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FISCAL YEAR 1977

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

1977

1976-77 Report to the University
The Laboratory for Applications of Remote Sensing

We are pleased to transmit to you this report on the research and educational activities at LARS for the past fiscal year. Interest and involvement in this field continues to grow both nationally and at Purdue. Staff participation this past year was up in all categories in some cases substantially. Examples are:

	1975-76	1976-77
Faculty Participants	21	32
Graduate Students	53	54
Undergraduate Students	38	65

Nationally, plans continue to move forward for the launch of Landsat-C in the next few months and the design and construction of Landsat-D, a wholly new sensor system for launch in 1981. The major thrust of the national program is to reduce the entire technology to practice. One critically needed function in this thrust is training and education, a function which the academic community must assume. At LARS we have again assumed a leadership role in this effort and our educational activities are described in the pages following.

Research into more advanced capabilities also continues as a major activity in the field; LARS research programs and accomplishments for the year are also outlined on the pages which follow.

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

Distribution:

The President
The Provost
The Policy Committee
The Management Committee
The Division of Sponsored Programs
Interested Department Heads

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CONTRIBUTIONS OF LARS TO PROFESSIONAL AND ACADEMIC EDUCATIONAL PROGRAMS

I. INTRODUCTION

The background knowledge essential to implementing remote sensing procedures and the techniques of remote sensing have now advanced to a stage where education is essential to their full use and appreciation over the world. World-wide interest has been stimualted by the launching of the Landsat satellite series. The interest in learning to use and apply remote sensing technology to real earth resources problems is evident in the continuous flow of technically-trained people through LARS and the large number of requests from scientists over the world for permission to spend time in the Laboratory in a training capacity. This interest has been stimulated by the results of LARS research efforts on the development of remote sensing techniques and their application to resource problems on a world-wide basis. Early in LARS history people began communicating with staff members and visiting the Laboratory regarding the unfolding technology.

Historically, the primary contribution of LARS to Purdue University has been providing an interdisciplinary research facility for the advancement of remote sensing technology and its application to resource problems. However, a second activity is growing rapidly, in scope and importance; namely, an education program in remote sensing technology and its application. At the Laboratory a direct contribution is being made in Technology Transfer which is reaching professionals from many disciplines and many lands through LARS-provided short courses, symposia and visiting scientist programs. The Technology Transfer program is aimed at the "user community", ranging from Purdue University personnel on outward to other universities, state and federal agencies, business and industry, and foreign personnel.

In addition, the opportunity exists for many Purdue scientists on academic appointments to do research on remote sensing problems at LARS in an interdisciplinary environment through which experience in depth concerning the field of remote sensing is provided. Several of these people have organized and introduced academic courses carrying university credit which in the aggregate provide a respectable background in the theory and technology of remote sensing and its application. Thus it is possible at Purdue for anyone seeking a baccalaureate degree in one of the fields where remote sensing is proving an important tool, such as geology, soil science, agronomy, land use, forestry, environmental science, etc. to structure a degree program that will prepare him to use remote sensing as an aid in his chosen field.

LARS is in an exceptionally favorable position to serve as a training as well as a research center. This arises by virtue of its position as an integral part of a broad-based, top-level university, its organizational structure, its truly interdisciplinary approach and its breadth and depth of experience in remote sensing research and application. Being closely integrated in the structure of a high-quality university the Laboratory is able to attract to its program on a part-time basis outstanding scientists representing the complete range of relevant disciplines. These people are well qualified educators as well as research workers. They provide

communication bridges between the various disciplines and the interdisciplinary teams at the Laboratory. The interdisciplinary nature of the research operations simplifies helping short course trainees and visiting scientists to integrate the wide-range of background knowledge impinging on remote sensing activity and to apply it to specific problems.

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 32 academic and 36 professional staff of the University who add to their teaching the knowledge gained in their remote sensing activities.

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

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

D. 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.

E. Develops educational aids and teaching materials on remote sensing for use by the University staff.

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

G. Directly supports with Laboratory resources the educational activities for approximately 20 academic staff members who directed graduate thesis research in problems involving remote sensing in FY77. In the spring semester the Laboratory contributed to the salaries, fringe benefits and overhead of 23 academic staff members at an annual rate of $530,000 and supported the same costs for graduate assistants at an annual rate of $201,000. There were 42 graduate degree candidates, 10 of whom were granted an advanced degree, who were advised by LARS staff members in FY77. In addition to advising students on staff appointments, LARS academic staff members also advised graduate degree candidates in their home departments. Six 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, Electrical Engineering and Nuclear Engineering include parts dealing with current remote sensing technology.

II. 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 FY77 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 FY77 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 Center, Texas; Indiana State University, Indiana; and EROS Data Center, South Dakota. The EROS Data Center Terminal was disconnected in November 1976 due to the acquisition of remote sensing analysis equipment by the Data Center.

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 45 visiting scientists involved in applying remote sensing technology to problems in 16 different foreign countries which they represented. During FY77 there were 10 visiting scientists involved in applying remote sensing technology to problems in 6 different foreign countries.

C. Symposia

The June 21-23, 1977 symposium was the fourth one to be presented by LARS, Purdue University, and the other co-sponsors. The attendance was 168 registered participants, who came from 76 different agencies; of this 168, 17 came from 6 foreign countries. This brings the total attendance at all 4 symposia to 695. The participants heard a total of 35 long and 36 short papers in addition to an address by The Honorable Charles Rose III, Representative from North Carolina. These papers were presented in the following sessions:

Plenary
Preprocessing I and II
Applications of Machine Processing to Agriculture I and II
Research Frontiers-Machine Processing and Applications
Preprocessing Systems I and II
Scene Modeling
Applications of Machine Processing to Hydrology/Geology
Data Analysis I: Nonparametric Classification
Applications of Machine Processing to Forestry
Data Analysis II and III: Classification Methods and Systems
Applications of Machine Processing to Land Use Mapping I and II

D. Short Courses

The monthly short course, which had been initiated the previous year on a regular monthly basis, was better attended in FY77 with a total of 94 paid attendees, 44 of whom also participated in the extra computer option. Seven of the 1977 Symposium attendees were prior short course attendees.

As in the previous year, the participants were a heterogenous group coming from federal government agencies (27%), state and local agencies (4%), foreign (18%), business and industry (18%), Purdue (6%) other universities (21%), other non-profit organizations (1%) and others (5%). Over 30 of the LARS staff participated in the instruction during 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 in 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. 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 20 titles. The series is especially useful for general briefings or introductory treatments of remote sensing topics.

During FY77 6 additional FOCUS topics were added to the previous 14 and all 20 were incorporated into LARS Information Note 052977. The titles included are:

The Multispectral Scanner
Cover Type Classification
Pattern Recognition
Mapping Soil Characteristics
Sample Classification
Earth Resources Data Processing System
Remote Sensing
Landsat: An Earth Resources Data Collection System
Role of Images in Numerical Data Analysis
Crop Species Identification
What is LARSYS?
Landsat Multispectral Scanner Data
Clustering
How the Earth Reflects
Multispectral-Multitemporal Concept
LARSYS Version 3.1
Regional Land Use Inventories
Reformatting Landsat Data
The Multiband Concept
Snowcover Mapping

F. The Fundamentals of Remote Sensing, A Minicourse Series

Instructional units of 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 cassette 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. Several LARS Short Course participants advised that their organizations had purchased this series and they had reviewed some of these individual courses prior to visiting LARS.

List of Minicourse Titles -

Remote Sensing: What is it?
The Physical Basis of Remote Sensing
Spectral Reflectance Characteristics of Vegetation
Spectral Reflectance Characteristics of Earth Surface Features
Mission Planning: Considerations and Requirements
Landsat: An Earth Resources Satellite System
Skylab: Earth Resources Experiment
Multispectral Scanners
Photographic Sensors
Side-Looking Airborne Radar
Pattern Recognition in Remote Sensing
Typical Steps in Numerical Analysis
Interpretation of Color Infrared Photography
Interpretation of Radar Imagery
Interpretation of Multispectral Scanner Images
Applications of Remote Sensing in Forestry
Applications of Remote Sensing in Geology
Crop Surveys Through Remote Sensing
Temperature Mapping of Water by Remote Sensing

G. 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 -

An Introduction to Quantitative Remote Sensing
LARSYS Software System - An Overview
Demonstration of LARSYS on the 2780 Remote Terminal
The 2780 Remote Terminal: A "Hands-On" Experience
LARSYS Exercises
Guide to Multispectral Data Analysis Using LARSYS
A Case Study Using LARSYS for Analysis of Landsat Data

H. 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 -

A Forestry Applications Simulation of Man-Machine Techniques for Analyzing Remotely Sensed Data
Determining Land Use Patterns through Man-Machine Analysis of Landsat Data

I. 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 30 minutes. Student viewing notes have been compiled for most of the videotapes.

List of Videotape Titles -

Introduction to Quantitative Remote Sensing
Duality of System Types and the Multivariant Approach
System Parameters Fundamental to Information Extraction
Introduction to Pattern Recognition for Remote Sensing Applications
Statistical Characterization of Pattern Classes
Derivation of Discriminant Functions
Feature Selection
Cluster Analysis and Sample Classification
Introduction to Radiation in Remote Sensing
Reflectance in Remote Sensing
Emission in Remote Sensing
Fundamentals of Remote Sensing Instrumentation
Mapping Sudan's Resources from Space

J. Color Booklet

The booklet "Remote Sensing of Agriculture, Earth Resources and Man's Environment" was revised and reprinted during FY77. This booklet graphically reveals the role remote sensing has played and will play in monitoring and analyzing earth's resources.

K. Courses with Definite Emphasis on Remote Sensing

Agronomy
598 Inventorying Agronomic Resources
cr. 3. Prof.'s Bauer, Baumgardner and Weismiller

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

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

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

579 Remote Sensing Seminar
cr. 9 or 1. Prof. Hoffer and Staff

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

L. 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 Staff

645 Communications II
cr. 3. Communications Sciences Staff

661 Image Processing
cr. 3. Prof. Huang

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

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

Nuclear Engineering
597B Technology Assesment and Energy
cr. 3. Prof. Bailey

III. GRADUATE TRAINING WITH LARS STAFF AND FACILITIES

A. Degree Candidates FY77

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

Balasubiamanian, P., Ph.D., IE, Prof. A. Ravindran, "Optimization Models in Public Health Planning."

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

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

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

Curtis, Charles, M.S., EE, Prof's D.P. DeWitt and L.F. Silva, Non-thesis option.

Ernst, Lisette, Ph.D., 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."

Garrison, C.A., Ph.D., Con. and Family Sciences, Prof. M.V. Peart, Thesis title not yet assigned.

Hanley, Ed, M.S., ME, Prof. D.P. DeWitt, Thesis title not yet assigned.

Hinzel, Eric, M.S., Agron., Prof. M.E. Baumgardner, Thesis title not yet assigned.

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

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

Kollenkark, Jeffrey, Ph.D., Agron., M.E. Bauer, Thesis title not yet assigned.

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

McGrew, Gloria, M.S., Geosci., Prof. D.W. Levandowski, Thesis title not yet assigned.

McMeekin, Jeffrey, M.S., CS, W.R. Simmons, Non-thesis option.

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

Noyer, Stephen, M.S., For. and Nat. Resources, Prof. R.M. Hoffer, Non-thesis option.

Overmeyer, K., M.S., ME, Prof. D.P. DeWitt, Thesis title not yet assigned.

Pearce, J., M.S., EE, Prof. L.A. Geddes, Non-thesis option.

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

Pomalaza, Carlos, M.S., EE, Prof. P.H. Swain, Non-thesis option.

Reinhardt, John, M.S., NE, Prof. R.E. Bailey, "Calculation of Plumes from Cooling Towers."

Sabagopan, Sowmya, M.S., IE, Prof. A. Ravindran, Thesis title not yet assigned.

Smith, J., M.S., EE, Prof. L.F. Silva, Non-thesis option.

Stellon, C., M.S., Stat., M.E. Bauer, Non-thesis option.

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

Stoner, Eric, Ph.D., Agron., Prof. M.F. Baumgardner, Thesis title not yet assigned.

Traxler, Dan, M.S., EE, Prof. D.P. DeWitt, Thesis title not yet assigned.

Wiersma, D.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."

B. Degrees Granted FY77

Adams, Dennis, M.S., CS, Prof. P.H. Swain, Non-thesis option.

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

Einselen, K., M.S., CE, Prof. R. Miles, Non-thesis option.

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

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

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

Selzer, Gary, M.S., CS, Howard Grams, Non-thesis option.

Sontag, Hugh, M.S., EE, Prof. L.F. Silva, Non-thesis option.

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

Vanderbilt, Vernon C., Ph.D., EE, Prof. L.F. Silva, "An Experimental Geometrical Characterization of Two Vegetative Canopies."

C. Other Graduate Students Advised by LARS Staff Members

Adrien, Pierre, M.S., Agron., Prof. M.F. Baumgardner, Thesis title not yet assigned.

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

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

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

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

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

Kardos, Kris, M.S., NE, Prof. R.E. Bailey, "The Applications of Multispectral Scanner Data to the Mapping and Modeling of Power Plant Thermal Discharges in Rivers."

Kit, E.F., M.S., EE, Prof. P.H. Swain, Non-thesis option.

Lehman, T., Ph.D., Geosci., Prof. D.W. Levandowski, "Remote Sensing of Lineaments and Domal Features, from a Special Platform, as Guides to Ore Deposits and the Localization of Ores."

Sontirat, V., M.S., Agron., Prof. M.F. Baumgardner, Thesis title not yet assigned.

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

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

SCIENTIFIC CONTRIBUTIONS OF LARS IN THE FIELD OF REMOTE SENSING

I. INTRODUCTION

Established in the early nineteen sixties, when modern remote sensing was in its infancy, LARS has been continuously recognized by NASA as a center of excellence in research. During this period LARS has been a leader in much of the research which has contributed to the rapid advancement in the science and technology of remote sensing.

The Purdue/LARS research effort covers spectral data acquisition including development of instrumentation, the handling, processing, analysis and interpretation of multivariant multispectral scanner (MSS) data and the use of remote sensing to study and inventory vegetation, especially crops and forests; geological features; soils; land use and water resources. Lately a share of the research effort has been directed toward health problems. This research depends on the acquisition, analysis and interpretation of spectral data from living subjects secured at relatively short distances.

A. 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 FY77, 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. 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 observation 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.

2. Crop Identification and Area Estimation Over Large Geographic Areas Using Landsat Data

This project, sponsored by NASA, was completed in October 1976 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 are not different from those made by the USDA. The area estimates for corn and soybeans in Indiana are less accurate indicating the greater complexity of scene relative to the sensor's ability to represent the scene. An important feature of the approach and results is that by classifying entire Landsat frames using the computer, the sampling error of the estimates is neglible.

3. 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, has been 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.

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

This project, sponsored by NASA, calls for LARS to provide the technical implementation of the remote sensing experiments of analogous vegetative areas in the United States and the Soviet Union. This was 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 completed. Several remote sensing systems ranging from ground-level to satellite altitudes are being used. Initially, the study has concentrated 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.

B. EARTH SCIENCES RESEARCH

1. Spectral Properties of Soils

If analysis of multispectral data by pattern recognition techniques is to be used most effectively to delineate meaningful soils boundaries and to recognize differences in physical, chemical and genetic properties of soils, a considerable research effort must be mounted to examine the spectral properties of soils. The radiation from surface soils on a given date of multispectral data acquisition by satellite will be affected by surface roughness, moisture content, green plant cover, organic residues on the surface, and specific soil properties.

Field and laboratory research was continued during this year to add to the body of knowledge of energy/matter interactions. Specific studies included the examination of the visible and infrared reflectance properties of a light-colored, well-drained silt loam Typic Hapludalf and a dark poorly-drained silty clay Typic Agriaquoll. Reflectance measurements of four surface conditions were obtained: soil surface without cover, soil surface with 25 percent ground cover of chopped corn stover, wet surface, and dry surface.

Results from these studies are being analyzed and should enhance the Laboratory's capabilities to interpret multispectral data from satellites.

2. Soil Classification and Survey

Landsat multispectral scanner data and computer-implemented clustering techniques have been used during the past year for mapping soils in three counties in Indiana -- Clinton, Jasper and Tippecanoe.

Clinton County is currently under progressive survey by the Soil Conservation Service, soil scientists at LARS have worked cooperatively with SCS soil surveyors in evaluating spectral maps prepared from Landsat data as an aid in the preparation of conventional soils maps. The results of this cooperative effort in Clinton County have shown that spectral maps from Landsat data can be overlaid onto completed soil survey field sheets and used to improve the delineation of soil boundaries. It was determined that the Landsat data can be a valuable tool for quality control.

During this year a cooperative research program was initiated by LARS and the SCS to use Landsat data to provide a mapping base for a soils map of Jasper County, Indiana, a county for which a soil survey has never been made. The objective of the study will be to produce by computer-implemented analysis of Landsat data a spectral map of Jasper County at a scale of 1:15,840. By appropriate field sampling and observations, descriptions will be prepared for the soils falling within the mapping units resulting from the spectral analysis.

One of the significant results of the research in soil survey was the use of digital analysis of Landsat data to delineate and measure the homogeneity of soil mapping units. This capability with Landsat data provides a convenient method for determining the percentage or quantitative measure of inclusions within a mapping unit.

In Tippecanoe County a project was initiated to study the use of multitemporal Landsat data for mapping soils. Three different dates are being used in this study -- 9 June 1975, 6 April 1975, and 20 June 1976. Results will be evaluated in the field and will be compared with spectral soils maps generated from aircraft scanner data obtained over four test areas in Tippecanoe County in 1969 and 1970.

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

C. ECOSYSTEMS RESEARCH PROGRAMS

The Ecosystems Program area involves both research and applications activities directed toward the utilization of remote sensing technology for natural resource inventories. Emphasis is placed upon development of the capability to identify, map, tabulate, and characterize selected land use (non-urban), forest resource, and water resource situations of importance to various user groups. Much of the research is directed at the testing and refinement of various computer-aided analysis techniques. The interpretation of color infrared photography and other data derived from supplemental sources is stressed, in order to better understand the scene characteristics and to define more effective man-machine interactions in analyzing multispectral scanner data. The following paragraphs briefly describe the major projects in which we have been involved this past year.

1. Demonstrations of Applicability of Remote Sensing Technology as an Aid in Solving Resource Management Problems in Indiana

This activity is funded by the NASA Office of University Affairs, and has as its general goal the development, testing and demonstration of useful applications of remote sensing for the people of Indiana. Projects undertaken this year have included:

a. Forest Tent Caterpillar Mapping

During the spring of 1975 the eastern tent caterpillar, a broadleaf hardwood defoliator, exploded to epidemic populations in southern Indiana. Predictions for 1976 based on egg mass surveys indicated that defoliation would be more severe. Ground surveys to determine the extent of damage are costly and inaccurate. The Indiana Department of Natural Resources sought LARS assistance in the collection and analysis of color infrared photography for the purpose of determining the extent and severity of defoliation.

During mid-May, 1976, LARS staff collected large-scale color infrared photography over a test site south and west of Bloomington. By July the data had been interpreted, transferred to USGS maps, and acreage by defoliation class determined. The LARS study indicated that the '76 defoliation was wide spread and that the insect had caused considerable damage.

b. Tri-County Fish and Wildlife Area Mapping

Wetlands managers are faced with a problem in collecting baseline data to use in the development of their management plans. The manager of the Tri-County Fish and Wildlife Area was faced with the problem of assessing the vegetation habitat, which was the result of prior flooding, in the Area's marsh region south of Lake Wawasee.

LARS support was enlisted to collect color infrared aerial photography and provide analysis of the wetlands habitat. Aircraft and ground data were collected in early July and by mid-August a large scale (1:10,000) map was prepared for the study site.

c. Coastal Zone Management Project

Indiana qualifies under the Coastal Zone Management Act of 1972 for funding to develop a management plan for the resources within the Lake Michigan Watershed. The Division of Forestry within the Indiana Department of Natural Resources was given the task of evaluating the forest resources within the 150,000 hectare management site.

LARS aid and expertise was requested to help provide baseline resource data for the study site. In the first year (of this two year project), data on the amount and distribution of forest cover was provided to the state. These data were made available by computer-aided analysis of Landsat multispectral scanner data.

The second year of this effort (1977) is designed to inventory the potential productivity and erosion hazards associated with the forest land. These data will be analyzed to identify the areas which should be affected by coastal zone legislation within Indiana.

d. Hoosier National Forest Demonstration Project

This demonstration project is working in cooperation with the U.S. Forest Service and has been active for the past two years. The specific objective of this activity is to demonstrate the feasibility of using computer-aided analysis of Landsat multispectral scanner data to provide basic resource data to forest managers and planners.

A successful demonstration of this project may alter the methods the Forest Service would use in the future for collecting baseline information. The technological advantages of such an approach would result in a tremendous saving in personnel time which is currently being utilized for making baseline maps.

2. Forestry Applications Project

As part of the NASA supported SR&T program, this task has been directed toward the development of forest inventory procedures which utilize Landsat data and computer-aided analysis techniques. The ultimate objective would be to define a cost-effective approach for utilizing Landsat data to conduct inventories of the 1.6 billion acres of forest and rangeland resources in the United States, as called for by the Renewable Resources Act of 1974. Emphasis in this task has been placed on the definition of effective, statistically sound approaches utilizing a-priori inputs such as climate, topography, soils, and previous inventory information. The initial phase of this activity involved a review of forest inventory literature which emphasized sampling techniques developed since the launch of Landsat-1.

The second phase of the task focussed on the forest survey activities being conducted by the various regional Forest Experiment Stations. A definition of bench marks (forest survey standards) against which effective Landsat inputs could be assessed was the major focus of this phase of the activity. Because the Forest Survey Program of the U.S. Forest Service depends

on estimates of forest acreage in order to allocate field plots, and because previous work has indicated that Landsat satellite data and computer analysis techniques can be utilized to measure aerial extent of forest cover relatively accurately, we would anticipate the use of such analysis techniques would allow an improvement over current survey sampling schemes.

Tasks during the next year will involve the use of permanent plot data obtained for many locations in Indiana in order to study the relationship of field measured parameters to the spectral response obtained by the Landsat scanner system. An assessment of the utility of such permanent plot data to the design problem will be conducted, and recommended approaches to the inventory problem utilizing Landsat data and computer-aided analysis techniques will be developed.

3. Multiple Resource Evaluation of Region II - U.S. Forest Service Land Utilizing Landsat MSS Data

The purpose of this Landsat Follow-On investigation was to assess the utilization of Landsat MSS data and computer-aided analysis techniques for land use planning activities of Region II of the U.S. Forest Service. The project was conducted in conjuction with personnel from the University of Colorado and the San Juan, Rio Grande, and Carson National Forests. The project involved a computer-aided analysis of Landsat satellite data in order to obtain (1) a cover type map of a 463,885 hectare area which included portions of the San Juan, Rio Grande, and Carson National Forests and (2) acreage tabulations for the various forest cover types in the study area. As part of the study, topographic data (including elevations, slope, and aspect) were digitally overlayed onto the vegetation classification to produce a "multiple source" data tape which was used to obtain a variety of output map products, upon request by the U.S. Forest Service personnel. An evaluation of the cost-effectiveness of this procedure indicated that computer costs for the combined vegetation classification and topographic data overlay were slightly less than 0.5 cents per acre for the area involved. The maps and tables thus produced were then evaluated and used in a variety of planning and management activities by Forest Service personnel. The flexibility of combining information in various ways for problems having totally different interests, and to produce 1:24,000 scale maps using the cover type and topographic data overlays indicates a significant potential for such digital data formats. A study is currently under way by the U.S. Forest service to more thoroughly assess the advantages and limitations of these types of map and tabular products for meeting the on-going information needs of the agency.

4. Inventory of Surface Waters in Michigan

The Southcentral Michigan Planning Council has been working with the U.S. Environmental Protection Agency and several citizen groups who live along the shore lines of many small lakes in a five county area of southcentral Michigan. Preliminary studies by the Council indicated that data from the Landsat satellites could fill a significant gap in information about the inland lakes in this area. Due to previous work on the spectral characteristics of water and the level of detail which LARS scientists had found could be obtained with Landsat satellite data, LARS was asked to work with the Southcentral

Michigan Planning Council on a project involving the mapping of the areal extent and location of lakes in the five county region of southcentral Michigan, and to relate the spectral characteristics of the lakes to water quality. Although the project is still in progress, results to date have clearly shown that accurate information on the areal extent, quality and location of inland water bodies can be obtained through the computer-aided analysis of Landsat MSS data, and that the level of detail that can be obtained with these techniques would be extremely difficult to obtain over such a large area using more conventional information gathering procedures.

5. Bolivian Resource Inventory Program

Bolivia, as is the case in many other developing countries, needs current, reliable information concerning the location, extent, and condition of its natural resources. Since the areas which need to be surveyed and mapped are very large and access to these areas is extremely difficult, conventional field surveying methods are of limited utility. For these reasons, the Bolivian government became interested in assessing the effectiveness of utilizing satellite-gathered data and modern computer-aided analysis techniques (such as those developed at Purdue University), to map natural resources in selected large geographic areas of Bolivia. Two major studies have been conducted this past year.

a. Geologic and Soils Mapping of the Bolivian Andes

This study involved a cooperative effort involving personnel from LARS and a team of two Bolivian scientists who utilized the LARSYS data analysis system to map the geologic and soil features in a specified area in the Bolivian Andes. The study demonstrated the utility of this type of satellite data and these analysis techniques. The results also emphasized the value of having scientists familiar with the study area involved in the analysis of the satellite data. The geologic and soils maps which were produced are currently being utilized by various government agencies in Bolivia, and are proving to be a valuable source of information for many of the planning and development activities.

b. Agricultural and Forest Inventory of the Santa Cruz Subregion

The second major project undertaken this past year in conjunction with the Bolivian government was jointly supported by Programa ERTS/Bolivia and the U.S. Agency for International Development (A.I.D.). The objectives were to map a 20,000 sq. km. area in the eastern plains of Bolivia; quantitatively evaluate the area of forest and agricultural lands in this subregion, on a province-by-province basis; and to train three Bolivian scientists in the use of computer-aided analysis techniques for processing and interpreting Landsat multispectral scanner data. The Santa Cruz region is in the upper reaches of the Amazon Basin, and the Bolivian government urgently needs basic information on the agriculture and forest resources of this area in order to more effectively plan and manage large scale agricultural projects in this rapidly growing region of Bolivia. The analysis of the Landsat data from this area resulted in 1:25,000 and 1:50,000 scale maps and tables of the various types of land use, on a

province-by-province basis. The accuracy and reliability of the maps are currently being assessed by field teams working in the areas involved.

6. Ohio River Basin Energy Study (ORBES)

The first year's activities of the ORBES has culminated in the writing of a preliminary technology assessment concerned with the development of energy facilities in the Ohio River Basin. This technology assessment was developed through an interdisciplinary, inter-institutional team composed of members from Ohio State University, Indiana University and Purdue University. R.E. Bailey of LARS; Nuclear Engineering and Interdisciplinary Engineering Studies was the leader and coordinator of the three university teams.

One of the unique features of this particular technology assessment is the high percentage of public input. Besides interacting with a 30 member citizen's advisory committee, the team held four public hearings throughout the river valley during the 1976-77 academic year.

The second year of what is planned to be a three year project will begin in September of 1977 and the study region is being expanded to include West Virginia and the western section of Pennsylvania. The present study region includes Indiana, Ohio, Kentucky and Illinois.

7. Thermal Discharge Study

Research is continuing in the area of thermal discharges from power plants and other large industrial users of heat. The THRM3D5 model for estimating 3-dimensional temperature fields in rivers caused by thermal outfalls is being expanded to have applicability in lakes and other large bodies of water. The input to the model is the surface temperature field measured using multispectral scanning techniques. Experimental verification has been completed for rivers using the Gallagher plant on the Ohio River and lake verification is in progress using power plants on Lake Michigan and Lake Springfield.

Power plants are going more and more into dumping their heat via large cooling towers. Cooling tower plume models are being developed which, when coupled with the remote sensing techniques, will afford us the opportunity of monitoring vegetative stress and local meteorological changes that can develop as a result of cooling tower operation.

D. DATA PROCESSING AND ANALYSIS RESEARCH

Progress continued during 1976-77 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 remote sensing technology in a very significant application, again provided motivation for much of our data analysis research activity during 1976-77. 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. The U.S.G.S. project was successfully concluded during this year and the final report has been compiled and submitted to the sponsor.

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 emcompass 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 a research project funded by the National Science Foundation, geophysical data as well as topographic map data are being registered with Landsat data to aid in exploration for minerals using remote sensing techniques. Also, research was begun recently under a contract with the NASA Wallops Island Laboratory to study methods of registering radar imagery with Landsat data to enable these data types to be analyzed together. 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 benefit from the remote sensing data.

E. MEASUREMENTS RESEARCH

The program in measurements research at LARS continued along the previously established track of specialized field instrumentation development and basic research into the physical aspects of remote sensing. More recently activities concerned with the application of remote sensing technology to application areas other than earth resources have continued to expand and develop.

During FY 1977 the following activities have been pursued in the measurements program area:

1. Field Data Acquisition

During the past year the LARS spectral data acquisition system was deployed at the North Dakota State University Agricultural Research Station at Williston, North Dakota, in the third year of a three year field data acquisition program. The system acquired spectral data as part of a field measurement research project that has been underway as a part of the NASA Large Area Crop Inventory Experiment (LACIE). The complexity of the experiments attempted during the three year period has increased during each year as confidence and competence with the field system has increased. The calibration techniques developed during this research project are rapidly becoming standard in the remote sensing community. Two basic spectral data acquisition systems are employed in the project. The first is a wide band relatively high resolution system that has been developed over a period of approximately six years. The system is capable of taking detailed spectral data over as many as eighty test plots in a given day. All of the spectral data are fully calibrated and correlated with a complete set of ancillary data that are acquired simultaneously. In addition to the high spectral resolution instrument a four spectral band instrument has been equipped with a data logging system and special calibration system that enables it to acquire data over seventy test plots in a time period of one hour. Thus, if it possible to get four-spectral band data throughout the day in order to ascertain the effects of solar illumination angle upon spectral reflectance. A significant feature of the field measurements program is that system maintenance and repair as well as calibration takes place at a test site fourteen hundred miles away from the instrument laboratories in West Lafayette, Indiana.

2. Instrument Development

A specially developed, low cost field spectroradiometer was completed during the 1977 fiscal year. This instrument is a relatively, low cost, light weight, small-sized, device that covers the wavelength range from .4μm to 2.5μm. The optical system is versatile enough that it can be used in a wide variety of remote sensing applications.

Two special attachments have been designed and developed for a previously attained multiband radiometer. These attachments permit the measurement of the transmition and reflectance of the leaves of plants that are being studied. The data developed are correlated with the field spectral data that are acquired over scenes containing the plants.

A special reflectometer designed for laboratory use that is capable of measuring bidirectional reflectance factor was completed. This instrument uses the high resolution field spectroradiometer as a sensor so that the data produced by the reflectometer can be correlated with field data. The reflectometer has been used principally to measure the bidirectional reflectance factor of relatively large area soil samples under carefully controlled laboratory conditions. The data produced by the instrument are in exactly the same format as that produced by the field instrument which facilitates comparative analysis procedures.

A thermal scanner that was previously acquired has been modified and developed into a unique rapid scan thermal data acquisition system for both field and laboratory applications. The scanner has been equipped with a special foreoptic and calibration system that has been permitted its application in field studies on vegetative canopies and laboratory studies on biological subjects. The scanner will ultimately be capable of producing high resolution digital data after the completion of an analog to digital conversion system.

3. Thermal Band Remote Sensing of Crops

The thermal scanner mentioned above has been used to obtain radiance temperature profiles in wheat canopies at the North Dakota test site. A special optical technique that employs a laser to measure the optical depth of a crop canopy, has been developed and employed to characterize geometrically the wheat canopies that were being studied. Ancillary agronomic and thermal data using a simplified radiation model to predict the radiant temperature of the canopy as would be viewed by a satellite equipped with a thermal imaging band. The results of these projects will be used to interpret the data from the Landsat C satellite when it is launched in the near future. The results of the project are being studied to assess the information content of the thermal band, but especially with respect to the quantitative determination of crop stress. A strong positive result would improve the capability of satellite remote sensing systems to assess crop production.

4. Medical Applications of Remote Sensing

The non-contact characteristics of remote sensing technology make it an attractive diagnostic tool in medicine where non-invasive diagnostic techniques are welcomed. Also, the technology shows firmness as a non-invasive system for evaluating the efficacy of medical devices. Several projects are underway in the measurements program area which are centered upon the adaption of the instrumentation procedure to a particular problem in medicine or biomedical engineering so that the powerful data analysis procedures that have been developed for earth resource applications can be brought to bear upon these medical problems.

Private industry has funded a project whereby the thermal scanner is used to evaluate the performance of electrosurgical disperse of electrodes. The electrodes are applied to human volunteers and activated with conven-

tional electrosurgical equipment. The thermal scanner is used to assess the amount of heating that takes place underneath and around the dispersive electrode. Since the data are fully calibrated, the results can be used to compare various electrode designs and aid in the development of improved designs. The research has also lead to a basic understanding of the current distribution under and near the disperse of electrodes and how the design of the electrodes affects this distribution. This work has been done in cooperation with the Biomedical Engineering Center at Purdue.

The thermal scanner has also been used in conjunction with color infra-red film in a feasibility study concerning the detection of breast cancer in humans. The color infrared film is color separated and digitized and the data registered with the thermal digital data produced by the thermal scanner. The data product is a multispectral digital array that resembles those produced by earth resource satellite. Similar analytical techniques are being employed on the breast cancer data that are employed on the satellite data. Preliminary results indicate that the probability of locating tumors exceeds that obtained with conventional medical thermography. The project is currently unfunded but efforts to obtain funding continue.

The small low cost spectroradiometer described above, is being used in conjunction with a special optical system to detect jaundice in prematurely born infants in the study that is being funded by NIH. The object of the research is to develop a non-invasive procedure for early detection of jaundice in caucasian and noncaucasian infants. The research is being conducted in conjunction with the neonatal facility at the Indiana University Medical Center in Indianapolis, Indiana. The same instrumentation system is being used in a project that is funded by the university cancer committee. This project is concerned with the application of remote sensing techniques to the detection and characterization of skin tumors in humans and the correlation of skin response to ultra-violet radiation as a method for quantizing the susceptibility of individuals to skin cancer development.

APPENDIX I

Visitors Summary

A. Overall Summary

1.	Federal Agencies	48
2.	State and Local Agencies	31
3.	Other State and Local Agencies	13
4.	Purdue University	17
5.	Other American Universities	50
6.	Industry	48
7.	Foreign	63
8.	Miscellaneous	

B. Visitors by Affiliation

1. Federal Agencies

a.	National Aeronautics and Space Administration	13
b.	U.S. Department of Agriculture/Statistical Reporting Service	4
c.	U.S. Geological Survey	2
d.	United Nations Aid Study	1
e.	U.S. Air Force	1
f.	U.S. Engineering Topography Laboratory	6
g.	U.S. Department of Defense	2
h.	U.S. Post Office	2
i.	U.S. Forestry Department	2
j.	U.S. Soil Conservation Service	6
k.	U.S. Army	2
l.	National Resource Service	3
m.	U.S. Health, Education and Welfare	1
n.	U.S. Environmental Protection Agency	2
o.	Kitt Peak National Observatory	1

2. State and Local Agencies

a.	Indiana Geological Survey	11
b.	State Organization for Mineral Geological Survey	1
c.	Soil Conservation Service	3
d.	Indiana State Highway Commission	16

3. Other State and Local Agencies

a.	Illinois	7
b.	Kentucky	1
c.	Tennessee	2
d.	West Virginia	1
e.	Michigan	1
f.	Minnesota	1

4.	Purdue University	17
5.	Other American Universities	50
6.	Industry	48
7.	Foreign Countries	
	a. Turkey	2
	b. India	13
	c. Mexico	6
	d. Germany	1
	e. Japan	5
	f. Bangladesh	1
	g. Malaysia	2
	h. Canada	3
	i. Colombia	3
	j. South Africa	1
	k. England	1
	l. Hungary	1
	m. Austria	1
	n. Costa Rica	2
	o. Iraq	2
	p. Sweden	3
	q. Taiwan	2
	r. Rowanda	3
	s. Poland	5
	t. Italy	1
	u. Iran	2
	v. Peru	1
	w. Yugoslavia	1
8.	Miscellaneous	37

APPENDIX II

Publications and Talks by LARS Staff

A. LARS Information Note Series

022575 P. E. Anuta and G. Mobasseri, ERTS Multispectral Image Transformations for Geological Lineament Enhancement. The enhancement and detection of linear features in Landsat imagery is of interest in geological mapping. This report describes tests of gradient and laplacian transforms for lineament enhancement. A test site in central Nevada is evaluated using continuous and thresholded gradient and laplacian enhancement.

The research reported in this paper was sponsored by NASA under Grant No. NGL-15-005-112 and Contract No. NAS9-14016.

052075 D. P. DeWitt 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, 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 report in this paper was supported by the National Aeronautics and Space Administration under NASA Contract NAS9-14016.

111275 L. A. Bartolucci, B. F. Robinson and L. F. Silva, Field Measurements of the Spectral Response of Natural Waters. The spectral response (air-water interface reflectance and water volume-scattering) of turbid river water and clear lake water was measured in situ with a field spectroradiometer. The influence of the river bottom on the spectral response of the water also was determined using a modified Secchi disc approach.

The results indicated that turbin river water had a higher spectral response than clear lake water (≈6%) in the red (0.6-0.7μm) and near infrared (0.7-0.9μm) portions of the spectrum. Also, the reflectance characteristics river water when the water was deeper than 30 cm.

The work reported in this report was sponsored by NASA under contract NAS9-13301.

122475 S. G. Jordan and T. R. West, Highway Route Location Utilizing Remote Sensing Techniques, Ft. Wayne, Indiana. Analysis of Landsat imagery (June 8, 1973) for northeastern Ft. Wayne, Allen County, Ind., provided evaluations of several route corridors for the Indiana Highway Commission currently planning a dual-lane by-pass around the city. County engineering soils and agricultural soils maps, plus 9" x 9" aerial photograph, were used as ground-based data. Classifications showed recent growth patterns of the city and poorly drained organic areas not indicated on surface-materials maps. Poorly drained soil areas were designated as one spectral class suggesting these widely spaced deposits possess common properties. The study allowed for corridor-siting beyond troublesome areas early in the planning process. This paper appears in the Proceedings of the Indiana Academy of Science for 1975, Vol. 86, 1976.

The work reported in this paper was sponsored by NASA under Grant No. NGL-15-005-186.

022676 J. C. Lindenlaub and J. D. Russell, A Minicourse Series on the Fundamentals of Remote Sensing. A minicourse series which presents, in a tutorial manner, concepts fundamental to remote sensing technology has been developed. Each of the 19 minicourses in the series includes a set of 35mm slides, an audio tape and a study guide. The content has been modularized so that, after completing the two introductory units, remaining modules may be studied in varying numbers as well as different logical orders. This flexibility allows the minicourses to be used in a variety of ways. They are presently being used in university credit courses, training of new staff and, along with some video taped presentations, make up the core content of a one week short course on Remote Sensing Technology and Applications. The educational philosophy used in the development of the minicourses includes clear statements of objectives for each minicourse, student activities to reinforce concepts when they are presented, self evaluation check tests and a permanent record in the form of a printed study guide. Design of the materials was carried out by a team of subject experts and education specialists. The conference presentation will use excerpts from the minicourse series to illustrate the modular format, flexible usage and educational philosophy.

The work reported in this report was sponsored by Continuing Education, Purdue University.

030576 P. W. Mausel, 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 eutrophication 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 was sponsored by NASA under Grant number NGL-15-005-112.

031276 P. W. Mausel, 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 areal 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 W. J. Todd, 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 NAS-9-14016.

051576 M. E. Bauer and B. J. Davis, 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 data for whole or multiple frames of Landsat data. The use of clustering as an objective and efficient method of dividing scenes into areas which are spectrally similar (strata) is discussed and initial results, including classification performances and comparisons of spectral strata with major physical factors, are presented. Published in the Proceedings of the Third Symposium on Machine Processing of Remotely Sensed Data, June 29-July 1, 1976, Purdue University, W. Lafayette, Indiana.

The research reported in this report was sponsored by NASA under Contract Number NAS9-14016.

052576 J. C. Lindenlaub and B. M. Lube, Matrix of Education and Training Materials in Remote Sensing. Remote sensing education and training materials developed by LARS have been organized in a matrix format. A description of the matrix is followed by three examples designed to illustrate how the matrix can be used to synthesize training programs tailored to meet the needs of individual students. A detailed description of each of the modules in the matrix is contained in a "catalog" section.

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

060176 R. M. Hoffer, Computer-Aided Analysis of SKYLAB Scanner Data for Land Use Mapping, Forestry, and Water Resource Applications. SKYLAB data were obtained over a mountainous test site containing a complex association of cover types and rugged topography. The application of computer-aided analysis techniques (CAAT) to the multispectral scanner (MSS) data produced a number of significant results. Techniques were developed to digitally overlay topographic data onto the S-192 MSS data to provide a method for increasing the effectiveness and accuracy of computer-aided analysis techniques for cover type mapping.

The research reported in this report was sponsored by NASA under Contract Number NAS9-13380.

062076 David A. Landgrebe, Remote Sensing Technology - A Look to the Future. The purpose of this paper is to provide a broad framework for the anticipation of future developments in the field of remote sensing systems based on machine analysis methods. Based upon both design and operations differences a remote sensing based information system logically is divided into three parts: the scene, the sensory system, and the processing system. The needs and prospects for advancements of each of these are examined. It is pointed out that the scene is the most complex part of the system, and that increased understanding of scene variables is very important to future advancements. The objective of the sensor is to adequately characterize the scene variables in the data. This implies the need for adequate characterization of the spectral, spatial, and temporal variations of the energy emanating from the scene. The potential regarding each of these three types of variations is discussed in turn as is that for the increased use of ancillary data from other sources. The third portion of the system, the processing system, is discussed in terms of processing algorithms, their implementation, human participation in the processing, and output products. The overall conclusion is that though much has been achieved in the last decade or so, the potential for further development is very great.

062176 D. J. Wiersma and D. A. Landgrebe, The Use of Spatial Characteristics for the Improvement of Multispectral Classification of Remotely Sensed Data. Two parallel and overlapping approaches to classification of remotely sensed data with the aid of spatial information are underway at the present time. The image processing approach attempts to model after the human visual system, while the second approach is primarily numerical. The technique of texture features[1,2], representing the image processing approach, and the sample classifier ECHO[3,4] representing the numerical approach are compared. The numerical approach is demonstrated to be superior in classification accuracy as well as being more efficient computationally.

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

062276 R. M. Hoffer, Techniques and Applications for Computer-Aided Analysis of Multispectral Scanner Data. Several procedures for digitally processing and analyzing data from satellite scanner systems that have been found to be particularly useful are described. The techniques were applied to a mountainous test site of approximately one million hectares in ares. In spite of the vegetation and topographic complexity of this test site, coniferous and deciduous forest cover, as well as other major cover types, could be mapped with an accuracy of approximately 85%, using both Landsat and SKYLAB data. Individual forest cover types were mapped with approximately 70% accuracy. Accurate acreage estimates of forest cover were obtained through use of these techniques over large geographic areas.

The work reported in this paper was sponsored by NASA under Grant No. NGL 15-005-112 and Contracts NAS9-13380 and NAS5-21880.

070576 J. K. Cochran and R. E. Bailey, Computer-Aided Extension of Digitized Remotely-Sensed Water Surface Temperatures into the Third Dimension. By using pattern recognition and basic physical laws, the emitted thermal radiation from water as measured by an airborne multispectral scanner system may be analyzed to produce a surface temperature map of that body of water. In this paper, it is shown how maps of the discharge plumes from electric generating stations which release into natural waters may be first generated and then combined with other simple boundary conditions to solve the partial differential equations which describe the conservation properties of heat transfer in water. The solution is achieved through the use of a digital map for the Gallagher Plant operated by Public Service of Indiana at mile 610 on the Ohio River is produced and then compared with field collected data to check the accuracy of the solution.

The research reported in this report was sponsored by NASA under Contract Number NGL-15-005-186.

070676 S. J. Kristof, J. D. Russell, T. K. Cary, B. M. Lube, and R. A. Weismiller, Determining Land Use Patterns Through Man-Machine Analysis of LANDSAT Data - A Tutorial Simulation. The tutorial simulation provides a step-by-step description of the typical steps in the analysis of remotely-sensed data for determining land use patterns using numerically-oriented pattern recognition techniques. The material emphasizes the respective roles of the analyst and the computer, describing the decisions made by an analyst and the various computer processing functions. The steps are documented with illustrations and an example analysis from the Texas Coastal Zone.

The research reported in this paper was sponsored by NASA under Contract No. NAS9-14016 and NAS9-14970.

081176 R. H. Beck, B. F. Robinson, W. W. McFee and J. B. Peterson, Spectral Characteristics of Soils Related to the Interaction of Soil Moisture, Organic Carbon and Clay Content. The spectral reflectances of 15 Wisconsin-aged, glacial till soils capped with loess in Indiana were measured with the Exotech 20-C from 0.53μm to 2.32μm. The soils were predominantly silty with a range of organic carbon from .60 to 1.33% and moisture contents of those soild were controlled at oven dry (105°C for 24 hours), 1/3 BAR, and 15 BAR. The interpretation of the results allows us to suggest three wavelength band widths for use in the field when attempting to classify surface soils and increase the accuracy in mapping them by multispectral scanner techniques:

1. To map organic carbon, use the band from 0.90 to 1.22μm.
2. To map water content, use the band from 1.50 to 1.73μm.
3. To map clay, use the band from 1.50 to 1.73μm.

082776 O. L. Montgomery, M. F. Baumgardner, and R. A. Weismiller, An Investigation of the Relationship Between Spectral Reflectance and the Chemical, Physical, and Genetic Characteristics of Soils. The purpose of this study was to examine the quantitative relationships between some of the most common chemical/physical properties and the reflectance (0.53 - 2.37μm) of 56 soils selected to represent a broad range of parent materials, climate, and drainage characteristics. Step-wise multiple regression analysis revealed that cation exchange capacity and contents of silt, clay, iron oxides and organic matter gave highest correlation with spectral response. This study indicated that the middle infrared region of the spectrum is the best region of reflectance for evaluating these relationships.

The work reported in this paper was sponsored by NASA under Grant No. NGL 15-005-112 and Contract No. NAS9-14016.

090776 M. Svedlow, C. D. McGillem and P. E. Anuta, Analytical and Experimental Design and Analysis of an Optimal Processor for Image Registration. The problem of registration of Landsat images taken at different times is studied. Several preprocessing methods were evaluated to determine the best method for improving registration accuracy. Alternative correlation methods were also evaluated. Theoretical bounds on registration error were derived and an evaluation of the effects of geometric distortion on registration accuracy are evaluated.

The work reported in this paper was sponsored by NASA under Contract No. NAS9-14016.

091576 D. P. DeWitt and B. F. Robinson, Description and Evaluation of a Bidirectional Reflectance Factor Reflectometer. The Note describes the LARS reflectometer for making bidirectional reflectances factor measurements on large area (30x30cm) samples in the 0.38 to 2.5 m spectral region. This reflectometer simulates field measurement conditions for studying the effects of solar zenith angle and viewing direction on remote sensing observation of targets. Results for typical sample surfaces - paints, soil and cloth - are presented and discussed.

The research reported in this paper was sponsored by NASA under Contract NAS9-14016 and NAS9-14970.

101476 T. R. West, S. A. Mundy and M. C. Moore, Evaluation of Gravel Deposits Using Remote Sensing Data, Wabash River Valley North of Terre Haute, Indiana. The objective was to locate high gravel content zones in the extensive outwash sand and gravel terrace. Non-supervised analysis of overlay data (three Landsat passes) proved best. Field checks tended to verify the existence of "gravel rich" and "gravel poor" classes. Cost comparisons of remote sensing with conventional exploration suggest an economic benefit for the procedure developed.

The work reported in this paper was sponsored by NASA under Grant No. NGL 15-005-186.

110976 D. A. Landgrebe, W. Simmons, and L. Biehl, An Empirical Study of Scanner System Parameters. The selection of the correct combination of parametric values (instantaneous field of view, number and location of spectral bands, signal to noise ratio, etc.) of a multispectral scanner is a complex problem due to the strong interrelationship these parameters have with one another. In this paper the results of an empirical study using the proposed Thematic Mapper parameters are presented. The results obtained shows that as the IFOV is decreased, classification accuracy declines slightly but mensuration accuracy improves, among other conclusions.

The research reported in this paper was sponsored by NASA under NASA Contract No. NAS9-14016.

111076 J. D. Russell, Systematically Disseminating Technological Information to Potential Users. The article describes the activities of the Technology Transfer program area at LARS. The Matrix of Instructional Materials is presented and each of the types of instructional materials used is described briefly. The instructional development sequence for educational materials is also presented.

The research reported in this paper was sponsored by NASA under Contract No. NAS9-14016.

111276 P. H. Swain, Land Use Classification and Mapping by Machine-Assisted Analysis of Landsat Multispectral Scanner Data. This report summarizes the results of a three-year effort to demonstrate the feasibility of applying digital analysis of satellite data to land use inventory and mapping. It has been shown that the synoptic view from satellite altitude together with modern sensor and computer processing technologies have much to offer those who need accurate and timely land use information. Also notable has been the success with which the evolving technology has been communicated from the university research laboratory to the potential user agency via the "user-in-residence" approach.

The research reported in this paper was sponsored by USGS under Contract No. 14-08-0001-14725.

120776 V. C. Vanderbilt, L. F. Silva and M. E. Bauer, A Laser Technique for Characterizing the Geometry of Plant Canopies. A measurement technique is needed which is capable of providing timely information concerning the geometric characteristics of a vegetative canopy, the location and orientation of its foliage. Such data is required as input to many models for the radiation regime in a canopy. Therefore, this report

(1) proposes such a technique, designated the 'laser technique',
(2) demonstrates the feasibility of the technique, and
(3) offers suggestions for the implementation of the technique.

The work reported in this paper was sponsored by NASA under Contract No. NAS9-14016 and Contract No. NAS9-14970.

010577 M. F. Baumgardner, Computers, Satellites and Food -- A Global Perspective. The past two decades have witnessed dramatic advances in science and technology which already impact the daily lives of many hundreds of millions of people. Every morning millions of television viewers in North America see images of cloud formations and patterns over this continent, images

generated from satellite sensor data only hours or even minutes prior to broadcast time. All of us are benefactors daily of satellite communication systems which provide the luxury of viewing events or political activities as they occur half a world away, or of dialing directly from our home or office telephones and within minutes or even seconds conversing with friends or colleagues in Bonn, Tehran or Hokkaido. Yet a new dimension of technology is coming into focus which may have an even greater impact on human life. The impact of this new technology will greatly be determined by the degree to which it can contribute to the solutions of three crucial dilemmas facing man -- world hunger, environmental deterioration, and wasteful consumption of finite resources.

010777 R. A. Weismiller, I. D. Persinger and O. L. Montgomery, Soil Inventory Prepared from Digital Analysis of Satellite Multispectral Scanner Data and Digitized Topographic Data. A soils inventory of Chariton County in north central Missouri was produced using computer-aided analysis of LANDSAT multispectral scanner data. This data was spatially registered at a scale of 1:24,000 and overlaid with watershed and physiographic boundaries. Approximately 65% of the county existed as bare soil which was classified into 14 spectral soil classes. The remaining 35% was classified as forest, pasture and close grown crops. These cover types were correlated with soil types. Topographic data were used to delineate and extract data by watershed and physiographic position. The physiographic boundaries also allowed for the separation of genetically different but spectrally similar soils. Field checking of approximately 100 sites was accomplished to verify the classification.

The research reported in this paper was sponsored by the Soil Conservation Service of Missouri under a Cooperative Agreement.

011277 P. E. Anuta, Digital Registration of Topographic Data and Satellite MSS Data for Augmented Spectral Analysis. The problem of utilization of topographic and other ancillary data exists in digital analysis of remote sensing data. The report describes techniques and an example of digital registration of topographic data to SKYLAB and Landsat MSS data for use in forest and land use classification of areas in the Rocky Mountain region.

The work reported in this paper was sponsored by NASA under Contract No. NAS9-13380.

011977 H. L. Grams, LARS Computer User's Guide. The LARS Computer User's Guide is designed to document and incorporate all the basic information one needs in order to gain access to the machine and use the equipment. Topics covered include a description of LARS Computer Services, administrative procedures, available documentation, and procedures for operating terminals or submitting batch jobs.

Sponsored by Comp. Fac.

012477 M. E. Bauer and Staff, Crop Identification and Area Estimation over Large Geographic Areas Using LANDSAT MSS. This report describes the results of a study involving the use of computer-aided analysis techniques applied to Landsat MSS data for identification and area estimation of winter wheat in Kansas and corn and soybeans in Indiana. Key elements of the approach included use aerial photography for classifier training, stratification of Landsat data and extension of training statistics to areas without training data, and classification of a systematic sample of pixels from each county. Major results and conclusions are that (1) Landsat data was adequate to accurately identify winter wheat in Kansas, but not corn and soybeans in

Indiana; (2) computer-aided analysis techniques can be effectively used to extract crop identification information from Landsat MSS data, and (3) systematic sampling of entire counties made possible by computer classification methods resulted in very precise area estimates at county as well as district and state levels.

The research reported in this paper was sponsored by NASA under Contract No. NAS5-20793.

032977 R. Kumar and L. F. Silva, Separability of Agricultural Cover Types by Remote Sensing in the Visible and Infrared Wavelength Regions. The purpose of the study was to determine the statistical separability of multispectral image data from agricultural cover types in 1 to 12 spectral channels. When four channels were used the spectral bands were distributed in visible, near and middle IR, and thermal wavelength regions for maximum separability. Cover type properties are used to explain the results.

The research reported in this paper was sponsored by NASA under Grant No. NGL 15-005-112.

042777 J. D. Russell and J. C. Lindenlaub, Disseminating Technological Information on Remote Sensing to Potential Users. The Laboratory for Applications of Remote Sensing has developed materials and programs which range from short tutorial brochures to post-doctoral research programs which may span several years. To organize both the content and the instructional techniques, a matrix of instructional materials has been conceptualized. Each row in the matrix represents a subject area in remote sensing and each column in the matrix represents a different type of media or instructional strategy.

The research reported in this paper was sponsored by NASA under Contract Number NAS9-14970.

052977 S. M. Davis, The Focus Series: 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. Each pamphlet in the series is designed to illuminate a single concept through one page of concisely written text supported by illustrations. Issues currently available are collected in this Information Note.

The work reported in this paper was sponsored by NASA under Contract Numbers NAS9-14016, NAS9-14970 and Grant Number NGL 15-005-112.

062177 Swain, P.H., Advancements in Machine-Assisted Analysis of Multispectral Data for Land Use Applications. Results are reported of a three-year study participated in by the Laboratory for Applications of Remote Sensing of Purdue University, the Center for Advanced Computation of the University of Illinois, and the Geographic Applications Program of the U.S. Geological Survey. The outcome of the study has been a demonstration of the feasibility of applying digital analysis of satellite data to land use inventory and mapping. Advancements have been made in the areas of data analysis techniques, data processing products, and education and training of personnel within the potential user agency.

The research reported in this paper was sponsored by USGS under Contract No. 14-08-0001-14725.

050377 Lube, B.M. and J.D. Russell, A Short Course on Remote Sensing. The article describes a monthly, week-long short course in the fundamentals of remote sensing. The individualized training program gives each participant a background in remote sensing, then provides actual practical applications tailored to his individual needs. The design and development of the workshop is described along with the various instructional components.

The research reported in this paper was sponsored by Continuing Education at Purdue University.

B. Journal Articles and Presentations by LARS Staff

Altaie, F.H., M.F. Baumgardner and S.J. Kristof, "Delineating Soil Boundaries in Iraq by Digital Analysis of Landsat Data", Agronomy Abstracts, p. 157, 1976.

Anuta, P.E., "Multivariate Digital Techniques for Preprocessing and Analysis of Geophysical Remote Sensing Data", Denver, Colorado, September 29, 1976.

Anuta, P.E., "Computer-Assisted Analysis Techniques for Remote Sensing Data Interpretation," GEOPHYSICS, Vol. 42, No. 2, April 1977.

Bailey, R.E. and R.A. Greenkorn, "An Analysis and Planning System for a Professional School", Eleventh Annual International Conference of the Society of College and University Planning, Washington, D.C., July 21-24, 1976.

Bartolucci, L.A., B.F. Robinson and L.F. Silva, "Field Measurements of the Spectral Response of Natural Waters", Photogrammetric Engineering and Remote Sensing Journal, 1977.

Bartolucci, L.A., "Applications of Remote Sensing in Developing Countries", Invited Presentation to Government Authorities, Santa Cruz, Bolivia, January 23, 1977.

Bartolucci, L.A. and R.M. Hoffer, "Temperature Mapping of Water by Remote Sensing", Educational minicourse consisting of slides, tapes and study guide, part of a copyrighted minicourse series entitled Fundamentals of Remote Sensing, 16 pp., 1976.

Bartolucci, L.A., "Remote Sensing and Water Resources", presentation to the Department of Natural Resources, Indianapolis, Indiana, April 4, 1977.

Bartolucci, L.A., "Aplicaciones de la Technologia Aeroespacial en Bolivia", Revista Economica, V.L. 3, No. 9, pp. 28-33, April-May 1977.

Bauer, M.E., and Staff, "Crop Identification and Area Estimation over Large Geographic Areas Using Landsat MSS Data," Final report to National Aeronautics and Space Administration/Goddard Space Flight Center for Contract NAS5-20793, 1977.

Bauer, M.E., M.M. Hixson, B.J. Davis, and J.B. Etheridge, "Crop Identification and Area Estimation by Computer-Aided Analysis of Landsat Data", Proceedings of the Symposium on Machine Processing of Remotely Sensed Data, West Lafayette, Indiana, June 21-23, 1977.

Baumgardner, M.F., "Evaluation of Computer-Aided Analysis of Multispectral Data for Resource Inventories in Developing Countries", United Nations/ Food and Agricultural Organization Short Course/Seminar on Remote Sensing, University of Reading, Reading, England, August 7-10, 1976.

Baumgardner, M.F., "Mapping the Earth from Space", presented to 30th Annual Credit Conference Banquet, Illinois Bankers Association, Champaign, Illinois, September 15, 1976.

Baumgardner, M.F., Report on the Tara Project on the Niger River, West Africa, to the Board of Directors of the Lilly Endowment, Inc., September 20, 1976.

Baumgardner, M.F., invited presentation on "Computers, Satellites and Food -- a Global Perspective":

The Annual Meeting of the North Atlantic Assembly, Williamsburg, Virginia, November 15, 1976.

University of Missouri, Columbia, Missouri, February 24, 1977.

A Symposium on Remote Sensing of Natural Resources, Utah State University, Logan, Utah, April 22, 1977.

Fort Wayne Rotary Luncheon, Fort Wayne, Indiana, April 25, 1977.

Schools of Agriculture and Natural Resources, Ohio State University, Columbus, Ohio, May 23, 1977.

Baumgardner, M.F., "The Use of Satellites for World Crop Inventories and Yield Forecasting", invited presentation to Annual Rotary/Kiwanis Farm-City Night Banquet, Warsaw, Indiana, November 4, 1976.

Baumgardner, M.F., Invited lecture sponsored by the Ministry of Natural Resources, Government of Kenya, Illustrated lecture presented in the Jomo Kenyatta International Conference Center, Nairobi, Kenya, December 9, 1976.

Baumgardner, M.F., Presentation to officials of the International Development Research Centre (IDRC) in East Africa Regional Office, Nairobi, Kenya, December 9, 1976.

Baumgardner, M.F., "Mapping the Earth from Space", invited presentation to Annual Banquet of Coles County Illinois, Soil and Water Conservation District, January 12, 1977.

Baumgardner, M.F., "Inventorying and Monitoring the Global Food Supply from Space", invited presentation to Annual Banquet of LaPorte County, Indiana, Soil and Water Conservation District, January 31, 1977.

Baumgardner, M.F., "Multispectral Properties of Soils", Agronomy Seminar, Agronomy Department, University of Missouri, Columbia, Missouri, February 25, 1977.

Baumgardner, M.F., "Monitoring Arid and Semiarid Land Environments", Natural Resources Seminar, Ohio State University, May 23, 1977.

Baumgardner, M.F., "Multispectral Properties of Soils", Agronomy Seminar, Ohio State University, Columbus, Ohio, May 24, 1977.

Baumgardner, M.F., E.H. Horvath, P.M. Adrien, A. Vasquez, and C.L. Elondo, "Using Satellites and Computers to Inventory the Natural Resources of the Tempisque Valley, Costa Rica", a report to the Inter-American Development Bank and the Government of Costa Rica, 58 pp., 1976.

Blair, B.O. and M.F. Baumgardner, "Detection of the Green and Brown Wave in Hardwood Canopy Covers Using Multidate, Multispectral Data from Landsat-1", Agronomy Journal 69, 1977.

Daughtry, C.T.S., "Factor Affecting the Concentration, Composition, and in vitro Disappearance of Tall Fescue and Orchardgrass Hemicellulose, Ph.D. Thesis, Purdue University, 115 pp., 1976.

Daughtry, C.T.S., D.A. Holt, V.L. Lechtenberg, and D.B. Dikeman, In vitro Disappearance of Tall Fescue and Orchardgrass Hemicellulose, Agronomy Abstracts, 68:105-106, American Society of Agronomy Meeting, Houston, Texas, 1976.

Davis, B.J. and M.M. Hixson, "Statistical Methods for Evaluating Results", LARS Seminar, December 2, 1976.

Davis, B.J., "Evaluation of Results" presented to short course "Advanced Topics in the Analysis of Remote Sensing Data", Continuing Education, Purdue University, West Lafayette, Indiana, April 4-8, 1977.

Hannemann, R.E., D.P. DeWitt, and J.F. Wiechel,"Neonatal Serum Bilirubin from Skin Reflectance", Pediatrics Research, May 10, 1977.

Hixson, M.M., "SPSS: A Painless Approach to Statistics", LARS Seminar, December 9, 1976.

Hoffer, R.M. and S.M. Davis, "Applications of Remote Sensing in Forestry", Educational minicourse consisting of slides, tapes, and study guide, part of a copyrighted minicourse series entitled Fundamentals of Remote Sensing, Office of Continuing Education, Purdue University, 16 pp., 1976.

Hoffer, R.M., "Interpretation of Radar Imagery", Educational minicourse consisting of slides, tapes and study guide, part of a copyrighted minicourse series entitled Fundamentals of Remote Sensing, Office of Continuing Education, Purdue University, 11 pp., 1976.

Hoffer, R.M., "Interpretation of Color Infrared Photography", Educational minicourse consisting of slides, tapes, and study guide, part of a copyrighted minicourse series entitled Fundamentals of Remote Sensing, Office of Continuing Education, Purdue University, 10 pp., 1976.

Hoffer, R.M., "Spectral Reflectance Characteristics of Vegetation", Educational minicourse consisting of slides, tapes, and study guide, part of a copyrighted minicourse series entitled "Fundamentals of Remote Sensing", Office of Continuing Education, Purdue University, 10 pp., 1976.

Hoffer, R.M., "Spectral Reflectance Characteristics of Earth Surface Features", Educational minicourse consisting of slides, tapes, and study guide, part of a copyrighted minicourse series entitled "Fundamentals of Remote Sensing", Office of Continuing Education, Purdue University, 9 pp., 1976.

Hoffer, R.M., "Computer Aided Analysis of Multispectral Scanner Data", Proceedings of the UN/IAF Workshop, Anaheim, California, 11 pp., 1976.

Hoffer, R.M., "Techniques and Applications for Computer - Aided Analysis of Multispectral Scanner Data", Invited paper presented at the XVI World Congress of the International Union of Forest Research Organizationa, Proceedings of the XVI IUFRO World Congress Division VI, Oslo, Norway, pp. 244-254, 1976.

Hoffer, R.M., "Remote Sensing -- It's Status and Potential for Monitoring Forest Resources", invited paper presented at a training seminar of the Weyerhaueser Timber Company, Centralia, Washington, September 24, 1976.

Hoffer, R.M., "Computer-Assisted Analysis for the Inventory of Natural Resources", Invited paper presented at the International Remote Sensing Workshop, sponsored by the United Nations and the International Astronautical Federation, Anaheim, California, October 4, 1976.

Hoffer, R.M., "Biological Considerations in Interpreting Spectral Data", invited paper presented at the NASA Crop Spectral Workshop, Washington, D.C., February 2-4, 1977.

Hoffer, R.M., M.D. Fleming, P.E. Anuta, and D. Adams, "Multiple Resource Evaluation of Region 2, U.S. Forest Service Lands Utilizing Landsat MSS Data", Final report on NASA Contract NAS5-20948, 130 pp., 1976.

Hoffer, R.M., and S.M. Davis, "Mission Planning: Considerations and Requirements", Educational minicourse consisting of slides, tapes, and study guide, part of a copyrighted minicourse series entitled, "Fundamentals of Remote Sensing, Office of Continuing Education, Purdue University, 16 pp., 1976.

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Hooley, R., R.M. Hoffer, and S. Morain, "Estimating Agricultural Output by the Use of Satellite Data", American Journal of Agricultural Economics, 1977.

Kirschner, F., S. Kaminsky, and D. Scholz, "Mapping Unit Composition as Defined by Digital Analysis of Landsat Multispectral Data", Indiana Academy of Science, November 4, 1976.

Kristof, S.J. and M.F. Baumgardner, "Mapping Land and Vegetation Resources in North Jordan by Digital Analysis of Landsat Data", Agronomy Abstracts, p. 162, 1976.

Landgrebe, D.A., "Present Status and Future Trends for Machine Processing of Remotely Sensed Data," invited panel member, IBM Scientific Center, Mexico City, Mexico, May 9, 1977.

Landgrebe, D.A., "Image Processing, Directions and Device Applications", Institute of Electrical and Electronic Engineers Communication Society Workshop, Tucson, Arizona, April 25, 1977.

Landgrebe, D.A., "A Look to the Future of Image Processing of Earth Observational Scenes", presented to Laboratory for Applications of Remote Sensing Advanced Short Course, Purdue University, West Lafayette, Indiana, April 8, 1977.

Landgrebe, D.A., "On the Use of Texture and Spatial Image Characteristics in Earth Observational Image Processing", presented to Laboratory for Applications of Remote Sensing Advanced Short Course, Purdue University, West Lafayette, Indiana, April 6, 1977.

Landgrebe, D.A., "Fundamentals and the Basis for Machine Analysis of Earth Observational Scenes", presented to Laboratory for Applications of Remote Sensing Advanced Short Course, Purdue University, West Lafayette, Indiana, April 4, 1977.

Landgrebe, D.A., "Processing Scenes of the Earth's Surface, A Temporal Perspective", invited presentation to Carnegie Mellon University, Pittsburgh, Pennsylvania, March 10, 1977.

Landgrebe, D.A., "Current Frontiers in Image Processing Technology," invited panelist to Conference on Image Processing Technology, Data Sources and Software for Commercial and Scientific Applications, Pasadena, California, November 3-5, 1976.

Landgrebe, D.A., K.S. Fu and T.S. Huang, "Image Processing and Pattern Recognition with Applications to Remote Sensing", invited short course lecturers, IBM Scientific Center, Mexico City, Mexico, October 4-8, 1976.

Landgrebe, D.A., "Computer Processing Methods in Remote Sensing: The Fundamentals and Potentials", presented to the Remote Sensing Workshop and the XXVII International Astronautical Federation, Anaheim, California, September 27-30, 1976.

Landgrebe, D.A., "Observation of the Earth's Surface from Space: Where do we Stand?", presented to EE694 Seminar, Purdue University, West Lafayette, Indiana, September 16, 1976.

Landgrebe, D.A., "Electrical Engineers and Earth Resources", EE400 Seminar, Purdue University, West Lafayette, Indiana, September 15, 1976.

Lube, B.M. and J.D. Russell, "A Short Course on Remote Sensing", Photogrammetric Engineering and Remote Sensing, Vol. 43, No. 3, p. 299-301, March 1977.

Marshall, A., O.L. Montgomery and M.F. Baumgardner, "Climate Effects on the Relationships Between Spectral Reflectance and the Chemical, Physical and Genetic Characteristics of Soils", Agronomy Abstracts, p. 164, 1976.

Mroczynski, R., "The Application of Spatially Processed Landsat Data to Forestry", presented to the American Society of Photogrammetry, Annual Convention, Washington, D.C., 1977.

Mroczynski, R. and F.E. Goodrick, "Association of Spatially Processed Landsat Data to Forestry", Proceedings of the American Society of Photogrammetry Symposium, Annual meeting of the American Society of Photogrammetry, Washington, D.C., p. 90, 1977.

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Russell, J.D., "Systematically Disseminating Technological Information to Potential Users", NSPI Journal, Vol. XV, No. 8, p.507, October 1976.

Russell, J.D. and J.C. Lindenlaub, "Disseminating Technological Information on Remote Sensing to Potential Users", presented at the Eleventh International Symposium on Remote Sensing of Environment, Ann Arbor, Michigan, April 25-29, 1977.

Scholz, D.K., "LARS and Remote Sensing", presented to Indiana Geologists Association, February 23, 1977.

Silva, L.F., D.P. DeWitt, J.A. Pearce, F.J. Bohac, and L.A. Geddes, "Temperature Distributions Under Electrosurgical Dispersive Electrodes", American Association of Medical Instruction Twelfth Annual Meeting, San Francisco, California, March 13-17, 1977.

Swain, P.H., "Toward Effective Use of Spatial Information in Multispectral Remote Sensing", presented at the U.S./Japan Seminar on Image Processing in Remote Sensing, College Park, Maryland, November 1976.

Swain, P.H., "Advanced Topics in the Analysis of Remote Sensing Data", presented to Laboratory for Applications of Remote Sensing Advanced Short Course, Purdue University, West Lafayette, Indiana, April 4-8, 1977.

Swain, P.H., "Approaches to the Use of Multi-Image Data with Applications to Remote Sensing", Computer Science Department Colloquium, Institute for Informatik, University of Hamburg, Hamburg, West Germany, May 16, 1977.

Swain, P.H. "Approaches to the Use of Spatial and Temporal Information in Multi-Image Remote Sensing Data Analysis", Technische Universitat, Hannover, West Germany, May 18, 1977.

Swain, P.H., "The State of the Art in Remote Sensing", Scientific Center, Autonomous University of Madrid/IBM-Spain, May 26, 1977.

Swain, P.H., "Advancements in Machine-Assisted Analysis of Multispectral Data for Land Use Applications", Proceedings of the Fourth Symposium on Machine Processing of Remotely Sensed Data, Purdue University, West Lafayette, Indiana, June 1977.

Swain, P.H. and H. Hauska, "The Decision Tree Classifier: Design and Potential", IEEE Transactions, Geoscience Electronics, 1977.

Swain, P.H. and D.A. Landgrebe, "Some Time for Texture in the Spectrum of Spatial Features", presented at the Engineering Foundation Conference on Algorithms for Image Processing, Franklin Pierce College, New Hampshire, August 1976.

Weismiller, R.A., I.D. Persinger, and O.L. Montgomery, "Soil Inventory Prepared from Digital Analysis of Satellite Multispectral Scanner Data and Digitized Topographic Data", Soil Science Society of America Journal, 1977.

Weismiller, R.A., S.J. Kristof, D.K. Scholz, P.E. Anuta, and S. Momin, "Evaluation of Change Detection Techniques for Monitoring Coastal Zone Environments", April 27, 1977.

Winn, R.A. and D.P. DeWitt, "Evaluation of a Fourier Transform Infrared Spectrophotometer for Measurement of Diffuse Reflectance", ASME Seventh Symposium on Thermophysical Properties, Washington, D.C., May 10-12, 1977.

APPENDIX III

Awards and Activities of LARS Staff in FY77

LARS as a unit.

The William T. Pecora Award. Presented to LARS in recognition of the individual and collective continuing contributions by past and present members to the understanding of terrestrial phenomena through remote sensing techniques.

Anuta, P.E.

Member, Administrative Committee of the Geoscience Electronics Professional Group of the Institute of Electrical and Electronic Engineers (IEEE).

Member, Working Group III-2 on Image Processing of Commission III of IEEE.

Baumgardner, M.L.

Member, Committee on Desertification, American Association for the Advancement of Science, 1976-78.

Vice-chairman, International Working Group of Remote Sensing in Ecological Botany, International Union of Biological Sciences, 1975-79.

Member, International Working Group on Remote Sensing, Commission on Soil Classification and Survey, International Soil Science Society, 1974-78.

Member, National Remote Sensing Committee, Agricultural Research Institute, 1973-77.

Member, Space Hydrology Committee, American Geophysical Union, 1976-78.

DeWitt, D.P.

Chairman, Radiation Properties Session, ASME Seventh Symposium on Thermophysical Properties, Washington, D.C., May 1977.

Hoffer, R.M.

Recipient, Meritorious Service Award, American Society of Photogrammetry.

Member, Board of Directors, American Society of Photogrammetry.

Member, National Planning Committee, American Society of Forestry.

Member, NASA Crop Spectra Workshop Panel.

Kirschner, F.R.

Consultant, USAID in Syria to advise on use of remote sensing as an aid in soil survey for the country.

Landgrebe, D.A.

Elected Fellow, IEEE.

Chairman of NASA Crop Spectra Workshop Panel.

Member, Executive Committee, Board of Trustees, University Space Research Association.

Lindenlaub, J.C.

President, IEEE Education Group.

Member, Technical Activities Board, IEEE.

Member, Educational Activities Board, IEEE.

Peterson, J.B.

Consultant, United States/Saudi Arabian Joint Commission on Economic Cooperation (JECOR) to advise on use of remote sensing as an aid to making soils and land use maps of the Kingdom.

Recipient, Honorary membership, American Society of Agronomy.

Weismiller, R.A.

Member, Land Use Planning Committee, Soil Conservation Society of America.

APPENDIX IV

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

1976-1977

Instrumentation to Measure Reflectance over Short Distance

Integration of Ancillary Data with MSS Reflectance Through Digital Registration

Measurement of Large Crop Areas

Use of Landsat Data to Facilitate Soil Surveying

Developed a method using Landsat data for determining wheat acreages over large geographic areas with accuracies similar to those of the Statistical Reporting Service, USDA, ground survey.
Developed techniques which for the first time use remote sensing data to facilitate soil mapping at scales useful in farm and field management decisions. The new techniques make possible more rapid mapping and better quality maps.
Broadened the capability to register both map and tabular data of many kinds to support the analysis of remote sensor data. LARS scientists in cooperation with the Missouri Soil Conservation Service, USDA capitalized on this research by using both Landsat data and ancillary data to develop a method of delineating soils which is much more effective than any method of soil mapping hitherto developed.
Successfully completed design and development of improvements in instrumentation which greatly aid the correlation of reflectances measured at short distances with those measured at greater distances, including: 1. Small, low cost, versatile field spectroradiometer of wide-wave length range, useful in many research applications; 2. Improved multiband radiometer which permits measurement of the transmission and reflectances of plant leaves; 3. Special reflectometer for measuring bi-directional reflectance.
Successfully applied remote sensing techniques to biomedical research. LARS staff members in cooperation with the Biomedical Engineering Center are making promising advances in the use of remote sensing techniques as a non-invasive diagnostic tool for human health.

APPENDIX V

Staff, Fiscal, and Facility Summary

Staff Summary

During FY77 there were 210 people (92.5 FTE) from 22 departments in 5 schools assigned to LARS projects. The following table shows a further break down of this information:

	# of Employees	FTE
Faculty	32	9.74
Professional	36	31.08
Clerical	30	14.42
Service	5	3.21
Graduate Students	42	15.89
Undergraduate Students	65	18.20
	210	92.54

A. Professorial Staff

1. Agriculture

a. M. F. Baumgardner - Professor of Agronomy and LARS Program Leader
b. B. O. Blair - Professor of Agronomy
c. R. M. Hoffer - Professor of Forestry and LARS Program Leader
d. F. R. Kirschner - Soil Scientist (USDA/SCS)
e. M. A. Martin - Assistant Professor of Agricultural Economics
f. R. M. Peart - Associate Professor of Agricultural Engineering
g. J. B. Peterson - Professor of Agronomy (post retirement appointment) and Associate Director of LARS
h. A. Spacie - Assistant Professor of Forestry

2. Consumer and Family Sciences

a. P. F. Hull - Instructor in Housing, Equipment, and Environmental Design
b. M. V. Peart - Associate Professor of Housing, Equipment, and Environmental Design

3. Engineering

a. R. E. Bailey - Professor of Nuclear Engineering
b. R. G. Barley - Associate Professor of Chemical Engineering
c. D. P. DeWitt - Associate Professor of Mechanical Engineering
d. M. J. Gray - Assistant Professor of Civil Engineering
e. R. E. Hannemann - Visiting Professor of Chemical Engineering
f. R. B. Jacko - Associate Professor of Environmental Engineering
g. D. A. Landgrebe - Professor of Electrical Engineering and Director of LARS
h. J. C. Lindenlaub - Professor of Electrical Engineering and LARS Program Leader
i. C. D. McGillem - Professor of Electrical Engineering
j. R. D. Miles - Professor of Civil Engineering
k. R. A. Rao - Associate Professor of Civil Engineering
l. S. R. Rao - Post Doctoral Research Associate
m. A. Ravindran - Associate Professor of Industrial Engineering
n. L. F. Silva - Professor of Electrical Engineering and LARS Program Leader
o. P. H. Swain - Assistant Professor of Electrical Engineering and LARS Program Leader
p. V. C. Vanderbilt - Post Doctoral Research Associate

4. Humanities, Social Science and Education

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

5. Science

a. V. L. Anderson - Professor of Statistics
b. L. A. Bartolucci - Project Director/Research Associate in Geoscience
c. D. W. Levandowski - Professor of Geoscience
d. T. R. West - Associate Professor of Geoscience
e. S. B. Vardeman - Assistant Professor of Statistics

B. Professional Staff

1. Agriculture

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

2. Engineering

a. P. E. Anuta - Research Engineer and LARS Associate Program Leader
b. L. L. Biehl - Project Manager/Engineer
c. J. D. Bourland - Coordinator for Engineering
d. R. K. Boyd - Data Analyst and Training Specialist
e. M. D. Collins - Computer Operations Shift Supervisor
f. B. J. Davis - Statistician/Analyst
g. S. M. Davis - Education and Training Specialist
h. J. B. Etheridge - Applications Programmer
i. S. L. Ferringer - Visual Designer
j. D. M. Freeman - Manager of Data Reformatting
k. K. M. Freeman - Data Librarian/Photographer
l. N. C. Fuhs - Applications Programmer
m. H. L. Grams - Manager of Computer Operations
n. W. C. Hockema - Computer Operations Supervisor
o. M. C. Hodge - Administrative Assistant
p. J. L. Kast - Program Developer
q. D. E. Parks - Publications Coordinator
r. K. J. Philipp - Reformatting Operations Assistant
s. T. L. Phillips - Deputy Director of LARS
t. B. J. Pratt - Administrative Assistant
u. P. R. Roberts - Administrative Assistant
v. B. F. Robinson - Research Engineer and LARS Associate Program Leader
w. C. R. Sand - Computational Facility Manager
x. S. K. Schwingendorf - Applications Manager
y. W. M. Shelley - Reformatting Operations Assistant
z. W. M. Simmons - Manager of Applications Programming
aa. P. W. Spencer - Applications Programmer

3. Humanities, Social Science and Education

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

4. Science

a. M. M. Hixson - Research Statistician

C. Staff Involvement at LARS in Number of Staff

July 1, 1976 - June 30, 1977

Department	Faculty (Page 54)	Professional (Page 56)	Graduate Students (Page 9)	Undergraduate Students	Service	Clerical
Agriculture						
Agricultural Economics	1					
Agricultural Engineering	1					
Agronomy	4	5	6			
Forestry	2	2	3			
Consumer and Family Sciences						
Housing, Equip., and Env. Design	2		1			
Engineering						
Chemical	2					
Civil	4		2			
Electrical	6	3	14			
Experiment Station		23	2	65	5	28
Industrial	2		2			
Interdisciplinary		1				
Mechanical	1		4			1
Nuclear	1		2			1
HSSE						
Education	1		1			
Communications		1				
Science						
Computer Science			2			
Geoscience	3		2			
Statistics	2	1	1	—	—	—
TOTAL	32	36	42	65	5	30

*Includes only those graduate students on the payroll. The total including all graduate students is 52.
(See Pages 2 and 12)

Fiscal Summary

A. Funds Available:

General Funds	$ 124,412	
Research Funds	2,152,504	
70 Fund	1,082,268	
Total Funds Available		$3,359,184

Expenditures:

General Funds	$ 124,412	
Research Funds	2,152,504	
70 Fund	983,192	
Total Expenditures		$3,260,108
Carry Forward		$ 99,076

B. Capital Equipment

(In Excess of $1,000)

ITEM	ORIGINAL COST	YEAR ACQUISITION
A/D Equipment	$ 185,336	1967-71
Camper/pickup	4,897	1967
Digital Display	487,640	1969
Hi-ranger	17,500	1971
Line Scanner	8,605	1972
Disk Drive 2314	105,990	1971
Recorded Port Mol SP300 mfg Ampex	8,450	1966
Monochromator Mol 98 mfg Perkin-Elmer	4,100	1967
Thermometer Mol prt-5 mfg. Barnes Engr.	6,959	1968
Camera w/lens 103 Hulchers	3,167	1971
Camera w/lens 103 Hulchers	3,167	1971
Spectroradiometer and Accessories	131,127	1972
Modems	8,920	1971
Tape Recorded/Reproducer	36,827	1972
Fast Scan Thermal Camera and Accessories	30,000	1974
Field Radiometers and Accessories	15,000	1975
Zoom Transfer Scope	4,750	1975
Generator	4,774	1976
029 Keypunch Interface	2,500	1976
Lamboda Intr. Portable Area Meter	3,300	1976
GT CRT Terminal	1,275	1976
GTX CRT Terminal	990	1976
Video Cassette Recorder	1,434	1976

Frequency Charger	1,665	1976
Shelving Unit	2,052	1976
Instrumentation Tape Recorder	7,850	1977
Strip Chart Recorder	1,613	1977
Data Terminals	2,875	1977
TOTAL	$1,092,763	

Facility Summary

Capital equipment accumulation in excess of $1,092,763

The LARS space is rented from Purdue Research Foundation by Purdue University

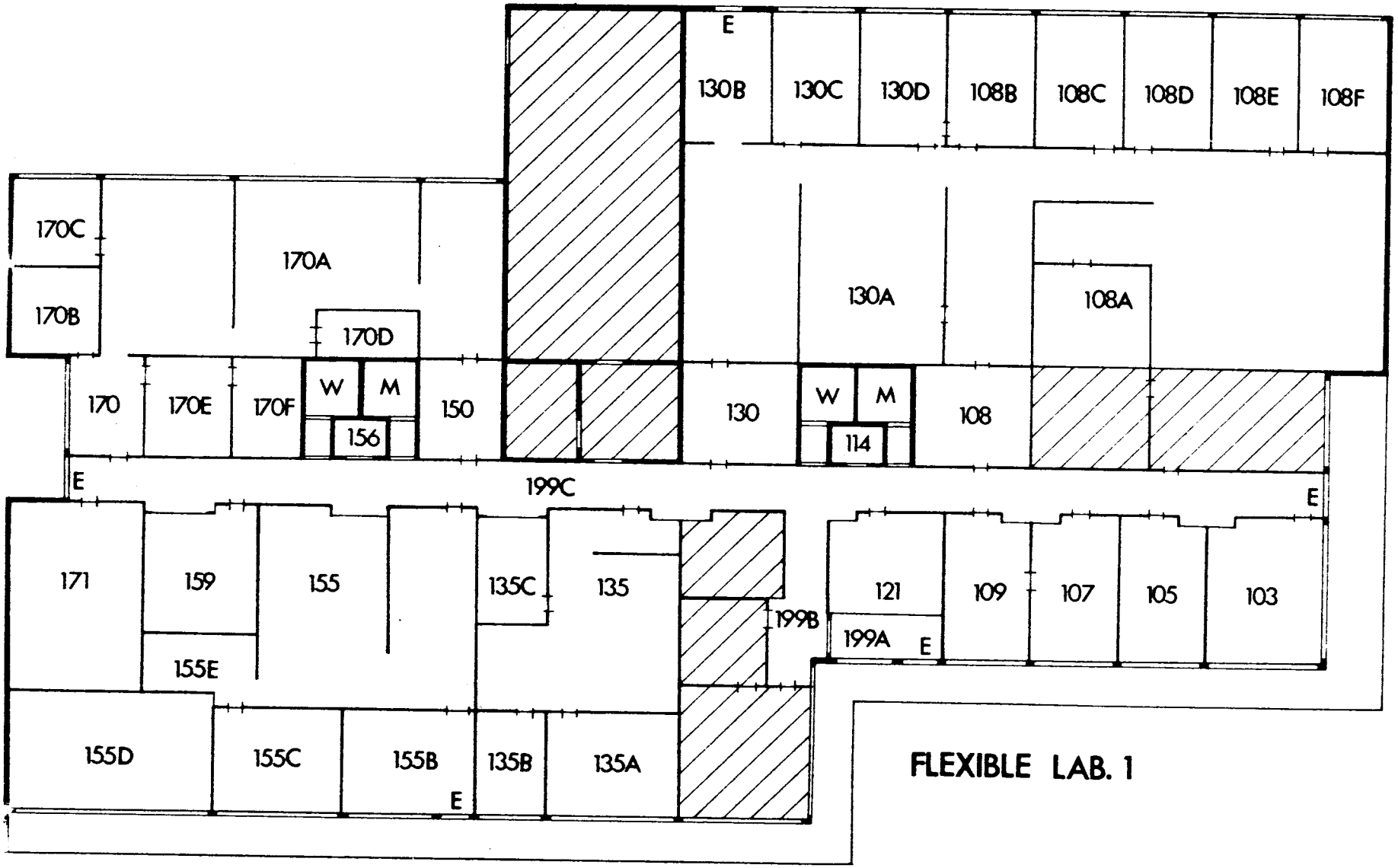
Sources of rental funds are from Physical Plant's Reserve for Rental

Utilities are paid by Physical Plant

Janitorial services are provided by Physical Plant for the Flex Lab II space, and PRF provides janitorial service in its rental figure for Flex Lab I

Funds for telephone rental are provided to LARS via general fund allocations

	SPACE	
Space	Sq. Ft.	Total Rent in FY77
Flex Lab I	10,754	$44,280.00
Flex Lab II		
Unit B	3,885	16,123.00
Units C and F	6,994	29,376.00
Unit D	3,170	2,219.00 (2 months)
		$91,998.00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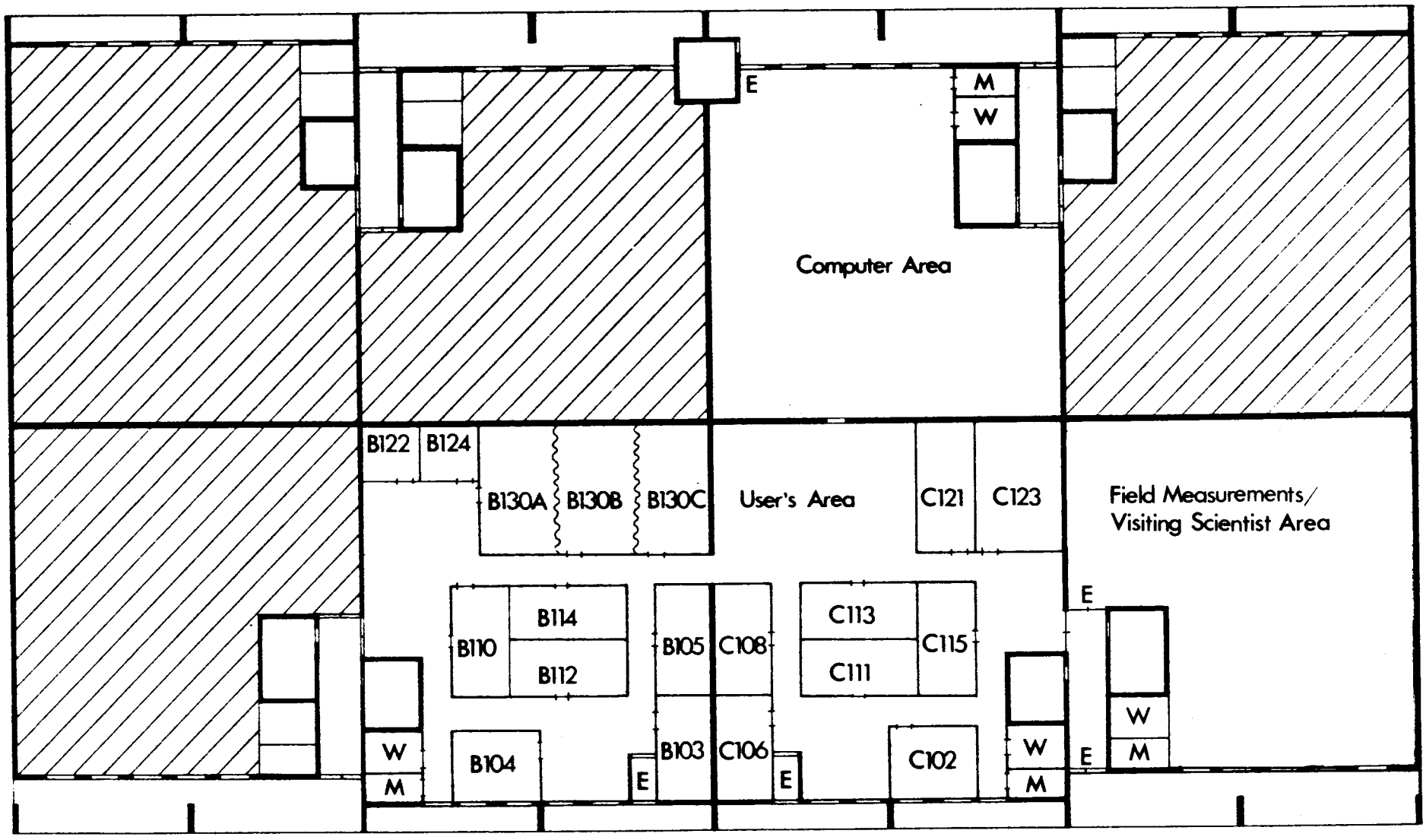
FLEXIBLE LAB. 1



FLEXIBLE LAB. 2