most important, particularly in the 0.80-1.10 μm MSS band. It is concluded that a spectrally-variable transmission correction is required to optimize classification of features using automatic pattern recognition techniques.

062375 Kettig, R. L. and D. A. Landgrebe, Classification of Multispectral Image Data by Extraction and Classification of Homogeneous Objects. A method of classification of digitized multispectral image data is described. It is designed to exploit a particular type of dependence between adjacent states of nature that is characteristic of the data. The advantages of this, as opposed to the conventional "per point" approach, are greater accuracy and efficiency, and the results are in a more desirable form for most purposes. Experimental results from both aircraft and satellite data are included.

062775 Phillips, T. L, H. L. Grams, J. C. Lindenlaub, S. K. Schwingendorf, P. H. Swain, and W. R. Simmons, Remote Terminal System Evaluation. The Laboratory for Applications of Remote Sensing at Purdue University has developed an earth resources data processing system which is being used by both LARS personnel and remote terminal users in part to determine the value of the system for training, technology transfer, and data processing. The results of Purdue's participation in this project are documented in this report. The facility has been used at seven separate sites and demonstrated to be a cost effective system for training personnel and technology transfer as well as meeting many data processing needs. This work was sponsored by NASA under Contract No. NGL 15-005-112 and Contract NAS9-14016.

063075 Peterson, J. B., Quantitative Inventorying of Soil and Land Use Differences by Remote Sensing. From using photography as the basic technique, remote sensing has advanced to the present single aperature multispectral scanner. This sensor system, used successfully in satellites as well as aircraft, greatly increases the spectral range of radiant energy which can be sensed, and recorded, processed and analyzed mechanically. Modern remote sensing technology is being used successfully to identify and delineate land use and soil differences.

As the technology continues to improve it is expected to become more helpful to inventorying land use and soils.

072175 Bauer, M. E., T. K. Cary, B. J. Davis and P. H. Swain, Crop Identification Technology Assessment for Remote Sensing (CITARS). This report summarizes the results of classifications and experiments performed by LARS/Purdue University for the Crop Identification Technology Assessment for Remote Sensing (CITARS) project.

072475 Fleming, M. D., J. S. Berkebile and R. M. Hoffer, Computer-Aided Analysis of LANDSAT-1 MSS Data: A Comparison of Three Approaches, Including a "Modified Clustering" Approach. Three approaches to computer-aided analysis of LANDSAT-1 MSS data were evaluated utilizing data from a test site in rugged, mountainous terrain. The approaches compared included non-supervised (clustering), modified supervised, and modified clustering. The modified clustering approach proved to be the optimal technique because of minimal computer time, highest classification accuracy, and most effective analyst/data interaction. This paper was presented at Purdue University's Symposium on Machine Processing of Remotely Sensed Data, June 1975.

The research reported in this paper was supported by NASA Contract NAS9-14016, NASA Contract NAS5-21880, and NASA Contract NAS9-13380.

100175 Peterson, J. B., F. E. Goodrick and W. Melhorn, Delineation of the Boundaries of a Buried Pre-Glacial Valley with LANDSAT Data. The continuity of a narrow meandering strip of Udoll (prairie) soils running east and west for approximately 40 miles across north central Indiana in an area predominantly of Udalfs (timber soils) is apparent in LANDSAT I (ERTS I) data.

This dark stretch of prairie soil is believed to have formed in the heavy textured, poorly drained glacial debris which filled a major pre-glacial tributary of the Teays River system.

Ready identification and location of the valley has significance to soil survey and land classification people as a guide to soil classification and land use and to geologists as a guide to location of a potentially economically significant aquafer.

This work was sponsored by NASA under Contract No. 15005186A.

100675 Anuta, P. E., Computer-Aided Analysis Techniques for Remote Sensing Data Interpretation. The preprocessing and analysis algorithms available at LARS are described briefly. Applications to non-multispectral scanner are discussed in conclusion. This is an overview paper presented at a conference and does not present any new or previously not reported techniques. The applications to non-MSS data are new.

The research reported in this paper was supported by the Cities Service Minerals Corporation.

110475 Grams, H. L., LARS Computational Facility Users Guide. The LARS Computational Facility User's Guide is designed to document and incorporate all the basic information one needs in order to gain access to the machine and to use the equipment. Topics covered include a description of the LARS Computer Facilities (both hardware and software), administrative procedures, documentation available, procedures for operating terminals and/or submitting jobs, and notes for programmers.

This work was sponsored by Purdue University with the LARS Computer Facility account.

111575 Bartolucci, L. A., P. H. Swain and C. L. Wu, Selective Radiant Temperature Mapping Using a Layered Classifier. A method of measuring temperatures of selected ground cover types using remotely sensed multispectral scanner data and a layered classification approach is described. A brief review of radiation theory is presented to show that for the wavelength bands and temperature ranges involved in remote sensing applications, a linear calibration function can be satisfactorily utilized. Finally, an example of the application of the layered classifier for temperature mapping of water is shown.

This work was sponsored under contract number NAS5-21773 and Grant number NGL-15-005-186.

121275 Hoffer, R. M. and Staff, Computer-Aided Analysis of SKYLAB Multispectral Scanner Data in Mountainous Terrain for Land Use, Forestry, Water Resource, and Geologic Applications. This report describes the results of an interdisciplinary research project involving the analysis of SKYLAB data obtained over the San Juan Mountains in SW Colorado. Computer-aided analysis techniques were applied to the S-192 MSS data for purposes of mapping land use, forest cover types, hydrologic and geologic features of significance. In spite of the vegetative and topographic complexity of the test site, computer classification accuracies of 85% and 71% were obtained for Level II Land Use maps and Forest Cover maps, respectively. Accurate acreage estimates of forest cover were obtained by computer analysis of SKYLAB S-192 data. A detailed wavelength band study clearly indicated the importance of the near infrared wavelengths for vegetation mapping. The value of the improved spectral resolution of the SKYLAB MSS, as compared to LANDSAT, was also shown. Another result of particular significance involved the use of digital computer techniques to geometrically correct and overlay multiple data sets, including SKYLAB, LANDSAT, and topographic (elevation, slope and aspect) data.

SKYLAB MSS data clearly showed for the first time that the middle infrared wavelengths are essential for reliably separating snow from clouds on the basis of spectral response. Forest density and snow melt differences within the snowpack area could be mapped through the use of the near infrared wavelengths. Calibration of the thermal infrared band allowed the surface temperature of a high elevation reservoir to be accurately determined from space. Geologic mapping, involving a variety of ratioing and classification techniques, indicated the need for additional study to better define the theoretical basis for use of these analysis procedures, in order to obtain reliable, predictable results. A number of additional significant results and recommendations are included in this report. This work was sponsored by NASA Contract No. NAS9-13380.

122075 Bauer, M. E., The Role of Remote Sensing in Determining the Distribution and Yield of Crops. The role of remote sensing in obtaining information about the distribution and yield of crops is discussed. Topics discussed under the physical basis for remote sensing are: energy sources, the atmosphere, spectral properties of vegetation, remote sensing data acquisition, and analysis and interpretation of remotely sensed data. The discussion of agricultural applications of remote sensing covers: crop identification and area estimation, crop condition assessment, yield prediction, range surveys, soil mapping, and agricultural land use in developing countries.
This report was produced under Contract NAS5-20793.

012176 Bizzell, R., F. Hall, A. Feiveson, M. Bauer, B. Davis, W. Malila and D. Rice, Results from the Crop Identification Technology Assessment for Remote Sensing (CITARS) Project. The CITARS task design and objectives are reviewed and final results are presented, together with conclusions and recommendations. It was found that several factors had a significant effect on crop identification performance: (a) crop maturity and site characteristics, (b) which of several different single-date automatic data processing procedures was used for local recognition, (c) nonlocal recognition, both with and without preprocessing for the extension of recognition signatures, and (d) use of multidate (multitemporal) data. It also was found that classification accuracy for field center pixels was not a reliable indicator of proportion estimation performance for whole areas, that bias was present in proportion estimates, and that training data and procedures strongly influenced crop identification performance.
The work was sponsored by NASA under Contract Number NAS9-14016.

012376 Berkebile, J., J. Russell and B. Lube, A Forestry Application Simulation of Man-Machine Techniques for Analyzing Remotely-Sensed Data. The manual is a detailed step-by-step description of an actual analysis of remotely-sensed data performed by a forester for a portion of the Hoosier National Forest. The decisions made during the analysis and their rationale are described. The importance of the man-machine interactions are emphasized. The steps are documented with illustrations and examples. The reader is asked to display a mastery of each step through self-check items.
This report was produced under NASA Contract Number NAS9-14016.

012276 Silva, L. F. and L. L. Biehl, A Study of the Utilization of EREP Data from the Wabash River Basin. This report describes the research performed during the total contract period (April 1, 1973 - December 8, 1975) of SKYLAB EREP Investigation 397, Study of the Utilization of EREP Data from the Wabash River Basin, NASA Contract Number NAS9-13301.

030176 Bauer, M. E., Technological Basis and Applications of Remote Sensing of the Earth's Resources. This paper briefly describes the development of remote sensing, then discusses the physical and technological basis for obtaining earth resources information from airborne and spaceborne sensors. It points out that information may be obtained from analyzing the spectral, spatial, and temporal variations of energy emanating from the earth's surface. Two types of analysis, image-oriented and numerical are discussed, with emphasis on the latter. Finally, applications of remote sensing technology are discussed.

This report was produced under Contract NAS5-20793.

030576 Mausel, P. W., W. J. Todd, M. F. Baumgardner, R. A. Mitchell and J. P. Cook, Evaluation of Surface Water Resources from Machine Processing of ERTS Multispectral Data. Water resource data that are useful to environmental scientists and planners frequently are missing, incomplete, or obtained irregularily. A new source of surface hydrological information can be obtained as often as every 18 days in some areas through machine-processing of Earth Resources Technology Satellite (ERTS) multispectral scanner data. This research focused on the surface water resources of a large metropolitan area. Marion County (Indianapolis), Indiana, in order to assess the potential value of ERTS spectral analysis to water resources problems.

The results of the research indicate that all surface water bodies over 0.5 ha were identified accurately from ERTS multispectral analysis. Five distinct classes of water were identified and correlated with parameters which included the i) degree of water siltiness; ii) depth of water; iii) presence of macro and micro biotic forms in the water; and iv) presence of various chemical concentrations in the water. The machine-processing of ERTS spectral data used alone or in conjunction with conventional sources of hydrological information can lead to the monitoring of the i) area of surface water bodies; ii) estimated volume of selected surface water bodies; iii) differences in degree of silt and clay suspended in water; and iv) degree of water euthrophication related to chemical concentrations. Water resources information obtained from ERTS analysis will be useful in helping to solve or better understand selected pollution, erosion, and planning problems in metropolitan and other environments.

The work reported in this report was sponsored by NASA under contract number NAS9-14016.

031276 Mausel, P. W., W. J. Todd and M. F. Baumgardner, An Analysis of Metropolitan Land-Use by Machine Processing of Earth Resources Technology Satellite Data. The technology available at Purdue University's Laboratory for Applications of Remote Sensing (LARS) to classify earth surface features from multispectral data is sophisticated. This paper describes the results of a successful application of state-of-the-art remote sensing technology in classifying an urban area into its broad land-use classes. This research proves that numerous urban features are amenable to classification using ERTS multispectral data automatically processed by computer.

Furthermore, such automatic data processing (ADP) techniques permit a real analysis on an unprecedented scale with a minimum expenditure of time. Also, classification results obtained using ADP procedures are consistent, comparable, and replicable; hence many spatial analysis problems caused by human errors or decisions are eliminated. The results of classification are compared with the proposed USGS land-use classification system in order to determine the level of classification that is feasible to obtain through ERTS analysis of metropolitan areas. (Anderson, Hardy, and Roach, 1972, 6)

The work reported in this report was sponsored by NASA under contract NAS9-14016.

032576 Todd, W. J., P. W. Mausel, and M. F. Baumgardner, Urban Land Use Monitoring from Computer-Implemented Processing of Airborne Multispectral Data. Machine processing techniques were applied to multispectral data obtained from airborne scanners at an elevation of 600 meters over central Indianapolis in August, 1972. Computer analysis of these spectral data indicate that roads (two types), roof tops (three types), dense grass (two types), sparse grass (two types), trees, bare soil, and water (two types) can be accurately identified. Using computers, it is possible to determine land uses from analysis of type, size, shape, and spatial associations of earth surface images identified from multispectral data. Land use data developed through machine processing techniques can be programmed to monitor land use changes, simulate land use conditions, and provide "impact" statistics that are required to analyze stresses placed on spatial systems.

The work reported in the report was sponsored by NASA under contract NAS9-14016.

B. Journal Articles and Talks by LARS Staff

Adrien, Pierre-Marie and M. F. Baumgardner, "Development Projects and Remote Sensing From Satellites: Perspectives", June 1976.

Anuta, P.E., "Computer-Aided Analysis Techniques for Remote Sensing Data Interpretation", 45th Annual International Meeting of the Society of Exploration Geophysicists, Denver, Colorado, October 12-16, 1975.

Anuta, P.E., "Dimensionalality Expansion of Multispectral Scanner Data for Earth Resources Survey", Workshop on Environmental Applications of Multispectral Imagery, U.S. Army Topographic Labs, Ft. Belvoir, Virginia, November 12, 1975.

Anuta, P.E., "Digital Registration of Topographic Data and Satellite MSS Data for Augmented Spectral Analysis", 42nd Annual Meeting of American Society of Photogrammetry, Washington D.C., February 22-28, 1976.

Anuta, P.E., H. Hauska and D. Levandowski, "Analysis of Geophysical Remote Sensing Data Using Multivariate Pattern Recognition Techniques", Symposium on Machine Processing of Remotely Sensed Data, Purdue University, June 29, 1976.

Bauer, M.E., "The Role of Remote Sensing in Determining the Distribution and Yield of Crops", Advances in Agronomy, 27:271-304, 1975.

Bauer, M.E., "Technological Basis and Applications of Remote Sensing of Earth's Resources", Geoscience Electronics, 14:3-9, 1975.

Bauer, M.E., "Use of Machine Clustering to Stratify LANDSAT Data", Presented to Managers of Large Area Crop Inventory Experiment, NASA/JSC, June 16, 1976.

Bauer, M.E., and B.J. Davis, "Stratification of LANDSAT Data by Clustering", Symposium on Machine Processing of Remotely Sensed Data, Purdue University, June 29-July 1, 1976.

Baumgardner, M.F., "Practical Applications of Space Systems: Agriculture, Forest, and Range", The report of the Panel on Agriculture, Forest, and Range to the Space Applications Board of the National Research Council, 1975.

Baumgardner, M.F., "Agricultural Applications of Remote Sensing Technology", Annual Meeting of Soil and Water Conservation Districts, State of Illinois, Springfield, Illinois, July 29, 1975.

Baumgardner, M.F., "Applications of Satellite Remote Sensing on the Developing Nations", National Academy of Sciences briefing of U.S. AID officials, August 4, 1975.

Baumgardner, M.F., "Using LANDSAT Data to Map the Natural Resources of Western Sudan", Invited seminar at the World Bank, Washington D.C., August 5, 1975.

Baumgardner, M.F., "Geologic Applications of Remote Sensing by Satellite", Invitational seminar at the Department of Geology, Ministry of Industry and Mining, Khartoum, Sudan, November 9, 1975.

Baumgarnder, M.F., "Remote Sensing for Development", National Academy of Sciences, Princeton, New Jersey, November 12-14, 1975.

Baumgardner, M.F., Monitoring Agriculture from Satellites", Alpha Zeta/Gamma Sigma Delta lecture, Purdue University, November 19, 1975.

Baumgardner, M.F., "Where Are We in Using LANDSAT Data for Delineating Meaningful Soil Boundaries?", Seminar for officials of the Soil Conservation Service, U.S. Department of Agriculture, Washington D.C., December 9, 1975.

Baumgardner, M.F., "Using Satellite Sensors As an Aid in Developing and Managing the Natural Resources of the World", Invitational seminar to the Science Attaches of the Foreign Embassies in Washington, D.C., December 10, 1975.

Baumgardner, M.F., "Remote Sensing in Agriculture", Speaker for Annual Banquet of the Whitley County Soil and Water Conservation District, Columbia City, Indiana, January 21, 1976.

Baumgardner, M.F., "Applications of Remote Sensing to Soils Inventories and Land Use Capabilities", Speaker for Annual Banquet, Moultrie County Soil and Water Conservation District, Sullivan, Illinois, January 26, 1976.

Baumgardner, M.F., "As the Earth Turns -- Your World Today", Invitational address, Annual Midwest Regional Turf Conference, Purdue University, March 1, 1976.

Baumgardner, M.F., "Applying Remote Sensing Technology to Agricultural Research", Invitational seminar, School of Agriculture, Alabama A & M University, Normal, Alabama, March 25, 1976.

Baumgardner, M.F., "Operational LANDSAT", Invitational briefing by American Institute of Aeronautics and Astronautics; briefing conducted by NASA, Washington, D.C., May 28, 1976.

Baumgardner, M.F., E.H. Horvath and S.J. Kristof, "Data From Satellite-Borne Multispectral Scanner Used as a Supplementary Information to Soil Study in the Province of Badajoz, Spain", Agronomy Abstract, p. 55, 1975.

Baumgardner, M.F., and D.W. Kingrey, "Now is Tomorrow", Friends United Press, Richmond, Indiana, 1975.

Baumgardner, M.F., and S.J. Kristof, "Changes in Multispectral Soils Patterns with Increasing Crop Canopy", Agronomy Journal 67:317-321.

Baumgardner, M.F., W.J. Todd and P.W. Mausel, "Urban Land Use Monitoring from Computer-Implemented Processing of Airborne Multispectral Data", Proceedings of the Association of American Geographers, 7:247-251, 1975.

Hoffer, R.M., "Computer-Aided Analysis of SKYLAB Scanner Data for Land Use Mapping, Forestry and Water Resource Applications", Invited paper presented at the 11th International Symposium on Space Technology and Science, Tokyo, Japan, July 3, 1975.

Hoffer, R.M., "Remote Sensing of Natural Resources Using Satellite Data and Computer-Aided Analysis Techniques", Invited paper presented to the Japanese Society of Photogrammetry, Tokyo, Japan, July 7, 1975.

Hoffer, R.M., "Remote Sensing Techniques for Land Use Mapping", Invited paper presented at the Chuba Regional Development Institute, Nagoya, Japan, July 10, 1975.

Hoffer, R.M., "Definition of an Optimal Wavelength Band Combination for Forest Cover Type Mapping Using SKYLAB S-192 Data", Paper presented at the SKYLAB Regional Planning and Development Conference, September 10, 1975.

Hoffer, R.M., "Mapping Forest Cover Types with SKYLAB S-192 Data", Paper presented at the Semi-Annual Meeting of the American Society of Photogrammetry, Phoenix, Arizona, October 27, 1975.

Hoffer, R.M., "Remote Sensing and Natural Resource Management", Invited lecture to Forestry 103 class, December 10, 1975.

Hoffer, R.M. and L.A. Bartolucci, "Digital Processing of LANDSAT and SKYLAB Multispectral Scanner Data for Water Resource Application", Invited paper, Transactions American Geophysical Union, 57(4):251, Abstract, 1976.

Hoffer, R.M., S.G. Luther and L.A. Bartolucci, "Snow Cover Monitoring by Machine Processing of Multitemporal LANDSAT MSS Data", Proceedings of the Workshop on Operational Applications of Satellite Snow Cover Observations, Lake Tahoe, California, August 18-20, 1975.

Hoffer, R.M. and staff, "Natural Resource Mapping in Mountainous Terrain by Computer Analysis of ERTS-1 Satellite Data", Agricultural Experiment Station Research Bulletin 919 and LARS Information Note 061575, Purdue University, 124 pp., 1975.

Hoffer, R.M. and staff, "Computer-Aided Analysis of SKYLAB Multispectral Scanner Data in Mountainous Terrain for Land Use, Forestry, Water Resource, and Geologic Applications", The final report on SKYLAB EREP Project 398, LARS Information Note 121275, Purdue University, 381 pp., 1975.

Landgrebe, D.A., Two seminars, one technical to the NASA Remote Sensing staff and one general seminar open to the public for the NASA Goddard Colloquium Series, Greenbelt, Maryland, November 24, 1975.

Landgrebe, D.A., Lecture for IBM Earth Resources Management Symposium, Houston, Texas, January 28, 1975.

Landgrebe, D.A., Purdue Alumni Association Meeting, Purdue Club of St. Louis, Missouri, February 12, 1976.

Landgrebe, D.A., Lecture for Short Course, "Image Processing and Pattern Recognition", Department of Electrical Engineering, Purdue University, April 13, 1976.

Landgrebe, D.A., and R.L. Kettig, "Computer Classification of Remotely Sensed Multispectral Image Data by Extraction and Classification of Homogeneous Objects", IEEE Transactions on Geoscience Electronics, GE-14, 1:19-26, January 1976.

Landgrebe, D.A., D.S. Moore and S.J. Whitsitt, "Variance Comparisons for Unbiased Estimators of Probabilities of Correct Classifications", IEEE Transaction on Information Theory, IT-22 1:102-105, January 1976.

Landgrebe, D.A. and D.J. Wiersma, "The Use of Spatial Characteristics for the Improvement of Multispectral Classification of Remotely Sensed Data", presented at the Symposium on Machine Processing of Remotely Sensed Data, Purdue University, June 29-July 1, 1976.

Lindenlaub, J.C., "Audio Tutorial Instruction", 1975 Frontiers in Education Conference, Atlanta, Georgia, October 20-22, 1975.

Peterson, J.B., "Quantitative Inventorying of Soil and Land Use Differences by Remote Sensing", Invited paper presented at Annual Meeting of Soil Conservation Society of America, San Antonio, Texas, August, 1975, also LARS Information Note 063075.

Russell, J.D. and J.C. Lindenlaub, "A Minicourse Series on the Fundamentals of Remote Sensing", American Society of Photogrammetry, Washington D.C., February 25-27, 1976.

Stoner, E.R., M.F. Baumgardner, and P.H. Swain, "Determining Density of Maize Canopy from Digitized Photographic Data", Agronomy Journal 68:55-59, 1976.

Swain, P.H., "Remote Sensing Technology and Applications", short course presented monthly beginning July 1975, LARS, Purdue University, West Lafayette, Indiana.

Swain, P.H. "LARSYS Advanced Analysis Seminar/Workshop", a 3-day short course on advanced analysis techniques using LARSYS presented at NASA/Langley, March 1975; NASA/Wallops Island, July 1975; EROS Data Center (USGS), Sioux Falls, South Dakota, May 1976.

Swain, P.H., "Computer Analysis of Remotely Sensed Data", Large Area Crop Inventory Experiment (LACIE) Training Program, Lockheed Electronics Company, Inc., Aerospace Systems Division, Houston, Texas, April 22-23, 1976.

Swain, P.H., "Clustering", FOCUS, LARS, Purdue University, West Lafayette, Indiana, June 1976.

Swain, P.H. and L.A. Bartolucci, "Selective Radiant Temperature Mapping Using a Layered Classifier", IEEE Transactions on Geoscience Electronics, GE-14 2:101-106, April 1976.

Swain, P.H. and H. Hauska, "Application of a Class of Sequential Classifiers to Multitemporal Remote Sensing Data", Proceedings of Symposium on Machine Processing of Remotely Sensed Data, June 1976.

STAFF, FISCAL, AND FACILITY SUMMARY

I. Staff

During the 1975-1976 fiscal year there were 147 people (84.5 FTE) from 15 departments in 5 schools assigned to LARS projects. This included 8.5 FTE faculty, 29 FTE professional, 14.5 FTE graduate students, 14 FTE undergraduate students, 3 FTE service staff, and 15.5 FTE clerical staff. The number of staff involved at LARS from the various schools and departments are shown in the attached table. LARS does not function as an academic department. However, all staff involved with LARS projects are assiged to the various academic administrative units of the university as shown in the following table.

Professorial Staff

July 1, 1975 - June 30, 1976

A. Agriculture

1. M. F. Baumgardner - Professor of Agronomy and LARS Program Leader
2. B. O. Blair - Professor of Agronomy
3. B. L. Dahl - Assistant Professor of Landscape Architecture
4. R. M. Hoffer - Professor of Forestry and Conservation and LARS Program Leader
5. J. B. Peterson - Professor of Agronomy (post retirement appointment) and Associate Director of LARS
6. A. Spacie - Assistant Professor of Forestry

B. Engineering

1. R. E. Bailey - Professor of Nuclear Engineering
2. D. P. DeWitt - Associate Professor of Mechanical Engineering
3. D. A. Landgrebe - Professor of Electrical Engineering and Director of LARS
4. J. C. Lindenlaub - Professor of Electrical Engineering and LARS Program Leader
5. C. D. McGillem - Professor of Electrical Engineering
6. S. R. Rao - Post Doctoral Research Associate
7. L. F. Silva - Associate Professor of Electrical Engineering and LARS Program Leader
8. P. H. Swain - Assistant Professor of Electrical Engineering and LARS Program Leader

C. Science

1. V. L. Anderson - Professor of Statistics
2. L. A. Bartolucci - Post Doctoral Research Associate in Geoscience
3. G. M. Jurica - Assistant Professor of Geoscience
4. D. W. Levandowski - Professor of Geoscience
5. T. R. West - Associate Professor of Geoscience
6. S. B. Vardeman - Assistant Professor of Statistics

D. Humanities, Social Science and Education

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

Professional Staff

July 1, 1975 - June 30, 1976

A. Agriculture

1. M. E. Bauer - Research Agronomist in Agronomy and LARS Program Leader
2. R. H. Gilbert - Research Agronomist in Agronomy (USDA/SCS)
3. F. E. Goodrick - Data Analyst in Forestry and Conservation
4. F. R. Kirschner - Soil Scientist (USDA/SCS)
5. S. J. Kristof - Research Agronomist in Agronomy
6. R. P. Mroczynski - Photointerpreter in Forestry and Conservation
7. C. F. Walker - Administrative Assistant in Agronomy
8. R. A. Weismiller - Research Agronomist in Agronomy and LARS Associate Program Leader

B. Engineering

1. P. E. Anuta - Research Engineer in Electrical Engineering and LARS Associate Program Leader
2. J. S. Berkebile - Research Analyst
3. L. L. Biehl - Project Manager/Engineer
4. T. M. Cary - Research Analyst
5. M. D. Collins - Computer Operations Shift Supervisor
6. B. J. Davis - Statistician/Analyst
7. S. M. Davis - Education and Training Specialist
8. J. B. Etheridge - Applications Programmer
9. S. L. Ferringer - Visual Designer
10. D. M. Freeman - Manager of Data Reformatting
11. K. M. Freeman - Data Librarian/Photographer
12. H. L. Grams - Manager of Computer Operations
13. J. K. Ho - Applications Programmer
14. W. C. Hockema - Computer Operations Supervisor
15. J. L. Kast - Program Developer
16. K. J. Philipp - Reformatting Operations Assistant
17. T. L. Phillips - Deputy Director of LARS
18. P. A. Pickett - Remote Sensing Data Analyst and Training Specialist
19. B. J. Pratt - Administrative Assistant
20. P. R. Roberts - Administrative Assistant
21. B. F. Robinson - Research Engineer in Electrical Engineering and LARS Associate Program Leader
22. C. R. Sand - Computational Facility Manager
23. S. K. Schwingendorf - Applications Programmer
24. W. M. Simmons - Manager of Applications Programming
25. P. W. Spencer - Applications Programmer
26. L. L. Wilson - Pictorial Interface Supervisor
27. W. C. Zurney - Reformatting Operations Assistant

C. Science

1. S. G. Luther - Research Analyst in Geoscience

D. Humanities, Social Science and Education

1. D. P. Morrison - Education and Training Coordination

Staff Involvement at LARS in Number of Staff

July 1, 1975 - June 30, 1976

Department	Faculty (Page 61)	Professional (Page 62)	Graduate Students (Page 28)	Undergraduate Students	Service	Clerical
Agriculture						
Agronomy	3	7	2			
Forestry and Conservation	2	2	4			
Landscape Architecture	1					
Engineering						
Experiment Station		27	3	38	4	15
Electrical	6	3	10			
Mechanical	1		1			
Nuclear	1		1			
Science						
Geoscience	4	1	2			
Computer Science			2			
Statistics	2		1			
HSSE						
Education	1					
Communications		1	1			
Management						
Industrial Management			1			
TOTAL	21	37	28*	38	4	15

*Includes only those graduate students on the payroll. The total including all graduate students is 53.

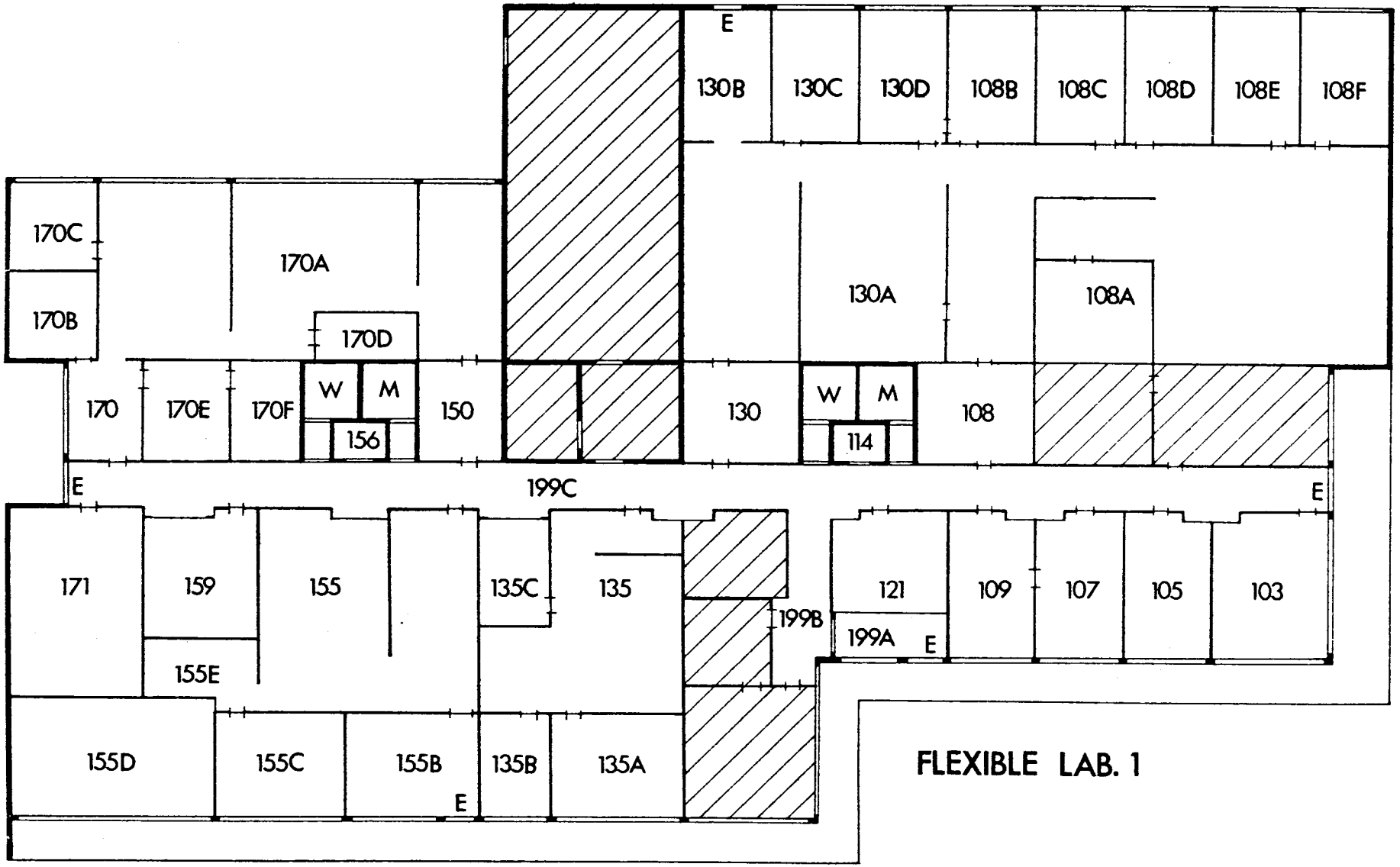
II. FISCAL SUMMARY

A. Summary of Resources

Funds Available:		
Research	$2,121,509	
General Funds	109,583	
70 Fund	835,851	
		$3,066,943
Funds Expended		
Research	$2,053,230	
General Funds	109,583	
70 Fund	700,747	
		2,863,560
Carry Forward		$ 203,383[1]

[1]Make-up of $203,383 is:

Computational Facility	$ 135,104
Research Carry Forward	68,279
Total	$ 203,383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170F
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135C
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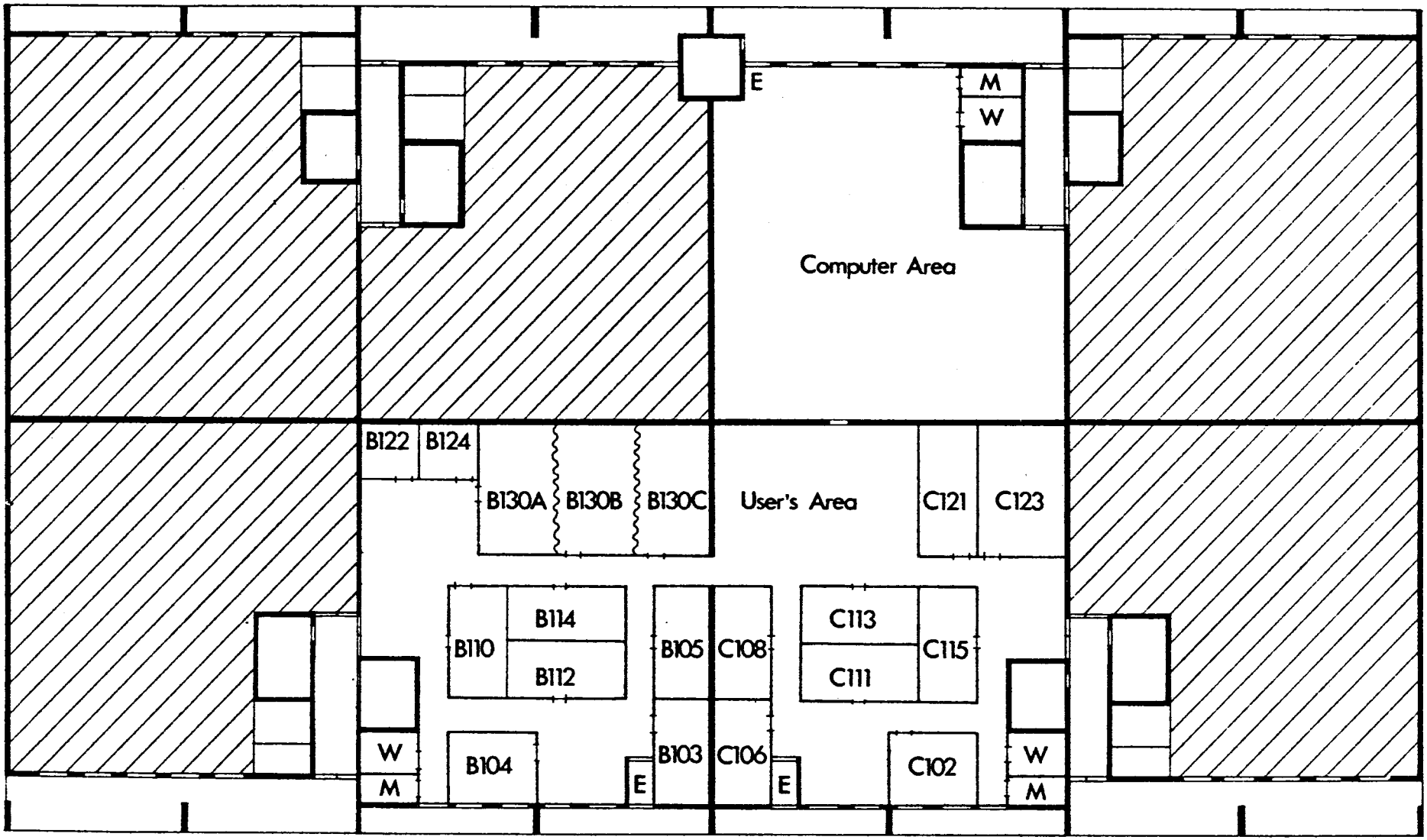
FLEXIBLE LAB. 1



FLEXIBLE LAB. 2