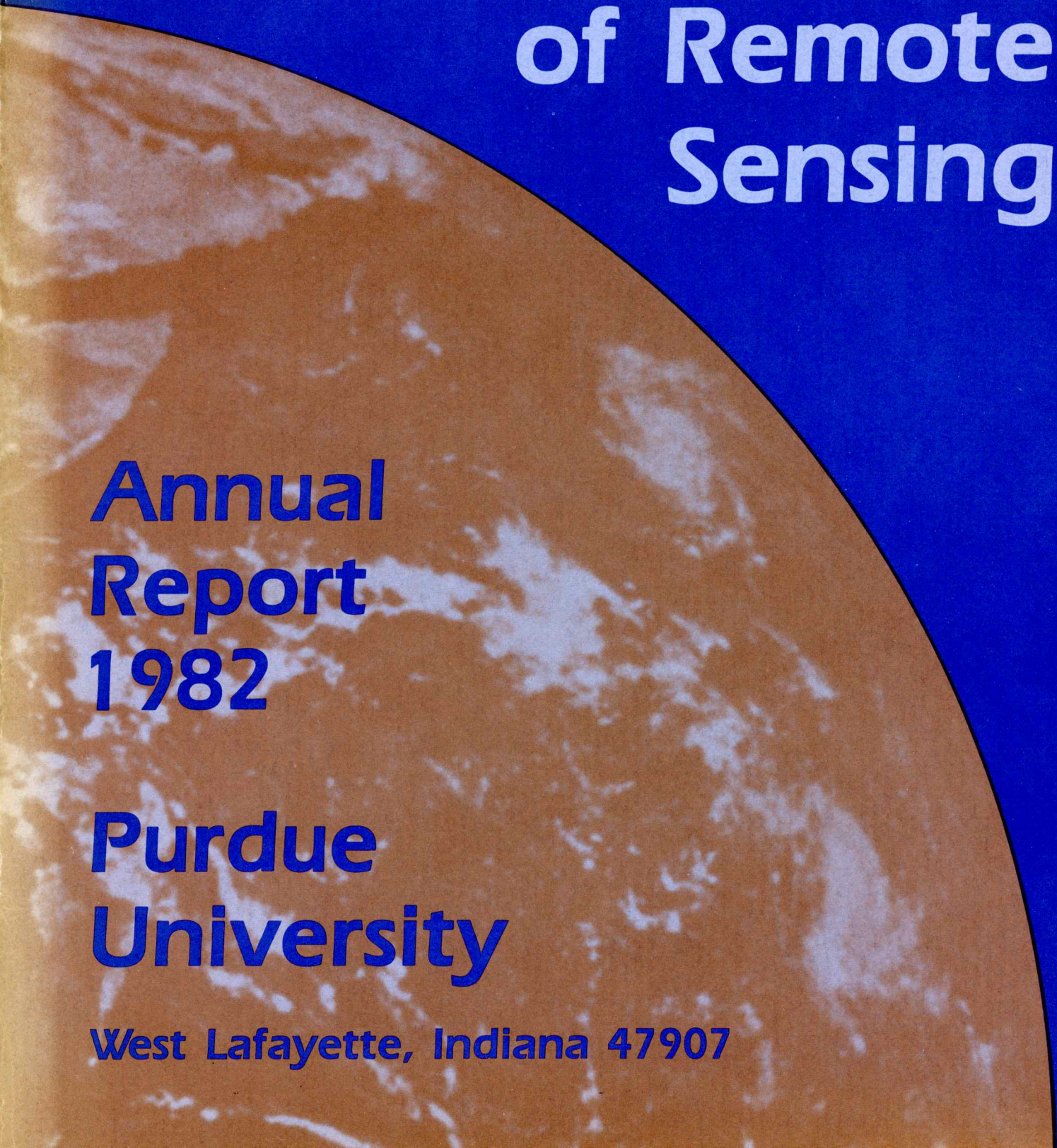
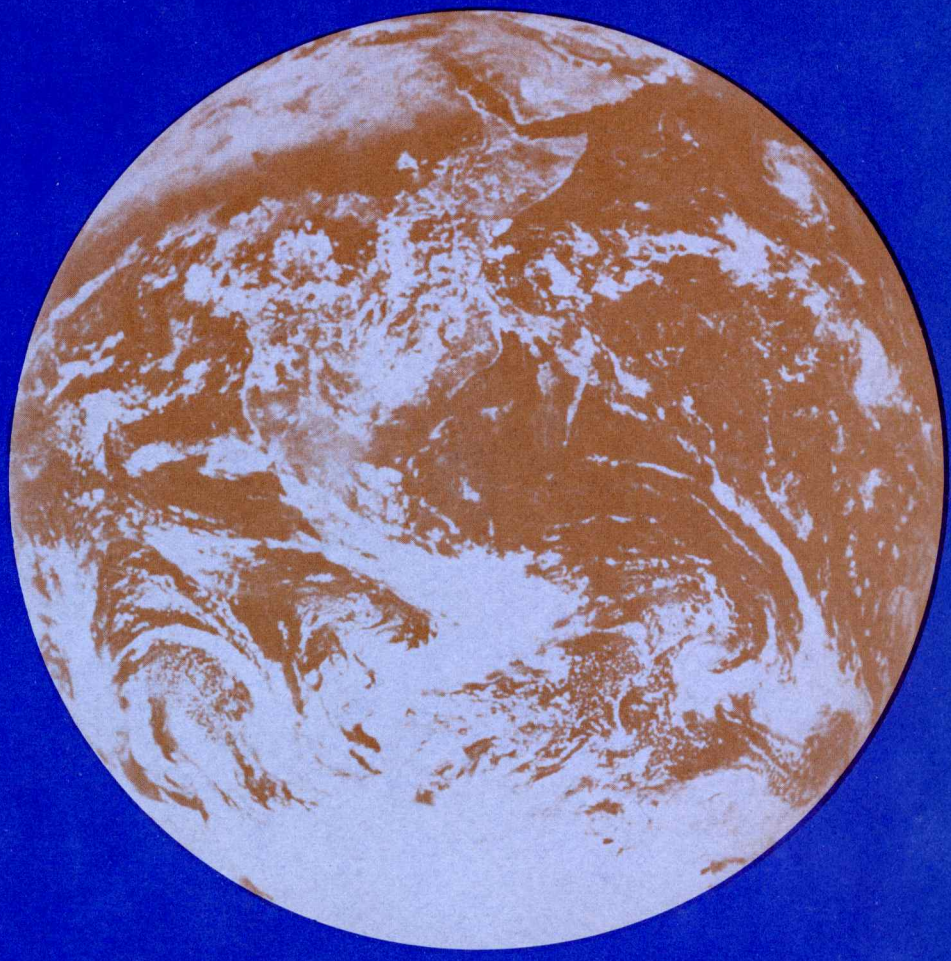
# Laboratory for Applications of Remote Sensing



## Annual Report 1982

## Purdue University

West Lafayette, Indiana 47907



**We are the first generation in human history to see the earth as a whole.**

**Robert Frosch**
Former Administrator
National Aeronautics
and Space Administrator

123182

PURDUE UNIVERSITY
LABORATORY FOR APPLICATIONS OF REMOTE SENSING

March 1983

This year has been one of transition as the Laboratory for Applications of Remote Sensing, along with many other institutions throughout the country, has responded to a reduction in federal contract funds to support its research and development activities. This reduction in support has resulted in a thorough review of all LARS activities and services. Adjustments have been and continue to be made in order to balance expenditures with income.

Several criteria have been used as guidelines for making the necessary adjustments at LARS. First, we have made every attempt to retain the capability to fulfill current contractual agreements. Second, an effort has been made to maintain an environment which can attract new funding. Finally, we have reaffirmed our conviction that the breadth and complexity of remote sensing technology and its applications require the services of numerous disciplines. Purdue University can best participate in the advancement of this technology by maintaining an interdisciplinary thrust.

Remote sensing technology is here to stay, and the technology will find increasing use in many different applications.

During the past year an overriding concern in LARS management has been the integration of the laboratory's research and teaching into the mainstream of the University. I will continue to strive for this integration.

Marion F. Baumgardner

Marion F. Baumgardner
Director

MFB:gcb

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

West Lafayette, Indiana 47907
(317) 494-6305

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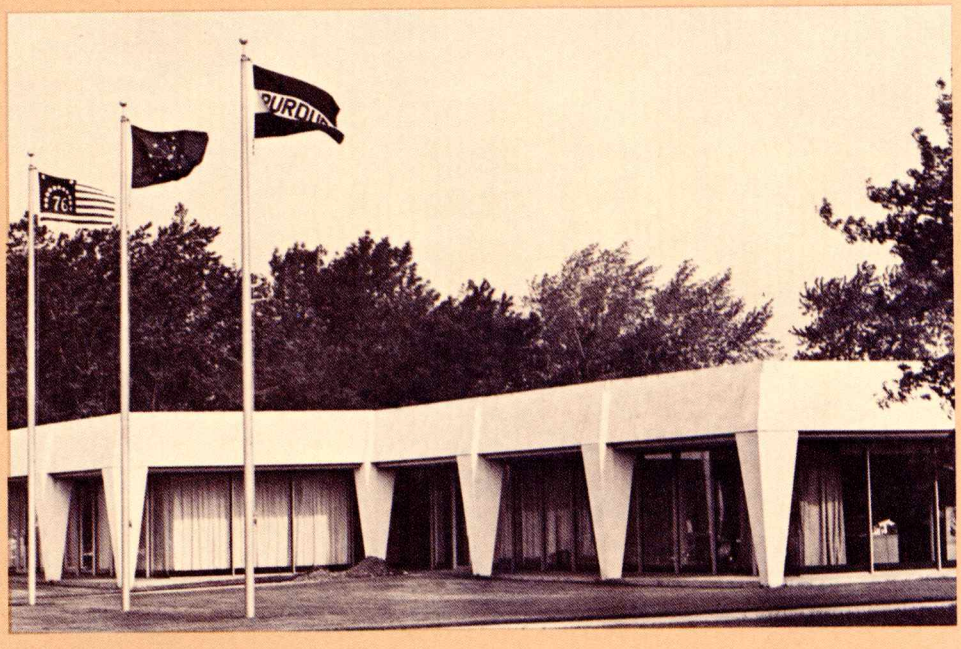


Right: **Flexible Laboratories 1 and 2, where LARS facilities are located.**

# Philosophy



The past two decades have witnessed many remarkable advances in our ability to observe the surface of the earth. Three areas of technology have contributed to what is now commonly referred to as **remote sensing:**

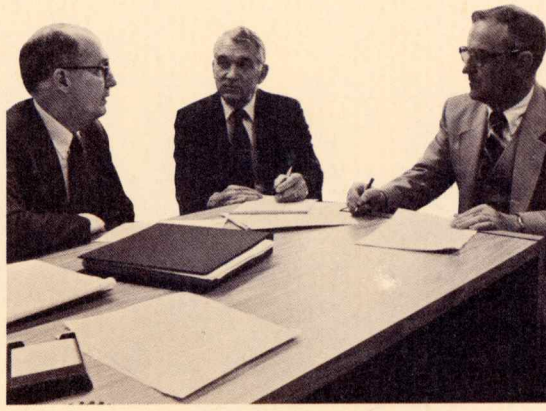
Data acquisition: A broad array of sensors, including advanced camera systems, spectroradiometers, multispectral scanners, and microwave sensors, are being used for collecting data in the laboratory and the field and from air- and spacecraft.

Data processing and analysis: Rapid development of computer hardware and software has provided the means to store, receive, analyze, and interpret the massive volume of data which is now being acquired by advanced sensor systems.

Data/information dissemination: Today's communications technology provides the capability to transmit instantaneously data from anywhere on earth to any other location on earth.

This technology places at our disposal a remarkable set of tools to inventory earth resources and to monitor changes which are occurring in the earth-surface environment.

During its 16-year history, LARS has made significant contributions in the development and application of this technology. LARS scientists and engineers are recognized nationally and internationally for their excellence in research and technology transfer activities.



Above. **The Management Committee, D. A. Landgrebe, director of the Engineering Experiment Station, M. F. Baumgardner, director of LARS, and B. R. Baumgardt, director of the Agricultural Experiment Station, provide administrative direction for the laboratory.** Below. **Program leaders discuss research and administrative matters during a weekly meeting.**

## Marion F. Baumgardner

**Professor of Agronomy; Director, Laboratory for Applications of Remote Sensing**

B.S., Texas Tech, Agriculture; M.S., Ph.D., Purdue, Agronomy; Honorary D.Sc., DePauw

Dr. Baumgardner's research interests lie in surveying and monitoring land resources, in particular soil productivity, land erosion and salinization, and spectral properties of soils. His interest in international agricultural development has led him to study the global food/population equation and to seek techniques for improving the acquisition, analysis, and utilization of agricultural resource information. He has been recognized by numerous national and international organizations and is a fellow of the American Society of Agronomy, the Indiana Academy of Sciences, and the Soil Science Society of America. He is a member of the Advisory Editorial Board, International Journal of Remote Sensing, chair of the Program Committee, 1983 Annual Meeting of SCSA, of the Soils Panel, American Association for the Advancement of Science, and of the World Food Supply Subdivision, Soil Conservation Society of America.

**Recent Publications**

Stoner, E. R. and M. F. Baumgardner. 1981. Characteristic variations in reflectance of surface soils. Soil Sci. Soc. Amer. J. 45:1161–1165.

Baumgardner, M. F. and E. R. Stoner. 1982. Soil mineralogical studies by remote sensing. Transactions 12th International Congress of Soil Science, New Delhi, India.

Baumgardner, M. F. 1983. Global perspectives on land use, Monograph on Land Use. F. Miller, ed., American Society of Agronomy, Falls Church, Virginia. (in press)

# Administration



**Departmetal Affiliation of LARS Staff**

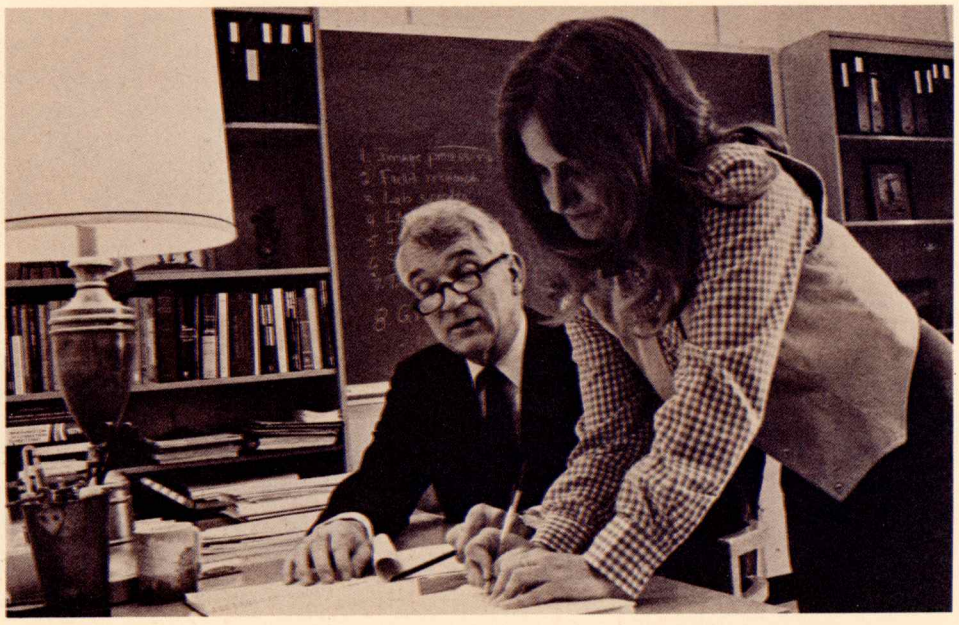
| School/ Department | Faculty | Professional | Graduate Students | Under-Graduates | Service | Clerical |
|---|---|---|---|---|---|---|
| Agriculture | | | | | | |
| Agronomy | 6 | 4 | 7 | | | |
| Forestry | 3 | 1 | 2 | | | |
| Engineering | | | | | | |
| Civil | 2 | | | | | |
| Electrical | 8 | 4 | 15 | | | |
| Experiment Station | | 28 | | 50 | 8 | 16 |
| Mechanical | 2 | | 1 | | | |
| Construction | 1 | | | | | |
| H.S.S.E. | | | | | | |
| Communications | | 1 | | | | |
| Political Science | 1 | | | | | |
| Science | | | | | | |
| Computer Science | | | 3 | | | |
| Geoscience | 2 | 1 | 2 | | | |
| Statistics | 2 | 2 | 3 | | | |
| Total Employees | 27 | 41 | 33 | 50 | 8 | 16 |
| Full-Time Equivalent | 4.9 | 30.6 | 10.7 | 12.4 | 4.7 | 11.3 |

The Laboratory for Applications of Remote Sensing (LARS) is a research laboratory within Purdue University, focusing the University's resources on development of improved techniques for analyzing and using earth resources data. An interdisciplinary staff from various departments within the schools of Agriculture, Engineering, and Science composes the LARS team.

The director of LARS is responsible to a Management Committee consisting of the directors of the Agricultural Experiment Station and the Engineering Experiment Station. Along with the deputy director and business administrator, the director coordinates the logistics of project implementation, financial management, and facility availability.

Below. **Terry Phillips and Gloria Peterson forecast laboratory income and expenses.**

Below. **Marion Baumgardner develops the agenda for a meeting with the assistance of Glenda Bauer.**



## Terry L. Phillips

### Deputy Director, Laboratory for Applications of Remote Sensing

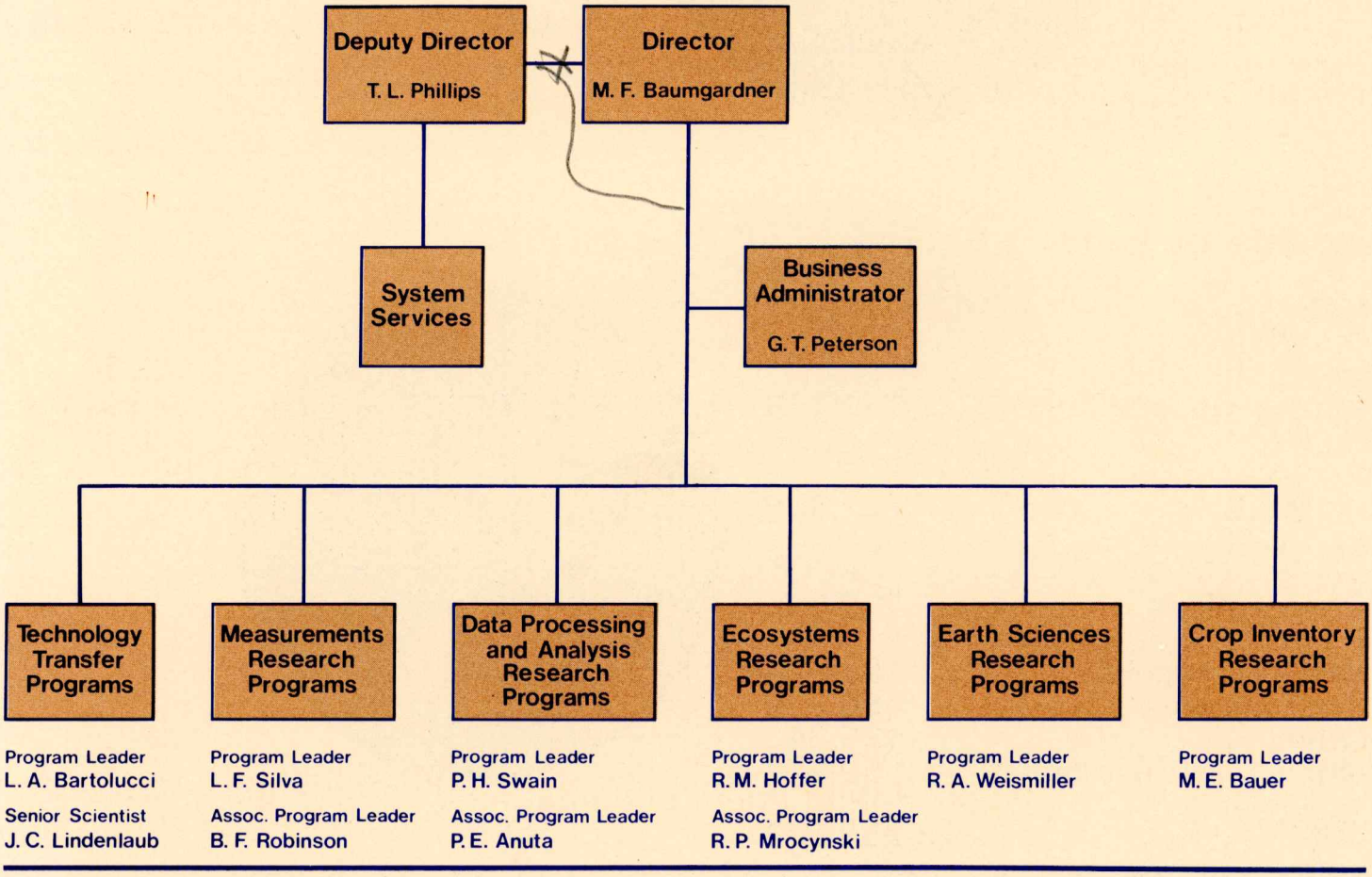
B.S., M.S., Purdue, Electrical Engineering

Mr. Phillips is engaged in the development of data handling and processing systems and has been active in the application of these systems for remote sensing since 1966. He has been principal investigator of several of the laboratory's contracts and has contributed to many others, primarily in the area of system design and geographic information systems. He is senior member of the Institute of Electrical and Electronics Engineers, an international director of the Data Processing Management Association, past president of the Sagamore Chapter of DPMA, and a member of the Association of Computing Machinery, Tau Beta Pi and Eta Kappa Nu. In 1976 Mr. Phillips was recognized by NASA for creative development of technology by virture of his role in the development of LARSYS.

The research and educational mission of LARS is interdisciplinary by design. Academic and professional personnel are members of individual University departments or the Engineering Experiment Station. The extent to which interdisciplinary research is successful is largely dependent on effective communication among the disciplines. This communication is encouraged by weekly meetings of directors and leaders of LARS program areas.

A key to the interdisciplinary research efforts is the laboratory's organizational structure. The six major programs conduct projects within their own areas while coordinating with the supporting staff in other areas. This design provides for flexibility in program development and the formation of compatible interdisciplinary teams to address specific research problems.

Below. **Organization of Laboratory for Applications of Remote Sensing.**




## Gloria T. Peterson

**Academic Business Administrator**

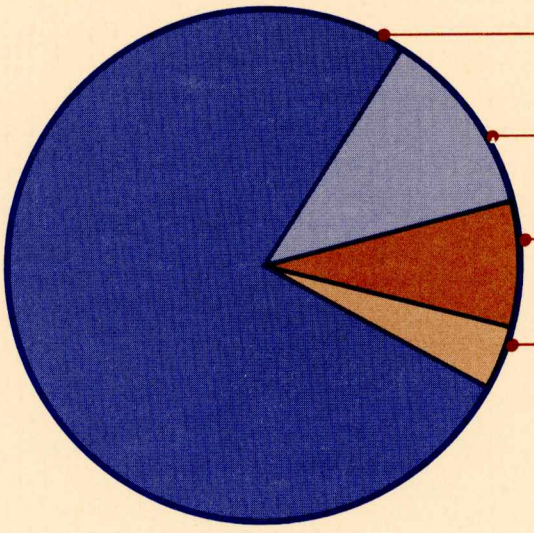
A.A., Allen Hancock Junior College, General Education; B.A., Sonoma State, Economics; M.S., Purdue, Family Economics/Consumer Education

Ms. Peterson's contributions to LARS are in the management of state funds, sponsored research contracts and finances associated with the research-oriented computer facility. She serves on Purdue's Sponsored Programs Committee, which deals with business aspects of contracts and grants.

# Financial Summary

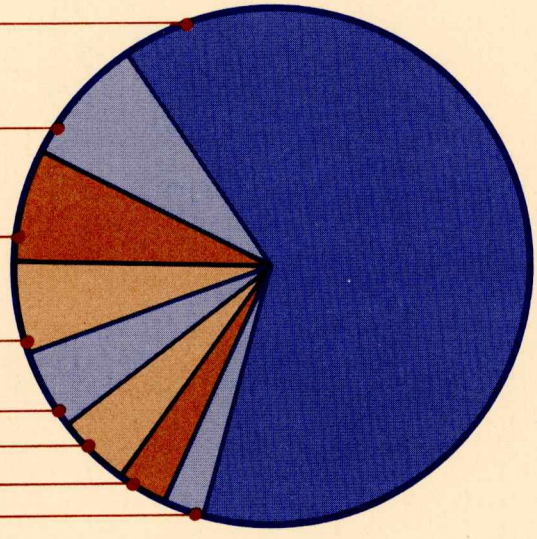


## Income by Type of Project



| | |
|---|---|
| Sponsored Research | $2,472,762 |
| Technology Transfer | 414,230 |
| Purdue General Funds | 250,168 |
| Other | 122,342 |
| Total | $3,259,502 |

## Income by Funding Source



| | |
|---|---|
| NASA | $2,091,837 |
| Purdue General Funds | 250,168 |
| Universities | 222,886 |
| Corporations | 188,991 |
| State of Indiana | 167,020 |
| International | 156,286 |
| Other | 122,342 |
| Other U.S. Government | 59,972 |
| Total | $3,259,502 |

During fiscal year 1982, the Laboratory for Applications of Remote Sensing received funds from the following organizations for research, education, and technical assistance:

Alabama A & M University

American Optical Corporation

Ball State University

Bureau of Land Management

COMTAL/3M Corporation

Control Data Corporation

Department of the Interior/Office of Water Resources and Technology

Ducks Unlimited

Elsevier North Holland

IBM

Indiana Department of Natural Resources

Indiana State University

Iraq

Joint U.S./Saudi Arabian Commission of Economic Cooperation

Kansas State University

National Aeronautics and Space Administration

National Science Foundation

Programa ERTS/Bolivia

Purdue University

Realist Corporation

U.S. Army Engineer Division

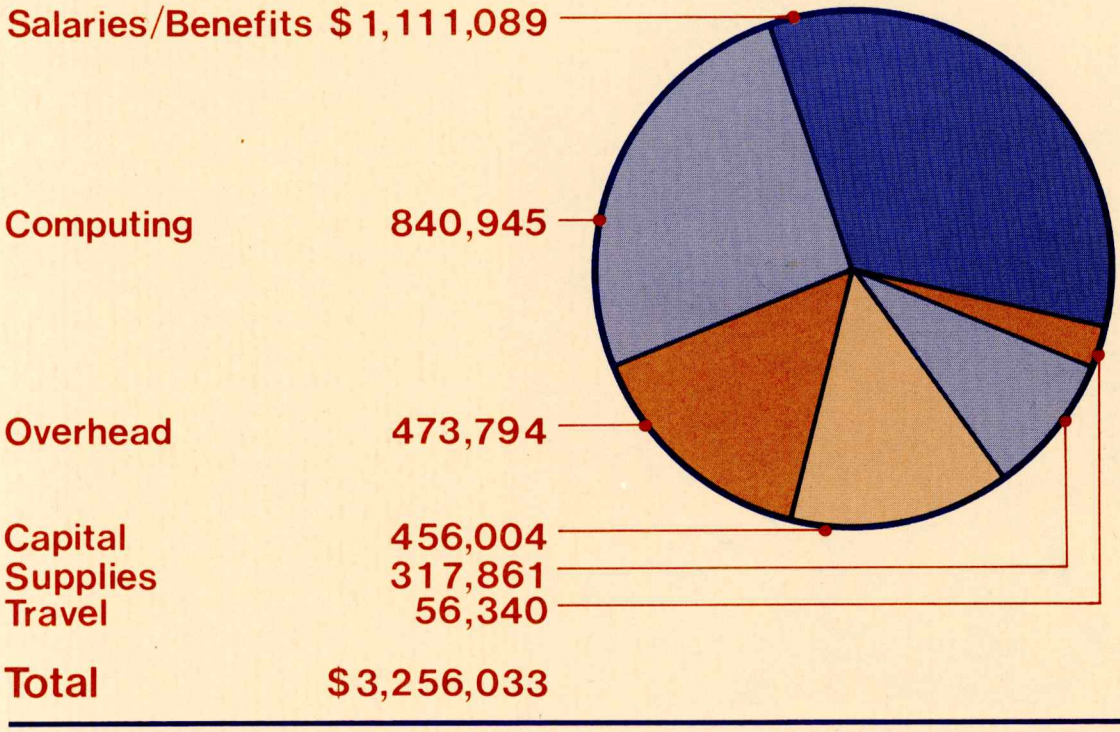
U.S. Department of Defense/Defense Mapping Agency

University of Arizona

University of California at Riverside

and numerous organizations that sponsored visiting scientists during their study and research at LARS.

## Expenditures



# Educational Programs

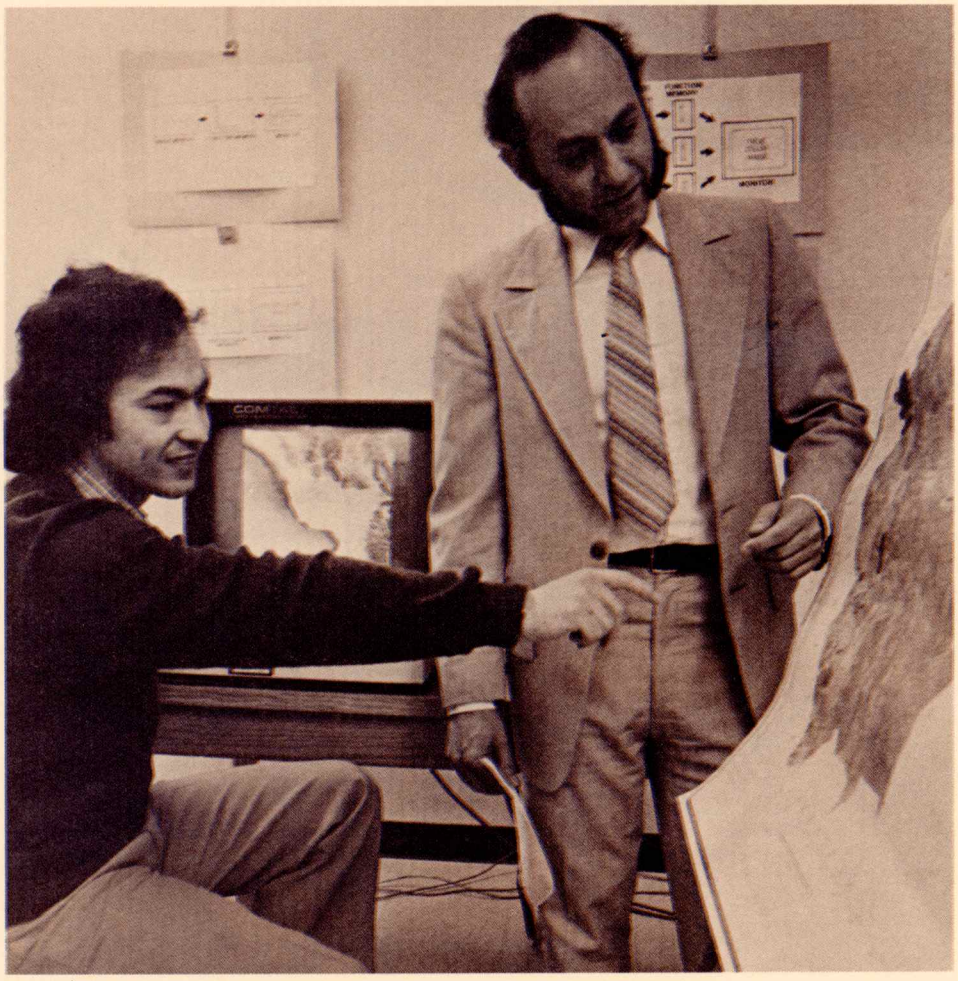


As part of an on-going effort to transfer an understanding of remote sensing technology, a variety of educational programs were offered this year.

## Short Courses

The short course Remote Sensing Technology and Applications was presented quarterly, with an additional symposium-related course that focused on crop inventory and monitoring.

Two customized short courses were also given, one at Purdue for the U. S. Army Corps of Engineers and one for the Defense Mapping Agency in Panama. A total of 74 people were trained during the year.



## International Symposium

The Eighth International Symposium on Machine Processing of Remotely Sensed Data, held in July 1982, attracted 197 participants, including 26 internationals from 15 countries. With a special emphasis on crop inventory and monitoring, the symposium was held in cooperation with:

- American Society of Photogrammetry
- Institute of Electrical and Electronics Engineers
- National Aeronautics and Space Administration
- National Oceanic and Atmospheric Administration
- U. S. Department of Agriculture

## GIS Workshop

A Geographic Information Analysis Workshop was held at LARS in cooperation with Yale University's School of Forestry and Environmental Studies. The two-day course, which attracted 22 participants, gave students theoretical background and hands-on experience with software for manipulating georeferenced data.

Left. **Carlos Valenzuela and Luis Bartolucci compare a digital Landsat image of Bolivia with a geologic map of the area.**

### Luis A. Bartolucci

**Technical Director of Training; Program Leader for Technology Transfer**

B.S., M.S., Ph.D., Purdue, Geophysics

Involved in remote sensing research since 1969, Dr. Bartolucci has been active in the development of remote sensing technology for applications in the area of water resources and in the use of thermal infrared radiation for remote sensing applications. He has been principal investigator and project director of several domestic and international research and training programs involving computer-aided processing and analysis of remotely sensed data for earth resources inventories. His current research interests lie in the improvement of data analysis techniques, especially with regard to Thematic Mapper data, and the development of Geographic Information Systems for developing countries. Dr. Bartolucci organized and founded the Society of Latin American Remote Sensing Specialists (SELPER) with headquarters in Quito, Ecuator. He has been an invited lecturer and consultant for the Defense Mapping Agency, Inter-American Development Bank, International Atomic Energy Agency, and several Latin American remote sensing agencies.

Above. **Doug Morrison selects Landsat imagery and aerial photography in preparation for the arrival of a group of visiting scientists.**

## Assistance to College and University Educators

Assistance to those teaching remote sensing in colleges and universities has been a focus for several activities. During the year, the final report and evaluation were completed for the first national Conference on Remote Sensing Education, held at Purdue in May 1981. The comments and evaluations from the 189 participants representing 43 different U. S. colleges and universities launched an effort to identify major needs among those in the educational community.

This year staff at LARS surveyed numerous remote sensing instructors to define and prioritize these needs. Concepts for seven projects were developed in response to this, and efforts are underway to turn these ideas into reality.

## Remote Terminal Network

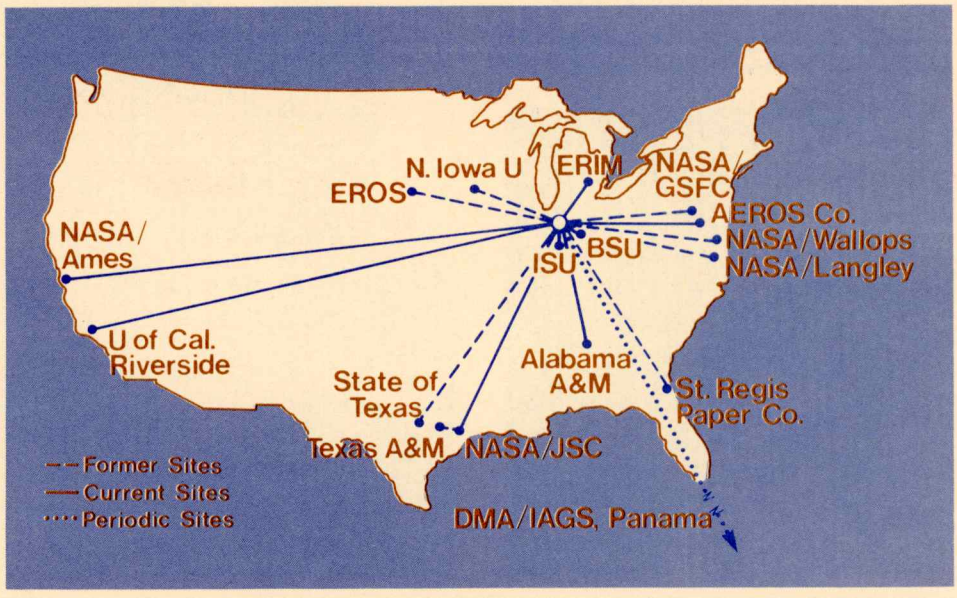
Normally a large personnel and financial commitment is necessary for acquiring a remote sensing analysis facility. LARS reduces this cost by providing to educators and researchers low-cost, low-risk network access to a dedicated remote sensing system. Two new sites were added this year — the AEROS Co. in Washington, D. C. and NASA/Ames in Moffett Field, California.

Through this network, remote users have access to software implemented on the IBM 370/158, to a large data base of multispectral data, and to technical assistance from experienced Purdue/LARS staff. The benefits received by LARS from the network include defrayed costs through the larger number of system users and increased communication with others working in remote sensing.

## Visiting Scientist Program

Eight visiting scientists spent a total of 33 man-months in study and research at LARS. They represented six countries: Bolivia, India, Japan, Kenya, Mexico, and the People's Republic of China. Dr. Carlos Brockmann from ERTS/GEOBOL in Bolivia, who visited in conjunction with an on-going technical assistance program, was also adjunct professor of geosciences while at Purdue.

Below. **The remote terminal network provides access to data and state-of-the-art remote sensing software for subscribers across the country.**




### Douglas B. Morrison

**Training Coordinator**
B.S., Montana State, English; M.A., Washington, Speech

After several years of personnel work with industry, Mr. Morrison returned to education in 1969 at Purdue University. He began working at LARS in June of 1974 with the newly formed Technology Transfer program area and has been Training Coordinator under that program since then. In this capacity he has coordinated the visits of nearly 100 visiting scientists, over 500 short course participants, and over 1000 symposium attendees. He has been co-editor of the symposium proceedings since 1975.

### Joan S. Buis

**Systems Training Specialist**
B.S., Purdue, Mathematics

Ms. Buis has taught the workshops and hands-on exercises for the week-long short course on numerical analysis of remote sensing data and has assisted visiting scientists at LARS in their processing of Landsat data. She has been responsible for maintaining LARSYS as well as designing and implementing new LARSYS processors and has served as manager of the LARS remote terminal network.

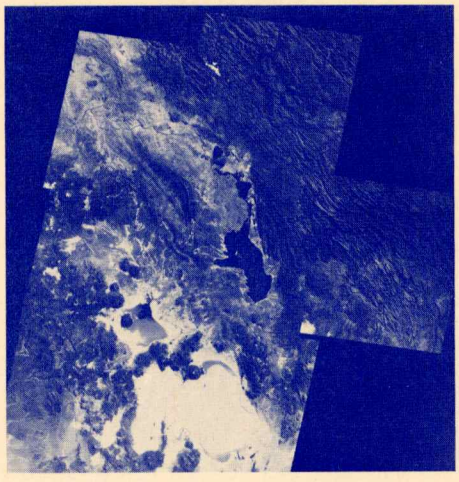
# Technical Assistance to Bolivia — A Case Study



On-going work with the Republic of Bolivia has resulted in the conceptualization and design of a digital Geographic Information System (GIS) for the entire territory of the republic. The design of this digital geographic information system provides the capability to store, manage, analyze, and update natural resource, environmental, and socio-economic data on a national basis.

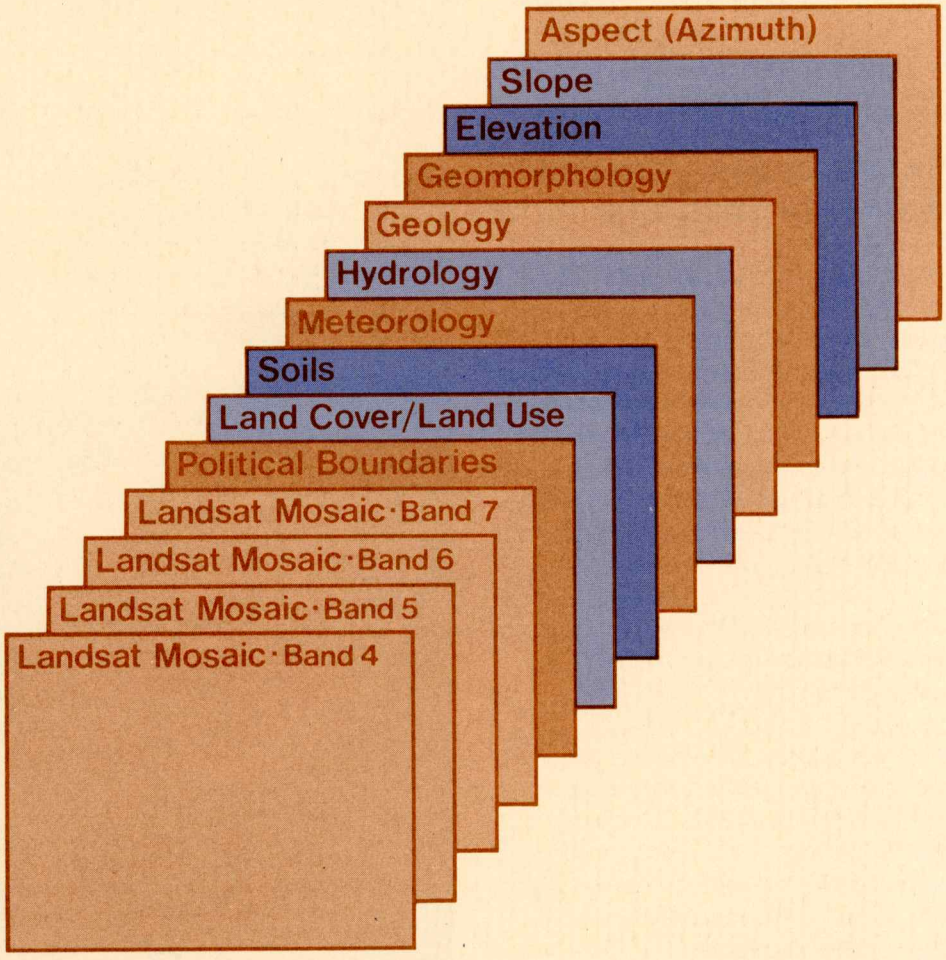
Included in this work was the thorough investigation and subsequent development of an algorithm that defines the optimum resource map projection for Bolivia, i.e., the ALBERS conical equal-area projection. A hierarchical classification scheme for the various thematic elements of the GIS was also developed.

Below. **A digital mosaic of the Oruro department in southwest Bolivia provides data for one of the levels of the geocoded, image-plane data base,** Right.



The design was tested through the development and implementation of this system for the Oruro Department, a mountainous area of more than 53,000 square kilometers in southwestern Bolivia. Additional products of this work were the development and implementation of an addressing scheme for storing georeferenced data in digital image format, development of a method for storing large quantities of data in an interactive mode, and the design of digitizing software for a microprocessor.

The most important achievement derived from this cooperative effort with the Bolivian ERTS/GEOBOL Program has been the effective transfer of the technology through the training of Bolivian technical personnel.




**Carlos E. Brockmann**

**Adjunct Professor of Geosciences; Visiting Scientist at LARS**

Ph.D., Universidad Nacional de la Plata (Argentina), Geosciences

Before coming to Purdue for a one-year appointment, Dr. Brockmann served as director of the Bolivian ERTS/GEOBOL Remote Sensing Center for nine years and, before that, as director of the Department of Photogeology of YPFB, a Bolivian oil company. He has received world-wide recognition for his work in remote sensing applications in Bolivia and in 1975 was awarded the William T. Pecora Award.

## Videotapes

Five color video programs became available for purchase through Purdue's Continuing Education Administration. Prepared by senior staff members at LARS, the tutorial presentations transport viewers to laboratory and field sites to see how remote sensing data are analyzed and how the technology is used. The series includes:

**Spectral Properties of Soils** by Marion Baumgardner

**Correction and Enhancement of Digital Image Data** by Paul Anuta

**The Remote Sensing Information System** by David Landgrebe

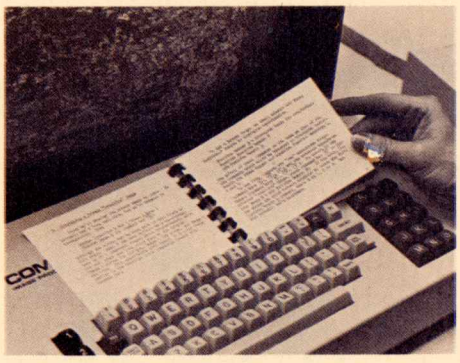
**The Role of Pattern Recognition in Remote Sensing** by Philip Swain

**The Role of Numerical Analysis in Forest Management** by Roger Hoffer

## Workshop Manual

The prototype of a new instructional tool "Flexible Workshop on Numerical Analysis of Multispectral Data" was developed and used in support of short course workshop exercises. This printed manual takes the student step-by-step through an analysis sequence with the theoretical discussions in each analysis step paralleled by case study examples.

The "flexible" aspect of this publication is that the case study may be chosen to suit the applications or geographic interests of the student. The module was designed for students who wish to study the analysis process prior to hands-on computer work or for those without access to a computer.



Above. **A new COMTAL user learns about the system with the aid of the "Introductory Operator Training Program" written at Purdue/LARS.**

## Image Analysis Documentation

Work was undertaken with the sponsorship of COMTAL/3M Corporation to develop software to enhance the analyst's ability to interact with multispectral image data on a high-quality image display system. An educational module was developed to introduce new users to the COMTAL Vision One series, and additional user documentation was completed for the LARS COMTAL system. Prototype documentation was also written for a proposed COMTAL-based geographic information system.

Left. **Shirley Davis prepares for a short course by reviewing a videotape by Phil Swain.**

### Shirley M. Davis

**Senior Education and Training Specialist**
A.B. with Honors, Sweet Briar, English; M.A., Western Reserve, English

A LARS employee since 1971, Ms. Davis has served as editor, remote sensing data analyst, writer, instructor and instructional developer of courses and of educational material in print and electronic media. She has been principal investigator for several technology transfer contracts. Ms. Davis' major contributions to remote sensing education have been as co-author, editor, and producer of numerous multimedia educational packages. She is second deputy of the Education and Interpretation Skills Committee, Remote Sensing Applications Division, American Society of Photogrammetry.

# University Courses

In recognition of the interdisciplinary nature of remote sensing, Purdue University offers students the opportunity to study this technology through five traditional academic departments. While earning degrees in these academic areas, students may take enough courses at both the graduate and undergraduate levels to specialize in remote sensing as a minor.

## Courses with Emphasis on Remote Sensing

### Agronomy

545 Surveying Agronomic Resources
Credits: 3; Professor Baumgardner

### Civil Engineering

567 Airphoto Interpretation
Credits: 3; Professor Miles

### Electrical Engineering

577 Engineering Aspects of Remote Sensing
Credits: 3; Professors Swain and Silva

### Forestry

291 Introduction to Remote Sensing
Credits: 2; Professor Hoffer

557 Aerial Photo Interpretation
Credits: 3; Professor Miller

558 Remote Sensing of Natural Resources
Credits: 3; Professor Hoffer

579 Remote Sensing Seminar
Credits: 1; Professor Hoffer

### Geosciences

518 Aerogeology and Remote Sensing
Credits: 3; Professor Levandowski

## Courses Related to Remote Sensing

### Agronomy

565 Soil Classification and Survey
Credits: 3; Professor Bryant

585 Soils and Land Use
Credits: 2; Professor Yahner

655 Soil Genesis and Classification
Credits: 3; Professor Franzmeier

### Civil Engineering

503 Photogrammetry I
Credits: 3; Professor Mikhail

603 Photogrammetry II
Credits: 3; Professor Mikhail

604 Analytical Photogrammetry
Credits: 3; Professor Mikhail

### Electrical Engineering

661 Image Processing
Credits: 3; Professor Kak

662 Introduction to Artificial Intelligence and Pattern Recognition
Credits: 3; Professor Fukunaga

668 Artificial Intelligence
Credits: 3; Professor Fu

### Geosciences

455 Exploration Geophysics
Credits: 3; Staff

523 Geomorphology
Credits: 3; Professor Melhorn

558 Geophysical Exploration for Engineers
Credits: 3; Professor Sexton

Research conducted at LARS offers valuable experience to graduate students with an interest in remote sensing. During the last year, 35 graduate students from seven academic departments participated in funded research through LARS. The following students who were employed at LARS completed degree work in areas related to remote sensing from August 1981 through December 1982:

**Pierre-Marie Adrien, M.S. in Agronomy, 1982**
Characteristic Variations in Reflectance of Saline and Alkaline Soils of the Bolivian Altiplano.
Major Professor: M. F. Baumgardner

**Getulio Batista, Ph.D. in Agronomy, 1981**
Study of Corn and Soybean Landsat MSS Data Classification Performance as a Function of Scene Characteristics.
Major Professors: M. E. Bauer and D. A. Holt.

**Susan A. R. Garrod, M.S. in Electrical Engineering, 1982**
Designing Instructional Materials for an Integrated Circuit Fabrication Laboratory Class.
Major Professor: J. C. Lindenlaub

**Larry D. Hinzman, M.S. in Agronomy, 1981**
Influence of Nitrogen Fertilization and Leaf Rust on the Reflectance Characteristics of Winter Wheat Canopies.
Major Professors: M. E. Bauer and S. A. Barber

**Hooshmand A. Kalayeh, Ph.D. in Electrical Engineering, 1982**
Classification of Remotely Sensed Image Data Using Multitype Information.
Major Professor: D. A. Landgrebe

**Douglas J. Knowlton, M.S. in Forestry, 1982**
Evaluation of Radar Data for Forest Cover Mapping.
Major Professor: R. M. Hoffer

**Kathleen Latz, M.S. in Agronomy, 1982**
A Study of the Spectral Reflectance of Selected Eroded Soils of Indiana in Relationship to Their Chemical and Physical Properties.
Major Professors: R. A. Weismiller and G. E. Van Scoyoc

**Eileen Luke, M.S. in Statistics, 1982**
Non-thesis option.
Major Professors: D. S. Moore and V. L. Anderson

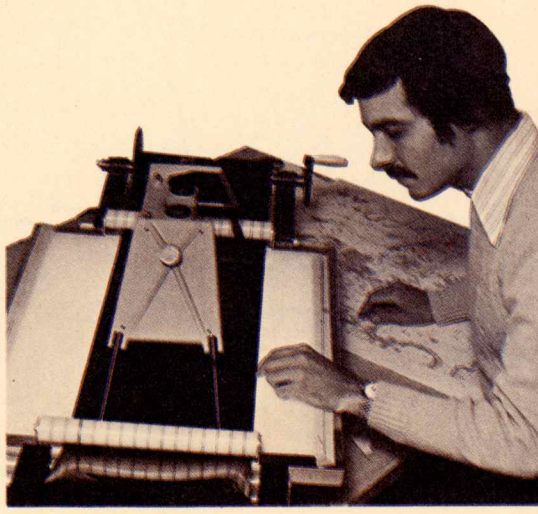
**Marwan J. Muasher, Ph.D. in Electrical Engineering, 1982**
Design and Application of Multistage Classifiers for Earth Resources Data Analysis.
Major Professor: D. A. Landgrebe

**Steven E. Pazar, M.S. in Agronomy, 1982**
Spectral Characterization of Iron Oxide and Organic Matter in Eroded Soils.
Major Professors: G. E. Van Scoyoc and R. A. Weismiller

**Victor J. Pollara, M.S. in Agronomy, 1982**
An Inquiry into the Use of Spectral Data for Assessing Crop Development Stage.
Major Professors: C. S. T. Daughtry and R. F. Dale

**Bernard L. Spence, M.S. in Civil Engineering, 1982**
Non-thesis option.
Major Professors: E. M. Mikhail and L. A. Bartolucci

**Judith P. Ward, M.S. in Agronomy, 1982**
Effects of Management Practices on the Reflectance of Corn and Soybean Canopies.
Major Professor: C. S. T. Daughtry and R. F. Dale



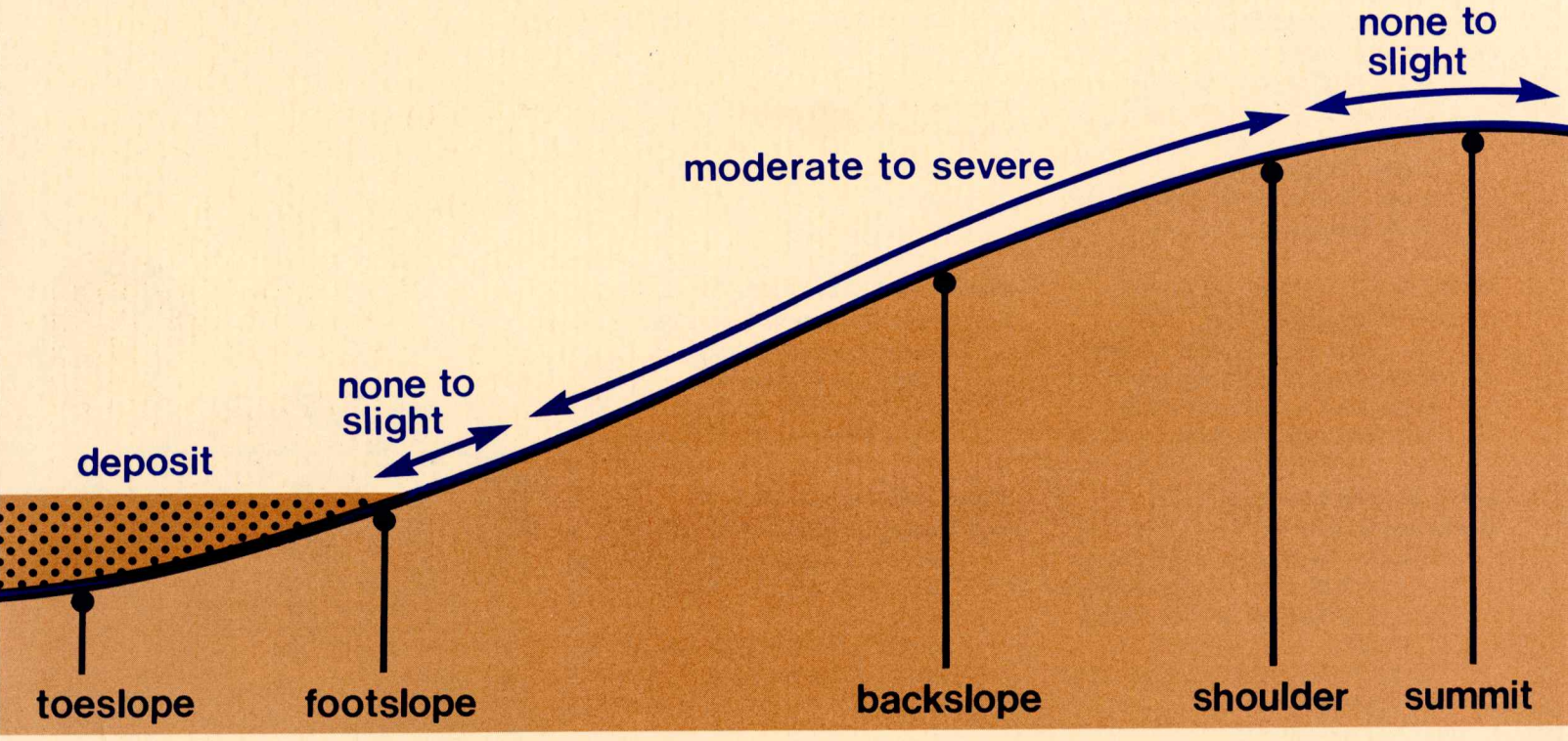
The loss of agriculturally productive soil due to erosion and salinity is a serious problem hampering global development. In order to apply agricultural practices that can decrease the loss of fertile crop land, methods of identifying, mapping, and monitoring erosion and salinization are needed. Thus the study of the spectral characteristics of soils continues to be the focus of the Earth Sciences Research program.

## Erosion Mapping

Recent advances in collecting and analyzing spectral reflectance data of soils suggest that remote sensing techniques may be an excellent tool for delineating and monitoring soil erosion. The goal of classifying soil erosion rests on the ability to define and understand the nature and degree of spectral separability between classes of erosion. This is a challenging objective because of the extreme complexity in factors that determine a soil's reflectance and because of the often localized nature of soil erosion.

The study of simulated erosion profiles has led to the development of an approach for examining the relationship between soil reflectance properties and erosion. The most important factors affecting the spectral response of soils in this study appear to be iron oxide and organic matter content. In addition, the interaction of these two factors within an eroded soil is related to the severity of erosion: as the severity of erosion increases, the organic matter content decreases and the iron oxide content increases. This results in a decrease in the organic-matter to iron-oxide ratio.

Below. **A topographic sequence with varying degrees of erosion provides the model for a study of eroded soils.**




**Richard A. Weismiller**

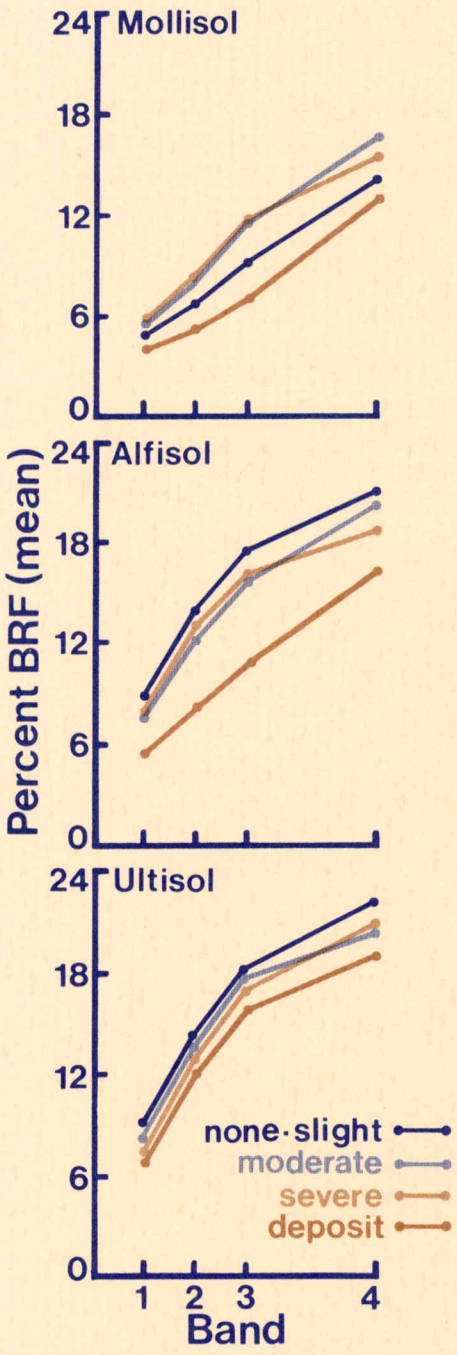
**Research Agronomist; Leader, Earth Sciences Research Program**

B.S. with Highest Distinction, Purdue, Agronomy; M.S., Purdue, Soil Mineralogy; Ph.D., Michigan State, Soil Chemistry-Clay Mineralogy

Dr. Weismiller's research interests lie in the multispectral radiation properties of soils and geologic materials, specifically in quantifying the relationships between multispectral radiation and the chemical-physical properties of earth surface features and in the application of remote sensing technology to soils mapping, soil erosion monitoring, and land use inventories. He is a member of the National Land Use Committee, Soil Conservation Society of America, program member for the 1983 Annual Meeting, SCSA, and chairman of the 1983 International Symposium on Machine Processing of Remotely Sensed Data. Dr. Weismiller is listed in American Men and Women in Science and is a member of Sigma Xi and Gamma Sigma Delta honorary societies.

**Recent Publication**

Weismiller, R. A., G. E. Van Scoyoc, S. E. Pazar, K. Latz and M. F. Baumgardner. 1982. Utilization of the spectral properties of soils for monitoring soil erosion. Proceedings of the International Conference on Soil Erosion and Conservation, Honolulu, Hawaii.




A model was developed and tested to predict iron oxide and organic matter content from soil reflectance. This model is evidence of the potential use of remote sensing for detecting soil erosion.

Left. **Simulated reflectance curves in Landsat MSS wavelengths demonstrate the correlation between reflectance and soil erosion. Soils shown represent the three primary soil orders common in Indiana.**

Below. **Steve Kristof discusses classification results with three visiting scientists from Peiking University.**

## Dr. John Peterson

**Senior Scientist**

B.S., Oregon State, Soil Science; M.S., Ph.D., Iowa State, Soil Science; Honorary Doctor of Agriculture, Purdue

Dr. Peterson's major research interest is the estimation of moisture tensions of soils from their spectral data. He was head of the Agronomy Department at Purdue for 23 years and then associate director of LARS until his retirement 11 years later. Dr. Peterson has served as a consultant to the Ford and Rockefeller Foundations, FAO, Inter-American Development Bank, Greece and Saudi Arabia. He is past president, fellow, and honorary member of the American Society of Agronomy and fellow of the American Association for the Advancement of Science. He has received the Stevenson Award for research in soil science and the Agronomy Society's Service Award.

## Stevan J. Kristof

**Research Agronomist, Retired**

B.S., Belgrad, Agronomy; M.S., Purdue, Horticulture; Ph.D., Belgrad, Soil Science and Plant Nutrition

Dr. Kristof's interests lie in characterizing soils and other natural features by computer analysis of multispectral data, in particular with regard to the identification and assessment of soil degredation, potential soil productivity mapping and land use capability mapping. He developed important initial techniques for using digital analysis of multispectral data as a basic tool for soil survey and for assessing the quality and quantity of various earth resources. Dr. Kristof is a member of numerous professional organizations, a member of the Council for Remote Sensing and Photointerpretation of the Yugoslav Academy of Sciences and Arts, and an honorary life member of the HUKD "Matija Gubec," Yugoslavia.

## Monitoring Soil Quality

As salinization of soils threatens productivity in arid and semi-arid areas, the need to identify and map geographic areas affected by salts becomes an important task of remote sensing. Physical and chemical properties of soils contribute significantly to their spectral characteristics in both the visible and infrared regions of the electromagnetic spectrum. The specific impact of different types and contents of salts upon spectral reflectance has been a subject of study this year.

Fifteen salt-affected samples from Iraq representing the Alfisol, Aridisol, Entisol, and Inceptisol orders were selected for investigating the relationship between the chemical and physical properties of these soils and their spectral characteristics. Stepwise regression analysis indicates that the most important chemical properties affecting the spectral reflectance of these soils are specific salt concentration, base saturation, sodium adsorption ratio (SAR), and organic matter content. Relationships between these properties and spectral response are being studied in ten wavelength bands spanning the spectrum from 0.52-2.32 μm.

Study is continuing in the influence of soil texture and color on the spectral reflectance characteristics of these soils as well as on the detection and mapping of different salinity levels of these soils using Landsat MSS data.

Left. **Sabah Al-Mahawili and Dick Weismiller use the Munsell color notation to describe two soil samples from different parts of the world.**


### George E. Van Scoyoc

**Associate Professor of Agronomy**

B.S., Ohio State, Agronomy; M.S., Ohio State, Soil Chemistry; Ph.D., Purdue, Soil Chemistry/Mineralogy


Dr. Van Scoyoc's major research interests include the surface chemistry of fibrous clays, aggregate stability of soil as related to residue decomposition, and spectral properties of eroded soils. He has been elected to Gamma Sigma Delta and Sigma Xi honorary societies and is a member of numerous agronomic and soil science societies in this country and abroad.

**Recent Publication**


Oscarson, D. W., G. E. Van Scoyoc and J. L. Ahlrichs. 1981. Effect of poly-2-vinyl pyridine-N-oxide and sucrose on silicate-induced hemolysis of erythrocytes. J. Pharm. Sci. 70:657-659.

# Ecosystems Research



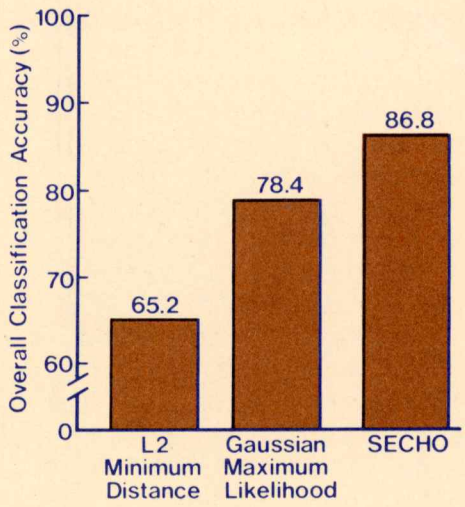
Ecosystems Research programs involve both research and application activities directed toward the development of remote sensing technology for natural resource inventories. During this year, simulated Thematic Mapper (TM) data and radar data have been evaluated for obtaining forest resource information.

## Analysis of Simulated Thematic Mapper Data

In anticipation of the increased amounts of data that will be obtained from the TM scanner and the special parameters of these data, a research effort was designed to assess the spectral and spatial characteristics of TM data for identifying and mapping forest cover types.

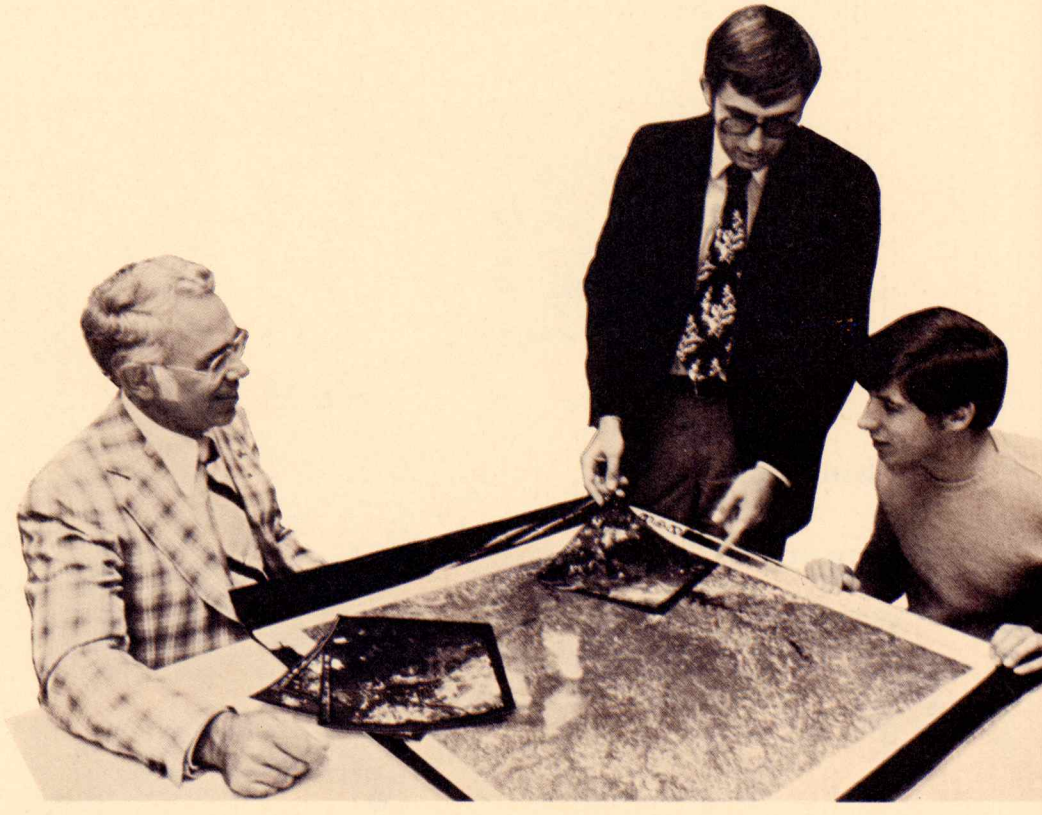
Results have indicated that the boundaries of forest stands are more accurately defined with TM data than with Landsat MSS data, but that classification of forest cover types is significantly poorer with the higher resolution data. Results also indicated that certain wavelength bands are particularly useful for identifying various species of forest cover and that appropriate combinations of three or four wavelength bands are generally adequate for identifying and classifying any particular cover type.

To achieve more accurate classifications, techniques for combining different wavelength bands are being tested as are approaches to classification that use spatial information along with the spectral data.




Right. **Comparison of the accuracy achieved for three algorithms used to classify simulated Thematic Mapper data for forest cover types.**

Below. **Roger Hoffer, Dick Mroczynski, and Doug Knowlton check the correspondence of aerial photography with Landsat data to be analyzed.**




### Roger M. Hoffer

**Professor of Forestry; Leader for Ecosystems Research Programs**

B.S., Forestry, Michigan State; M.S., Ph.D., Watershed Management, Colorado State


Dr. Hoffer's research interests involve the interpretation and analysis of multispectral scanner imagery, radar data, and color infrared photography, with particular attention given to the spectral characteristics of earth surface features. He has contributed significantly to the development and testing of computer-aided analysis techniques to differentiate, identify, and map natural resource features. Dr. Hoffer serves as chairman of the National Long Range Planning Committee, American Society of Photogrammetry, and as lecturer for George Washington University. A recipient of numerous awards and recognitions, he was granted the 1978 Alan Gordon Award from the American Society of Photogrammetry and in 1979 was selected "Best Teacher" in the Department of Forestry and Natural Resources by the Purdue Student Association.

**Recent Publications**


Hoffer, R. M. 1983. Computer-aided analysis of digital MSS data for forestry applications. Chapter 34, **Manual of Remote Sensing,** Second Edition, American Society of Photogrammetry, Falls Church, Virginia. (in press)

Setzer, A. W., R. B. Jacko and R. M. Hoffer. 1982. The use of color-IR photos for air pollution plumes. **Journal of the Air Pollution Control Association** 32(8):837-838.

Dean, M. E. and R. M. Hoffer. 1981. Evaluation of thematic mapper data and computer-aided analysis techniques for mapping forest cover. **Proceedings of the Indiana Academy of Science,** Indianapolis, Indiana. (in press)

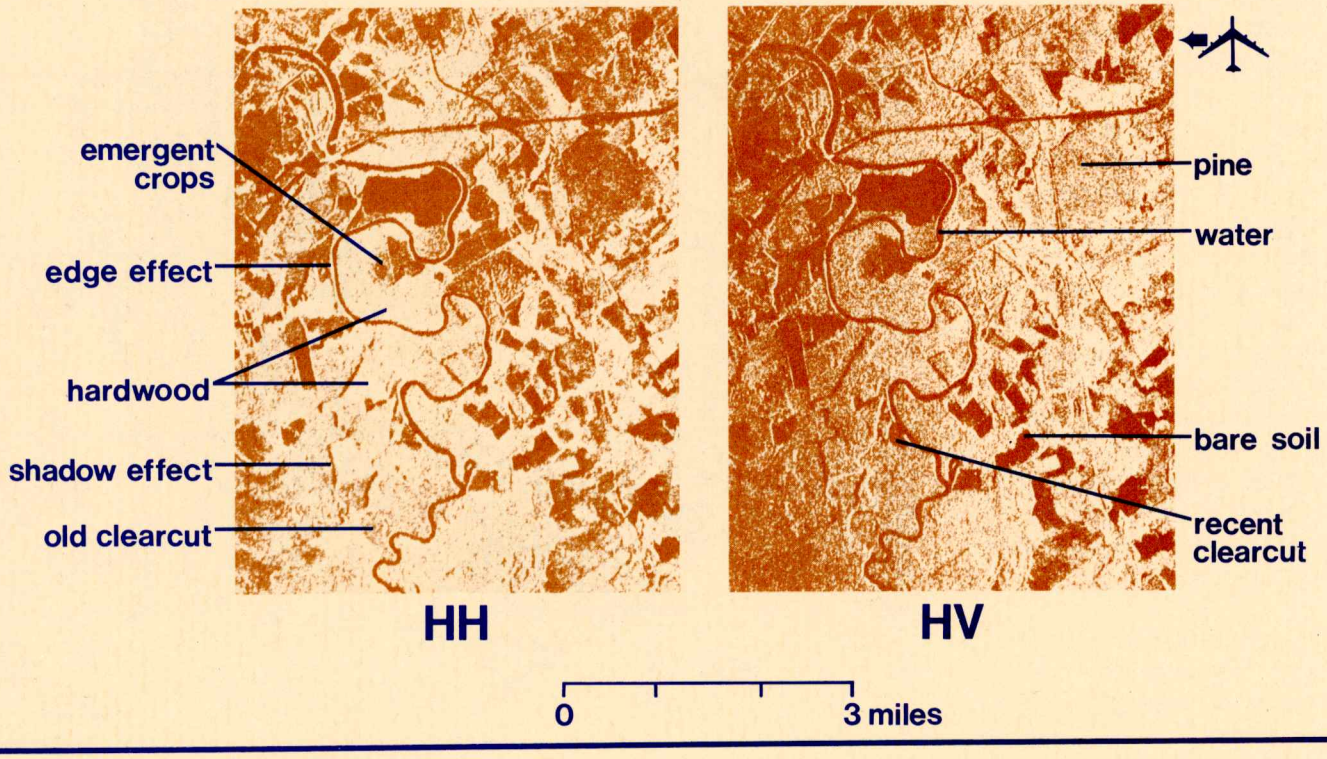
## Evaluation of Radar Data

Radar systems have several advantages over photographic and MSS systems, such as the capability to penetrate clouds, to be operated day or night, and to obtain imagery in which the tone and texture are related to the moisture content and physical structure of the materials present. Dual-polarized X-Band Synthetic Aperture Radar (SAR) data at 15- and 30-meter resolutions were examined qualitatively and quantitatively to determine the value of SAR data for differentiating forest and other cover types and to assess the utility of pattern recognition techniques for classifying SAR data.

Urban areas, water features, and areas of bare soil showed up clearly on the radar imagery, and deciduous forest could be easily separated from coniferous forest on the HH-polarized data. Coniferous forest and pasture, however, could not be separated on the imagery of either polarization. Likewise, many of the species and age classes of forest cover could not be separated on either polarization. Such limitations may prevent the operational use of X-band radar data for forest inventory, but it is hoped that longer wavelengths of SAR data may overcome these problems associated with cover type discrimination.

In order to evaluate the potential of pattern recognition techniques for classifying this radar imagery, the two polarizations were digitized and registered to produce a data set for digital analysis. Classification accuracies obtained from these data were approximately 65%, with the contextual classifiers (e.g., per-field and SECHO) yielding more accurate results than the Gaussian maximum-likelihood per-point classifier.

Below. **Tonal differences on dual-polarized radar imagery allow differentiation among deciduous forest, coniferous forest, and other cover materials. A "photo" key was developed to systematize visual differentiation of materials using the two polarizations.**




**Richard P. Mroczynski**

**Research Forester; Associate Leader for Ecosystems Research Programs**

B.S.F., Illinois, Forest Production; M.S., Illinois, Forestry

Associated with LARS since 1969, Mr. Mroczynski's primary research interests are in resource inventories as they provide inputs to natural resource information systems. He is chairman-elect of the Remote Sensing and Photogrammetry Working Group, Society of American Foresters, and was awarded a Certificate of Appreciation by NASA/Lyndon B. Johnson Space Center for leadership in the development of Landsat technology for the St. Regis Paper Company's Forest Resource Information System.

**Recent Publications**

Mroczynski, R. P. and D. Eisenhauer. 1982. Aerial surveys for pheasant habitat. Chapter 17, Remote Sensing for Resource Management, Soil Conservation Society of America, Ankeny, Iowa. pp. 191–197.

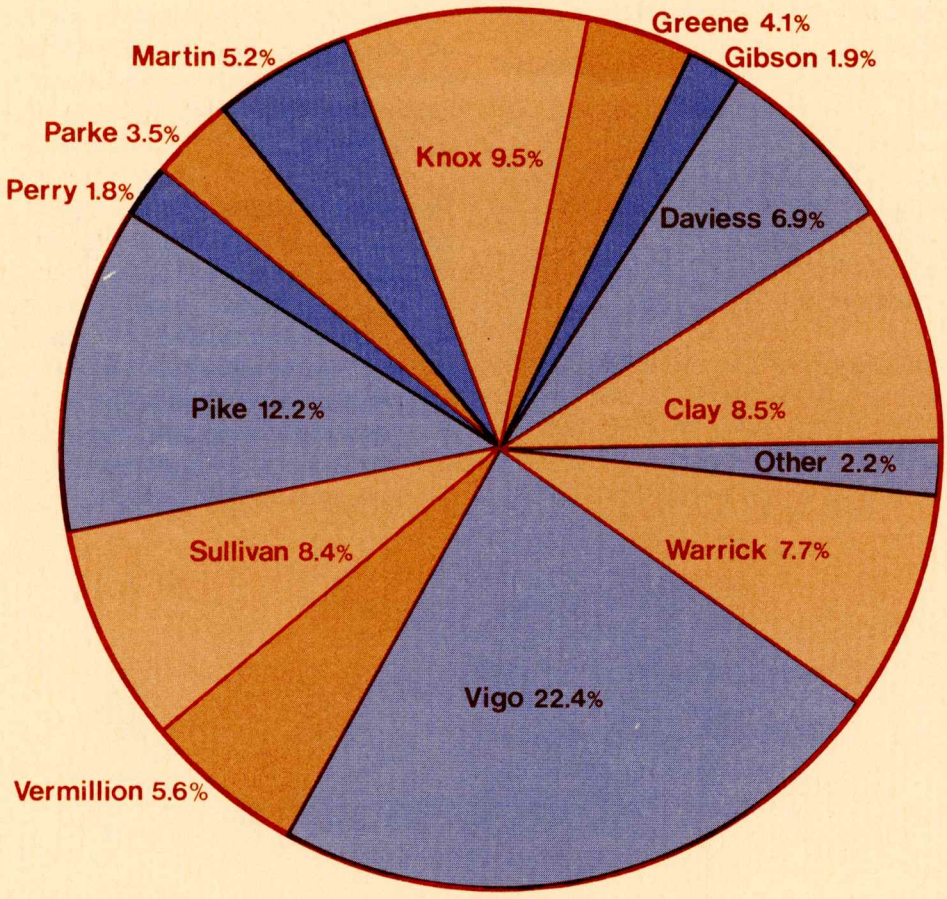
Mroczysnki, R. P. and R. A. Weismiller. 1982. Aerial photography: a tool for strip mine reclamation. Chapter 28, Remote Sensing for Resource Management, Soil Conservation Society of America, Ankeny, Iowa. pp. 331–337.

## Planning for Abandoned Mine Land Rehabilitation

An interdisciplinary team from Purdue's schools of Agriculture, Engineering, Science, and Humanities, Social Science, and Education worked under the leadership of LARS staff to prepare and submit grant requests for the the rehabilitation of approximately 300 acres of abandoned coal mine lands in Indiana. To rehabilitate these lands, which represent an immediate threat to the human health, safety, and general welfare of the residents of southwestern Indiana, grant requests of close to $6 million were developed in conjunction with the Indiana Department of Natural Resources, Division of Reclamation.

The first task completed was the creation of a comprehensive data base containing information about the location, type, and severity of abandoned mine land problems in the state. The sites were then ranked by severity according to a scheme developed by the Office of Surface Mining.

Using the ranking, the Division of Reclamation decided on the scope of the first year's reclamation program, and grant requests were prepared for these activities. Documents included project descriptions, construction-cost estimates, and environmental assessments.




Above. **Within Vigo County lies 22.4% of all the abandoned mine lands in southwestern Indiana. Similar summaries of abandond mine lands were prepared for all Indiana counties under Title IV of Public Law 95-78, Surface Mining Control and Reclamation Act of 1977.**

# Crop Inventory Research

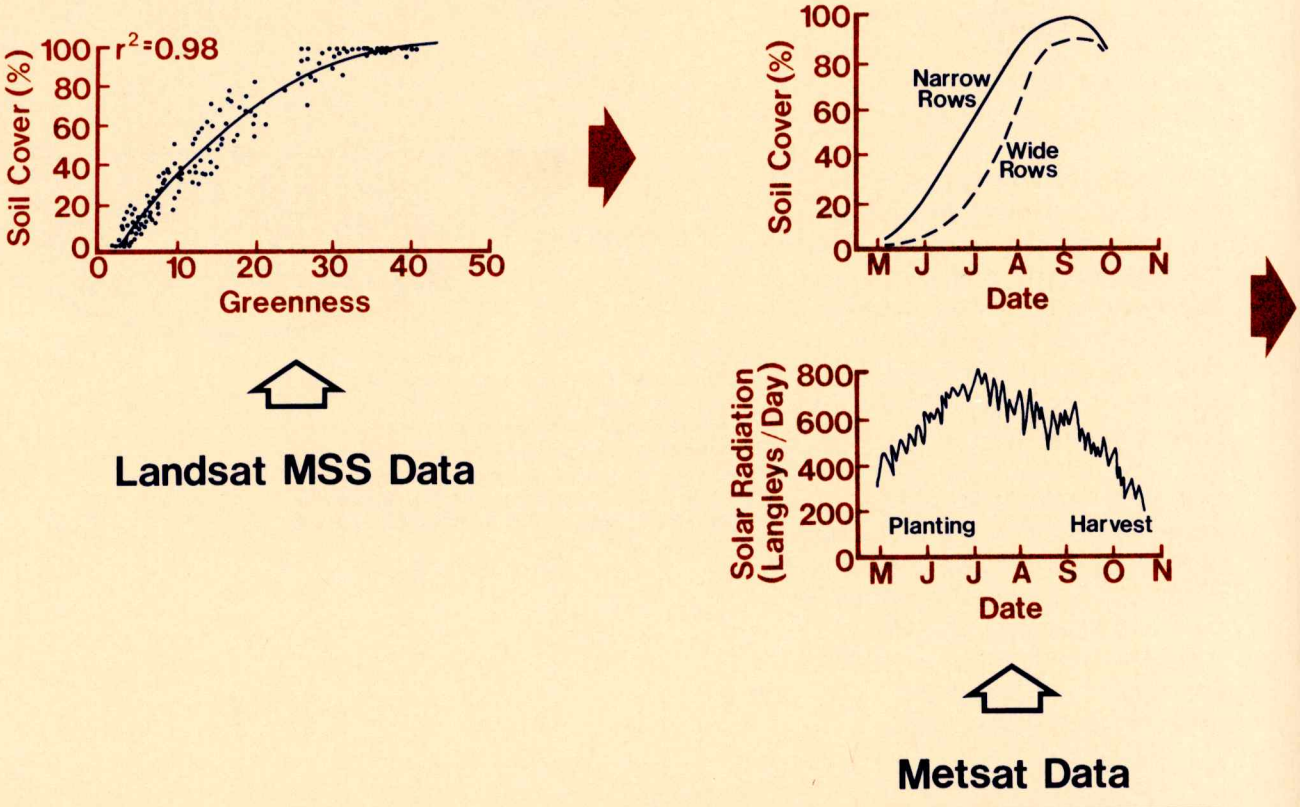


The successful management of crop production on a global basis requires accurate and timely information on soil productivity and crop acreage and condition. The repetitive, synoptic view of the earth obtained by satellite-borne sensors such as the Landsat MSS contains the data from which the needed information can be obtained.

The Large Area Crop Inventory Experiment demonstrated in the mid-1970's the feasibility of using multispectral remote sensing to inventory global wheat production, but rigorous research and development are yet required in order to reach the potential for monitoring and inventorying crop production that this technology offers.

The primary mission of the Crop Inventory Research program is to conduct basic and applied research to increase quantitative understanding of the radiative properties of crops and to develop procedures for obtaining crop production information from remotely sensed spectral measurements along with meteorological, soils, and ancillary data.

As part of the AgRISTARS Supporting Research Project under the sponsorship of the NASA Johnson Space Center, LARS is conducting research on spectral properties of crops and soils, techniques for assessing crop condition using spectral data, and the utility of Landsat data for large area crop models. Several specific tasks were carried out as part of these long-term interests.




**Marvin E. Bauer**

**Senior Research Agronomist; Leader of Crops Inventory Research Program**

B.S.A., M.S., Purdue, Agricultural Economics and Agronomy; Ph.D., Illinois, Crop Physiology

Dr. Bauer's research interests lie in the characterization and modeling of the spectral properties of crops in relation to their biophysical and agronomic characteristics and in techniques for using spectral data, particularly Landsat data, with meteorological and soils data to identify crops, estimate their area, and assess their condition. Dr. Bauer is editor-in-chief of Remote Sensing of Environment Journal and is listed in the 1982–83 edition of Who's Who in Technology Today.

**Recent Publications**

Hixson, M. M., M. E. Bauer and D. K. Scholz. 1982. An assessment of Landsat acquisition history on identification and area estimation of corn and soybeans. Remote Sensing of Environment Journal 12:123–128.

Walberg, G., M. E. Bauer, C. S. T. Daughtry, and T. L. Housley. 1982. Effects of nitrogen nutrition on the growth, yield, and reflectance characteristics of corn canopies. Agronomy Journal 74:677–683.

## Spectral Properties of Crops and Soils

Primary activity was in the acquisition and analysis of **in situ** spectral agronomic measurements of corn and soybean canopies in order to quantify their reflectance characteristics. Data were acquired at the Purdue Agronomy Farm and analyzed to determine the relationship of spectral response to:

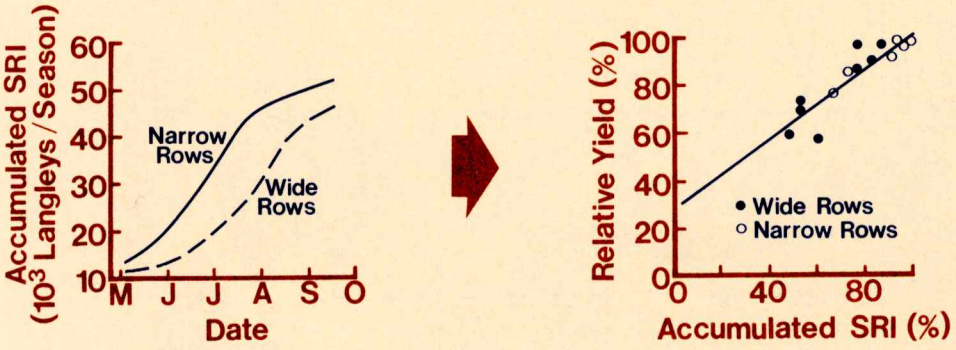
1. **crop development stage;**
2. **the amount of vegetation in terms of leaf area index, biomass, and percent soil cover;**
3. **differing agronomic treatments including crop variety, plant population, and planting date;**
4. **solar illumination angles, crop geometry, and sensor view angles.**

The relationships developed from **in situ** data were successfully extended to reflectance characteristics of commercial fields as recorded in Landsat MSS data. These results reaffirm the importance and applicability of research conducted at agricultural experiment stations for understanding the biophysical characteristics of crops and soils.

## Crop Condition Assessment

The interaction of solar radiation with plant leaves determines the amount of energy available to plants for photosynthesis. The proportion of solar radiation intercepted by a corn canopy (SRI) can be described as a function of leaf area index (LAI). Since LAI for corn may vary greatly with differences in planting date, stress, and plant population, measurement of LAI is tedious and time-consuming. This situation limits the use of yield models requiring LAI to studies of relatively small area.

Scientists at LARS have demonstrated the feasibility of estimating LAI and SRI with multispectral data and have used this information in crop models to predict grain yields. This research provided the foundation to extend many crop models to areas where it is impossible to measure the crop directly.




Left. **Reflectance is closely related to percent soil cover and leaf area index. Merging estimates of these variables, which can be obtained from Landsat data, with solar radiation data produces estimates of SRI. This variable integrated over the season accounts for much of the variation in corn and soybean yields.**


### Craig S. T. Daughtry

**Research Agronomist**

B.S., M.S., Georgia, Agronomy; Ph.D., Purdue, Agronomy


Dr. Daughtry's research interests include the characterization and modeling of biophysical and spectral properties of crops and soils and the integration of remotely sensed data into crop yield models. He was elected to Sigma Xi and Gamma Sigma Delta honorary societies. Dr. Daughtry is a member of the Crop Science Society of America, the American Society of Agronomy and the American Society of Photogrammetry, where he is chairman of the Plant Science Committee and of the Article Review Board for the Remote Sensing Applications Division.

**Recent Publications**


Daughtry, C. S. T., K. P. Gallo and M. E. Bauer. 1983. Spectral estimates of intercepted solar radiation by corn canopies. **Agronomy Journal**. (in press)

Daughtry, C. S. T., V. C. Vanderbilt and V. J. Pollara. 1982. Variability of reflectance measurements with sensor altitude and canopy type. **Agronomy Journal** 74:744–751.

Kollenkark, J. C., C. S. T. Daughtry, M. E. Bauer and T. L. Housley. 1982. Effects of cultural practices on agronomic and reflectance characteristics of soybean canopies. **Agronomy Journal** 74:751–758.

Above. **Craig Daughtry and Marv Bauer measure the area of leaves in a study to quantify the amount of radiation that crop canopies will intercept during the growing season.**

To refine the SRI concept, the quantity of photosynthetically active radiation (0.4-0.7μm) intercepted by crop canopies was also measured using the equipment and techniques pictured. These experiments should lead to better understanding of how light interacts with crop canopies and how crop production can be enhanced.

## Landsat Data for Yield Models

Purdue/LARS and the Earth Satellite Corporation designed a series of experiments to evaluate the contribution of spectrally derived information for a large-area crop-yield model, CROPCAST. Estimates of planting date, development stage, crop albedo, and stress were calculated from Landsat MSS data that had been collected over areas with different cropping practices, soils, and weather. When these estimates were provided to the CROPCAST model, initial results were promising, but a reduction in funds prevented a complete evaluation of the concept.

Below. **Measurements of photosynthetically active radiation (PAR) intercepted by corn and soybean canopies provide insights into the spectral reflectance characteristics of the canopies and their contribution to crop yield models.**

## Steven J. Hollinger

**Research Agronomist**

A.S., Mesa Jr. College, Agriculture; B.S., Colorado State, Agronomy; M.S., Purdue, Agriculture Meteorology; Ph.D., Purdue, Agronomy/Agriculture Meterology

With an overall interest in the effects of environment on crop growth and development, Dr. Hollinger's current research interests include the application of remote sensing techniques to estimate crop phytomass and water content and the assessment of crop condition at field level. He is active in the American Society of Agronomy, Crop Science Society of America, Soil Science Society of America, and American Meteorological Society.

## Other Staff

Drs. **Virgil L. Anderson** and **K. S. Pillai,** professors of statistics, advise Crop Inventory Research staff in the areas of experiment design, sampling, and multivariate analysis.

Dr. **Donald A. Holt,** professor of agronomy (now chairman, Department of Agronomy, University of Illinois), has served as advisor to graduate students and professional staff in the area of crop growth and yield modeling.

# Measurements Research



Established as one of the essential components of a research program in remote sensing, LARS Measurements Research area has developed a significant and respected capability for acquiring calibrated data in both the laboratory and field. These data are collected to study the reflective and radiative properties of crops, soils, and even skin. This activity has emphasized the development and proper use of field instruments, the acquisition and management of calibrated field and laboratory data, and basic research on the physical aspects of canopy/radiation interaction.

## Acquisition of Field Data

For the past several growing seasons, the LARS field data acquisition systems have been operating at the Purdue University Agronomy Farm where they have been collecting spectral data to support quantitative studies of the reflective properties of crops and soils. This has been done in conjunction with current LARS research in the Crop Inventory and Earth Sciences program areas.

These experiments at the Purdue Agronomy Farm, along with many other crops and soils experiments in the U. S. and Mexico, are part of the AgRISTARS Support Research Project under the sponsorship of NASA's Johnson Space Center. The purpose of the programs is to obtain calibrated, meaningful measurements at several sites with different soils and climate conditions to further the community's understanding of the reflective properties of crops and soils.

## Training in Procedures for Acquiring Field Data

The acquisition of reliable spectral data, which can be compared regardless of the instrument used, the location of the target, and the time of day, requires adherence to well-defined field procedures and calibration techniques.

During this past year, engineers and scientists from LARS have trained colleagues in field spectral data acquisition at numerous other universities and research institutes, including:

- University of Nebraska
- Kansas State University
- University of Kansas
- South Dakota State University
- Oregon State University
- University of Minnesota
- NASA Earth Resources Laboratory
- NASA Goddard Space Flight Center
- Centro International de Mejoramiento de Maiz y Trigo (CIMMYT) in Mexico

Right. **Inside the mobile laboratory, Barrett Robinson prepares to record spectral reflectance measurements that will be obtained from field instruments.**


### Barrett F. Robinson

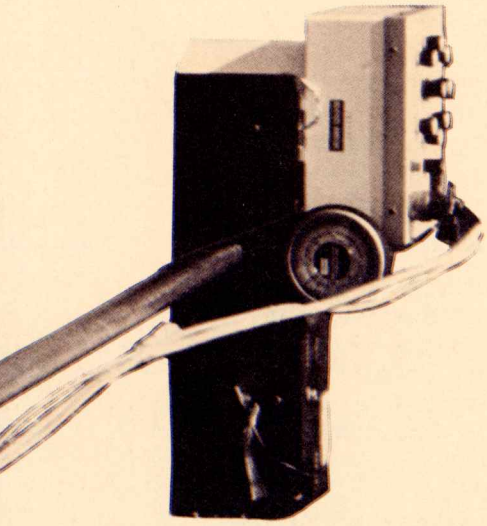
**Senior Research Engineer; Associate Leader, Measurements Research Program; Coordinator, Undergraduate Laboratories, School of Electrical Engineering**

B.S.E.E., Purdue; M.S., Purdue, Mathematics


Mr. Robinson's current research interests are in the development of sensors and instrumentation for remote sensing and biomedical research. He served as session chairman and treasurer for the 1982 Conference on Diffuse Reflectance Spectroscopy and as session chairman for the 28th Annual Technical Symposium, Society of Photo-Optical Instrumentation Engineers, 1982. In 1979 Mr. Robinson received a NASA Group Achievement Award. He is a member of the Institute of Electrical and Electronics Engineers.

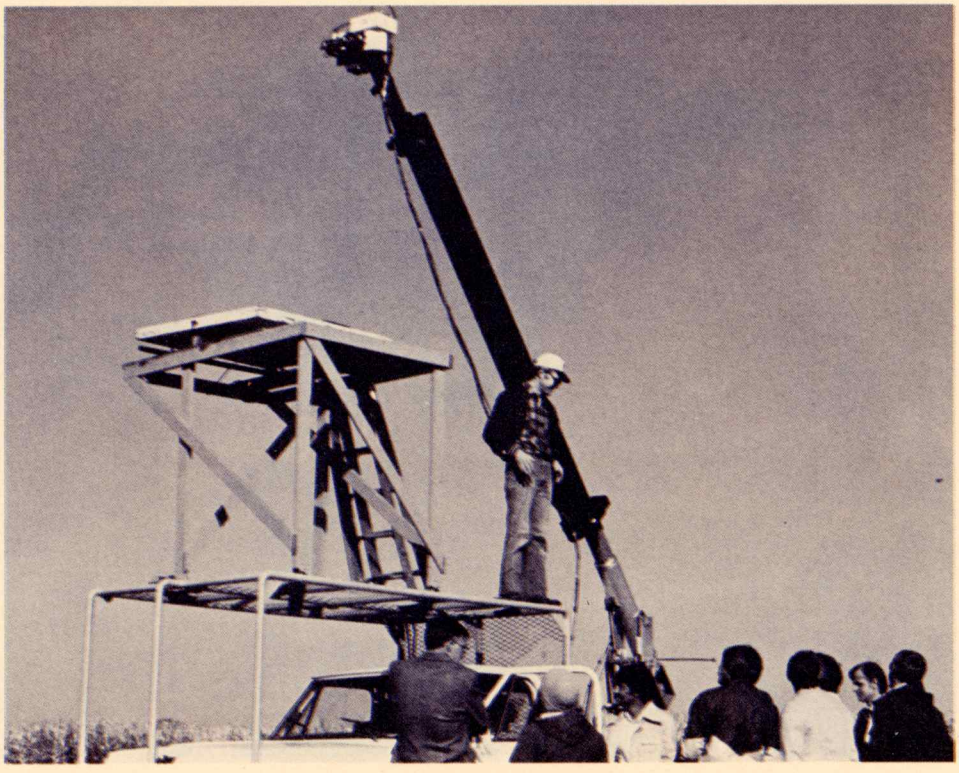
**Recent Publication**


Robinson, B. F. and D. P. DeWitt. 1983. Non-Imaging Sensors. Chapter 7, Manual of Remote Sensing, Second Edition, American Society of Photogrammetry, Falls Church. Virginia. (in press)



Left. **When the radiometer is mounted on the tower and boom designed at LARS, the instrument can be easily positioned to view the earth at any angle.**

Below. **With the aid of Larry Biehl, scientists and engineers from many universities learn well-developed data-acquisition and calibration procedures that will enable them to obtain meaningful, calibrated data for studying the reflective properties of crops grown under different soil and climate conditions.**



## Research in Scene Understanding

Today's satellite sensors view the earth from directly above, but additional information may be available if satellite sensors also obtained measurements at other angles.

To study the angular reflectance properties of crops, a specially designed apparatus was built this past year that can quickly position multiband radiometers to several different zenith and azimuth view angles. The apparatus, which includes a 10-meter tower, a 3-meter boom on which the radiometer is mounted, and a platform for a reference reflectance surface, allows the radiometer to be positioned for a selected view azimuth and then rotated to different zenith viewing angles, including the sky. Reflectance data are obtained several times throughout the day in order to obtain measurements for different sun angles.

These studies of the angular reflectance properties of crops are important preparation for analysis of data from future satellites that will view the earth from many different angles.


## Larry L. Biehl

**Project Manager/Engineer**
B.S., M.S., Purdue, Electrical Engineering


Mr. Biehl's primary research interests lie in the collection, calibration, correlation, and management of field and laboratory-obtained spectral data and in the development of software for efficient analysis of these data. He has had roles in the Skylab program as a data analyst, in NASA's Thematic Mapper Study as project manager and analyst, and in both the LACIE Field Measurements Project and the AgRISTARS Supporting Research Project. Mr. Biehl is a member of the Institute of Electrical and Electronics Engineers and of Eta Kappa Nu and Tau Beta Pi honorary societies.

**Recent Publications**


Biehl, L. L., M. E. Bauer, B. F. Robinson, C. S. T. Daughtry, L. S. Silva, and D. E. Pitts. 1982. A crops and soils data base for scene radiation research. **Proceedings of Eighth International Symposium on Machine Processing of Remotely Sensed Data,** Purdue University, West Lafayette, Indiana.

Biehl, L. L. and B. F. Robinson. 1982. Data acquisition and preprocessing techniques for remote sensing field research. **Society of Photo-Optical Instrumentation Engineers,** Vol. 356, SPIE, Box 10, Bellingham, Washington.

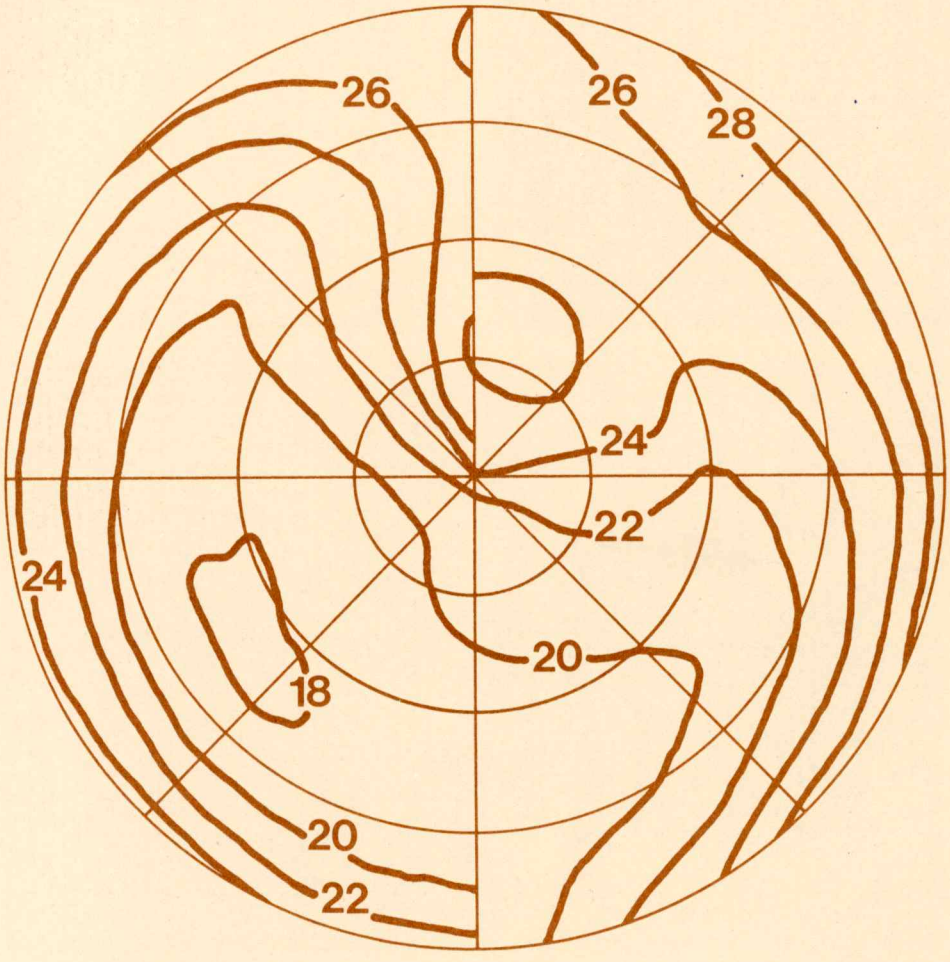
## Characterizing Light-Scattering Properties

To study the spectral light-scattering properties of a healthy leaf, a specially designed polarization photometer for use in the laboratory or field was developed and constructed at LARS this past year. The instrument, which includes a light source, six interference filters, polarization analyzing filters, and a silicon photodetector, is capable of acquiring the data necessary to determine the specular, polarized, and diffuse light-scattering characteristics of a leaf measured at the Brewster angle. With the instrument, light-scattering by cells in the bulk of the leaf can be monitored on a minute-by-minute basis.

## Industry Involvement

Research and development activities have been pursued during the past year with the Realist Corporation and the American Optical Company.

Above. **Vern Vanderbilt tests the polarization photometer with the aid of Lois Grant.**




Left. **Contours show reflectance factors in the .76-.90μm wavelength band for a June 21, 1982, corn canopy in the early afternoon. Concentric circles represent view zenith angles from 0° at center to 17°, 35°, 52°, and 70° radiating outward; radial lines represent view azimuth angles with North at the top. Note minimum reflectance for view angles toward the antisolar direction and increasing reflectance values with increasing view zenith angles.**


### LeRoy F. Silva

**Professor of Electrical Engineering; Leader of Measurements Research Programs**

B.S.E.E., Purdue; M.S.E.E., M.I.T.; Ph.D., Purdue, Electrical Engineering

Dr. Silva's research interests lie in the physics and optics of natural materials and in the sensors designed to measure spectral, spatial, and temporal variability of these materials. He has published in the areas of electronics, magnetics, optics, bioengineering and remote sensing. He is a member of Eta Kappa Nu and Sigma Xi honoraries, the National Society of Professional Engineers, and the American Association for the Advancement of Science and is senior member of the Institute of Electrical and Electronics Engineers. Dr. Silva is a Registered Professional Engineer, State of Indiana.

### Vern C. Vanderbilt

**Research Engineer**

B.S.E.E., M.S.E.E., Ph.D., Purdue, Electrical Engineering

Dr. Vanderbilt's research interests lie in optical and microwave remote sensing and in radiative transfer in scattering and absorbing media, such as plant canopies. He has worked in design of electro-optical laboratory and field apparatus and in measuring, analyzing and modeling the light/canopy geometric process. He is a member of Tau Beta Pi, Eta Kappa Nu, Sigma Xi, and Society of Physics Students.


**Recent Publications**

Kollenkark, J. C., V. C. Vanderbilt, C. S. T. Daughtry and M. E. Bauer. 1982. Influence of solar illumination angle on soybean canopy reflectance. Applied Optics 21:1179–1184.

# Data Processing and Analysis Research



Scanner data obtained from aircraft or satellite systems often contain errors and distortions which make it difficult if not impossible to analyze the data for earth resources information. Prior to analysis, therefore, various operations must be carried out on the data to make them optimally useful, and these operations are the focus of the Data Processing Research group.

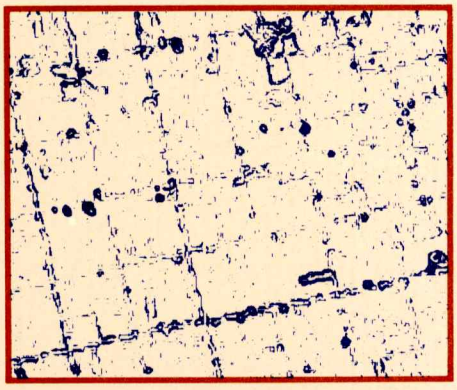
The operations performed on the data fall into three general categories: geometric operations, radiometric operations, and enhancements. Geometric operations correct spatial distortions introduced by the sensor and its vehicle and then transform the data into some desired frame of reference. Radiometric operations correct errors in the sensor measurements and then transform these into a desired numerical scale. Enhancements are transformations which make the data more useful in one of several ways such as sharpening edges in an image or reducing the complexity of an image.

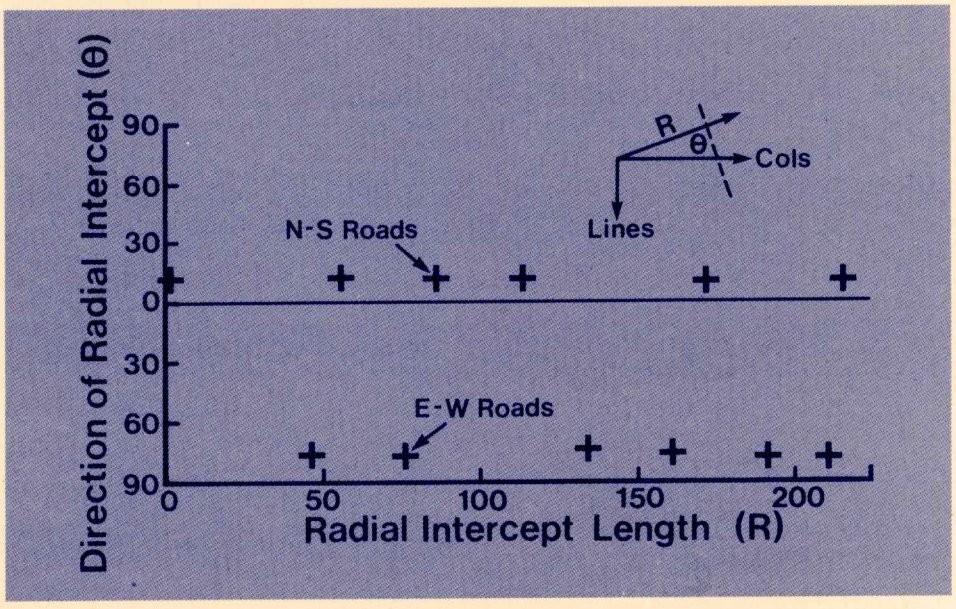
## Data Registration

Work during the year focused on the problem of combining or registering remote sensor images which were obtained at different times or from different sources. This problem has been studied since the beginning of the aerospace remote sensing era but remains unsolved. In particular, existing registration processors continue to fail when drastic differences exist in the scenes, as may be the case for scenes from an agricultural area in May and August.

The approach of current research is to use image analysis techniques to locate temporally invariant features in the scene pairs. One method transforms the scene into edge segments and analyzes those edges to identify roads and other linear features.

Improvements in techniques for registering data from different dates will allow more accurate mapping of earth resources and detection of changes in earth surface condition.







## Philip H. Swain

**Associate Professor, School of Electrical Engineering; Leader of Data Processing and Analysis Research Program**

B.S., Lehigh, Electrical Engineering; M.S., Ph.D., Purdue Electrical Engineering


Dr. Swain's research interests include image processing, pattern recognition, parallel processing systems, artificial intelligence and man/machine interaction. He is a member of the NASA Panel on Imaging Science, lecturer on remote sensing data analysis for George Washington University, a member of the Pattern Recognition Society and a senior member of the Institute of Electrical and Electronics Engineers. Dr. Swain is a member of four honorary societies — Sigma Xi, Tau Beta Pi, Eta Kappa Nu, and Phi Beta Kappa — and was recognized for service to the IEEE Computer Society for organizing the Central Indiana Chapter and serving as its chairman for two years.

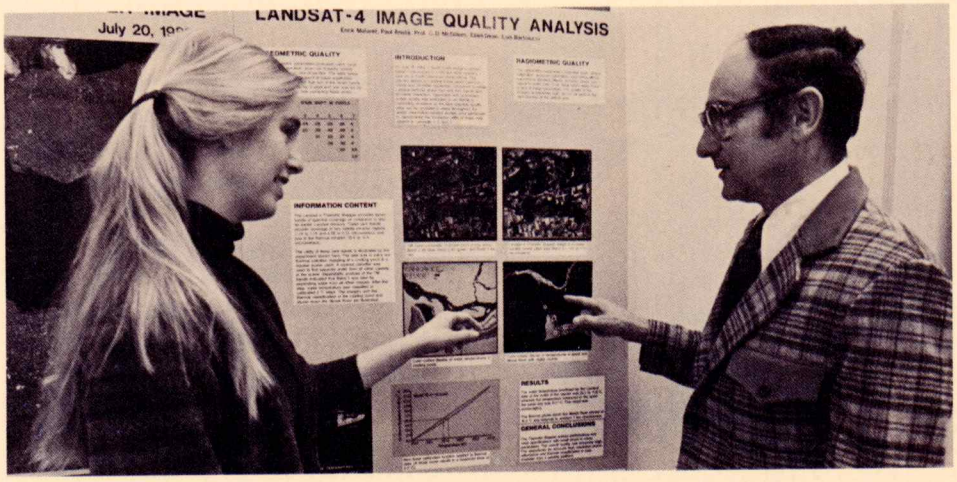
**Recent Publications**


L. J. Siegel, H. J. Siegel and P. H. Swain. 1982. Performance measures for evaluating algorithms for SIMD machines. IEEE Trans. Software Engineering SE-8:319–331.

P. H. Swain, V. C. Vanderbilt and C. D. Jobusch. 1982. A quantitative applications-oriented evaluation of Thematic Mapper design specifications. IEEE Trans. Geoscience and Remote Sensing GE-20:370–377.

J. C. Tilton, P. H. Swain and S. B. Vardeman. 1982. Estimation of context for statistical classification of multispectral image data. IEEE Trans. Geoscience and Remote Sensing GE-20:445–452.

Right. **Paul Anuta and Ellen Dean put the final touches on a poster paper describing their work in evaluating the geometric and radiometric characteristics of Thematic Mapper data.**




## Evaluation of Landsat-4 Data Quality

The Landsat-4 satellite, launched in 1982, carries two multispectral scanners which view the earth along 185km swaths from an altitude of 705km. One sensor, the Thematic Mapper (TM), which provides data in seven spectral bands at a resolution of 30m, is expected to greatly increase information about the surface of the earth.

At LARS, the geometric and radiometric quality of these data are being evaluated to aid NASA in its ability to provide data of high quality. Early results indicate that the data quality from the new sensor is extremely high with only minor errors in geometry and radiometry.

Landsat-4 also carries a multispectral scanner (MSS) similar in coverage to the ones on Landsat 1, 2, and 3 but with an 80m resolution. The difference in data quality between these two systems is striking. In addition to higher resolution, the TM data have a lower overall noise level than the MSS data.

Facing page. Above. **An aerial photograph of an agricultural site in Iowa provides context for an edge and line enhancement of a portion of the same area using Landsat-3 data.** Below. **The Hough transform of major roads represents each road by an angle and a radial distance from the origin; the crosses identify the correct location of twelve of the roads in the scene.**

## Development of an Interactive Georeferenced Information System

During 1981–82, LARS pursued the development of data processing technology for remote sensing through research sponsored by the COMTAL/3M Corporation. A manufacturer of state-of-the-art image processing systems, COMTAL is interested in developing applications of its equipment. The important role such equipment can play in remote sensing image analysis is well known. LARS utilizes a COMTAL Vision One/20 image processing system as an adjunct to its LARSYS software to facilitate interactive classifier training and provide a facility for color display of data and analysis results.

LARS has proposed to design and implement a georeferenced information system (GIS) in which remote sensing image processing via the COMTAL Vision One/20 would be a key component. Such a GIS, incorporating data from a diversity of remote sensing and other sources, would have broad applicability in such fields as geography and land-use planning, geologic mapping and mineral exploration, agricultural inventory, forest wildland, wetland monitoring, etc.

LARS has this year implemented clustering, a key remote sensing data analysis algorithm, on the COMTAL system for such purposes. We have also produced tutorial materials which are now used by COMTAL to introduce new users of the Vision One to its considerable array of image processing capabilities.

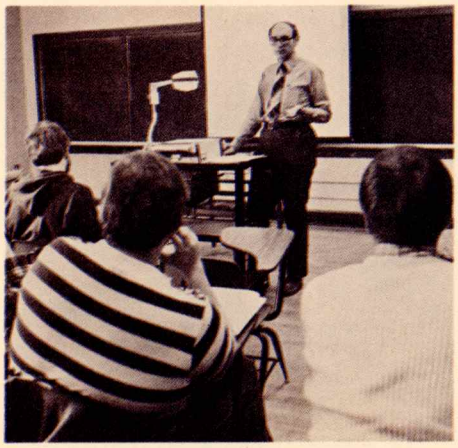
**Paul E. Anuta**

**Associate Leader for Data Processing and Analysis Research Program**
B.S.E.E., Purdue; M.S.E.E., Connecticut

Mr. Anuta's research interests lie in the development of image processing technology for earth surface resources mapping, geophysical imagery, and military reconnaissance, with particular emphasis on methods of combining dissimilar data types for multivariate digital analysis. He is co-chairman of the International Society of Photogrammetry Working Group on Image Processing, a member of the American Society of Photogrammetry, and senior member of the Institute of Electrical and Electronics Engineers. Mr. Anuta received the Talbert Award from the American Society of Photogrammetry for a technical paper.

**Recent Publication**

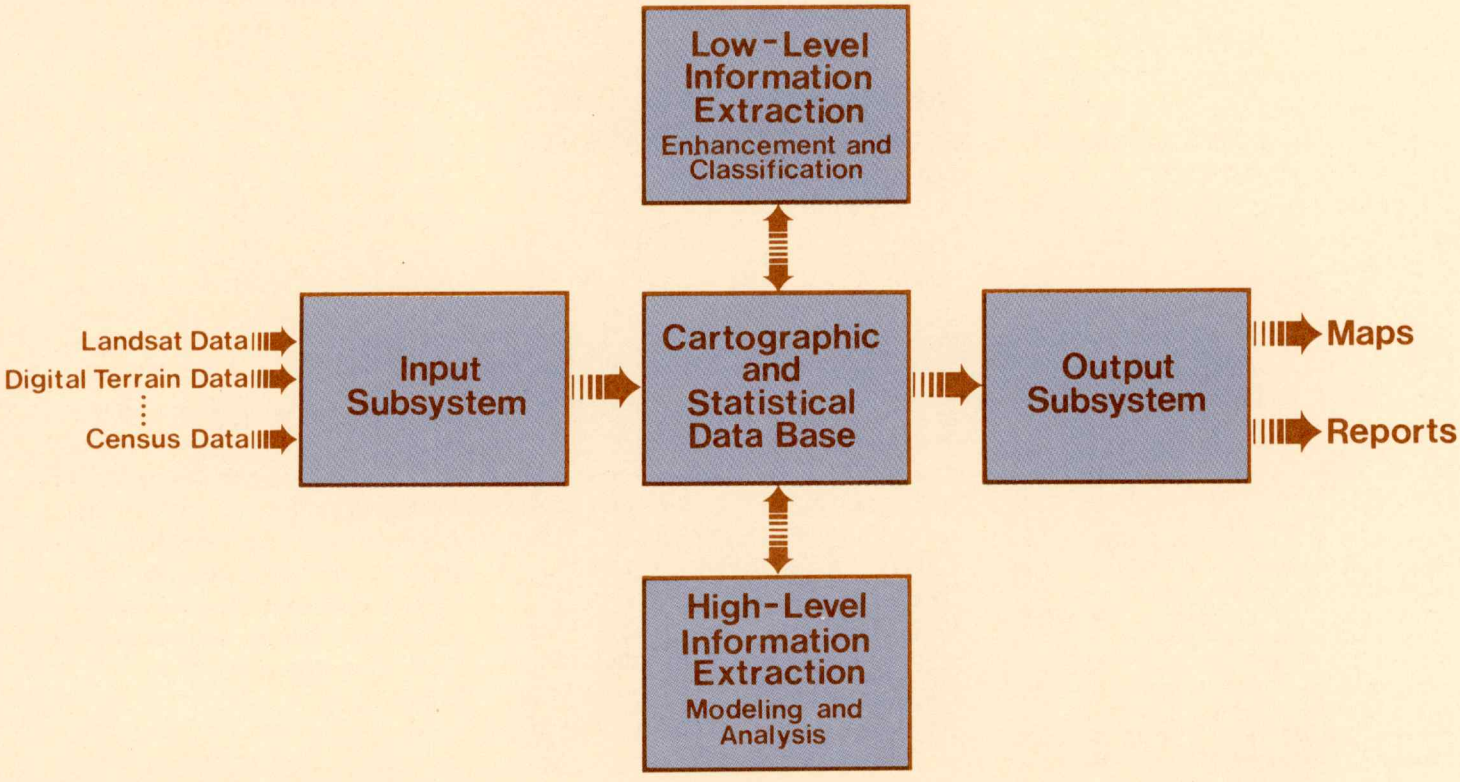
Anuta, P. E. and F. Davallou. 1982. Resolution matching for registration of dissimilar images. **Proceedings of the IEEE Computer Society Conference on Pattern Recognition and Image Processing,** Las Vegas, Nevada.



Above. **Phil Swain lectures to his electrical engineering class about georeferenced information systems.**

The evolving importance of georeferenced information systems in the practical application of remote sensing technology was reflected in other activities at LARS during the year. A large project involving the development of a prototype GIS for the government of Bolivia is noted elsewhere in this report. In addition, Purdue/LARS co-sponsored, with Yale University, a two-day Geographic Information Analysis Workshop, which was held at Purdue in July in conjunction with the annual Symposium on Machine Processing of Remotely Sensed Data.

Below. **Five major components of a georeferenced information system provide a way for analysts to derive useful information from merging Landsat data with data from diverse sources.**




## David A. Landgrebe

**Associate Dean of Engineering; Director of the Engineering Experiment Station**

B.S.E.E., M.S.E.E. Ph.D., Purdue, Electrical Engineering

Dr. Landgrebe's research interests include signal representation, systems, and data processing. Director of the Laboratory for Applications of Remote Sensing from 1969 to 1981, he has chaired a number of National Academy of Sciences and NASA study groups and advisory committees, including panels that contributed to the design of the Landsat program and the specifications of the Thematic Mapper. He is a member of NASA Space Science Board's Committee on Data Management and Computation, Associate Editor and member of the editorial board of Remote Sensing of the Environment Journal, a fellow of the Institute of Electrical and Electronics Engineers, a member of the Administrative Committee of the IEEE Geosciences and Remote Sensing Society, and numerous other professional and honorary societies. Dr. Landgrebe was awarded the NASA Exceptional Scientific Achievement Medal for his work in machine analysis methods for remotely sensed earth resources data.

**Recent Publications**

Landgrebe, D. A. Land observation sensors in perspective. Invited paper, Remote Sensing of Environment. (in press)

Kalayeh, H. M. and D. A. Landgrebe. Predicting the required number of training samples. IEEE Transactions on Pattern Analysis and Machine Intelligence. (in press)

Kalayeh, H. M., M. J. Muasher, and D. A. Landgrebe. Feature selection when limited number of training samples are available. IEEE Transactions on Geoscience and Remote Sensing. (in press)

## System Services

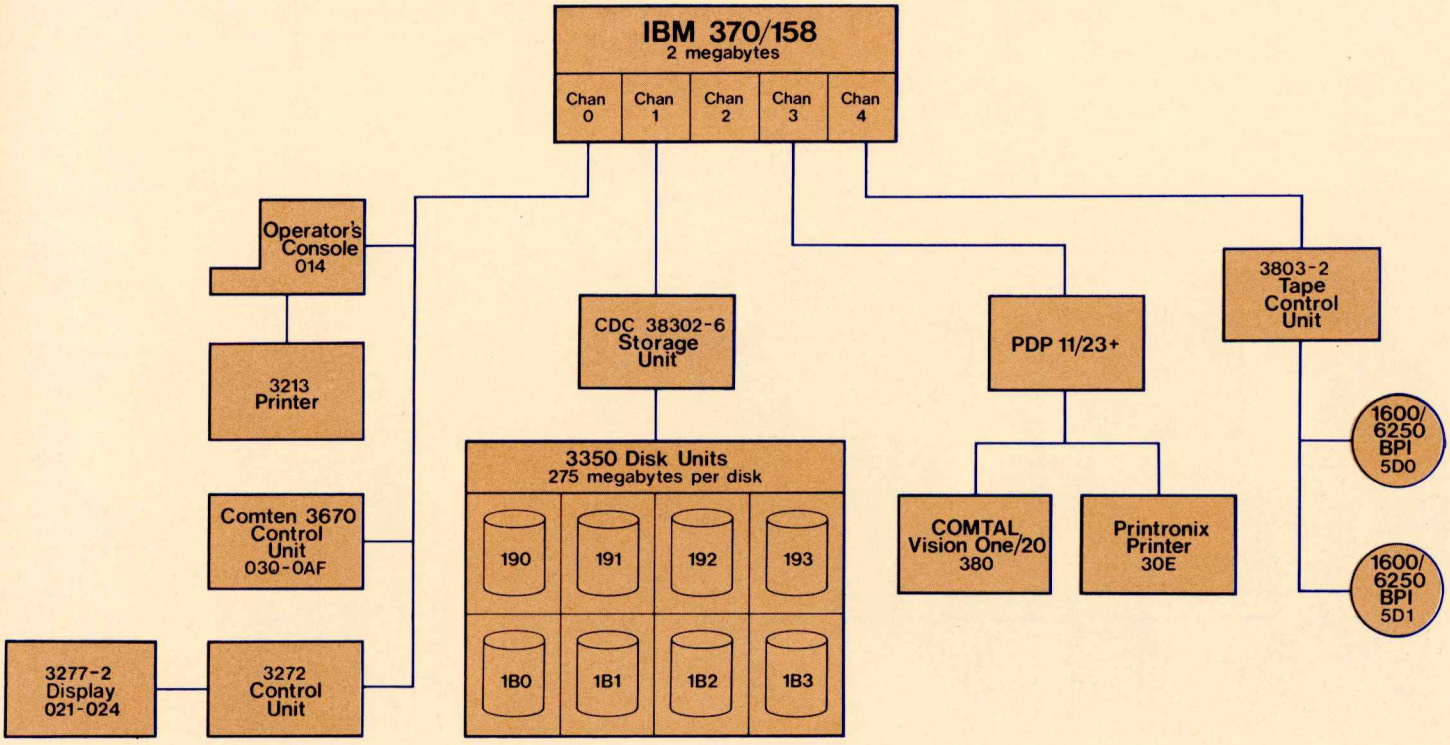
The primary objective of LARS System Services is to provide a computing capability to support research and educational projects at LARS and Purdue University. Hardware, software, policies, and organization are all oriented toward meeting this objective. In addition, the computer at LARS is used via network access for remote sensing research by groups throughout the United States.

The primary users of the facility this year were NASA projects at LARS and at the Johnson Space Center, LARS Technology Transfer programs, the National Pesticides Information Retrieval System, and many university users. Most of these projects are described elsewhere in this report. The system significantly adds to the computational tools available to all Purdue University researchers; university users come from departments in every school at Purdue.

LARS has elected to provide researchers with a highly interactive, multi-user, general-purpose computing environment. This approach maximizes the accessibility of software tools and the speed and ease of program development. The LARS system offers the following ensemble of benefits:

- Access to a system designed and tuned to large-scale interactive, research computing
- Access to a standard operating system
- Access to IBM hardware and software
- Access to widely recognized software packages which are uniquely available on IBM systems (e.g., SAS)
- Access to a wide variety of remote sensing software and data

Below. **Configuration of LARS computer system.**




### James L. Kast

**Manager of User Services**
B.S., Purdue, Mathematics; M.S. Purdue, Management

Mr. Kast's professional interests lie in the development of a service-oriented data processing environment for research and applications by a scientific user community and of networks and data bases capable of supporting coordinated research programs at geographically dispersed locations. During the past year he managed the evaluation, installation, and implementation at NASA's Johnson Space Center of a data base management system for earth resources research and assisted in the development and implementation of the National Pesticides Information Retrieval System. Mr. Kast is a member of the Data Processing Management Association and of Phi Beta Kappa, Phi Kappa Phi, Phi Eta Sigma, and Beta Gamma Sigma honorary societies.

### S. Kay Hunt

**Manager for Software Products**
A.B., Indiana, Mathematics

Ms. Hunt supervises the design, implementation, upgrading and documentation of application software products and special software services. She also provides consulting and educational support for users of the LARS computer. Ms. Hunt's recent work has been in developing digitizing and data base software. She is a member of Alpha Lambda Delta, Enomene, Pleides, and Mortar Board honorary societies.

The principal software products currently implemented on the system are:

LARSYS — an integrated set of computer programs written to aid an analyst in a quantitative analysis of multispectral digital data through pattern recognition.

LARSPEC — a system of computer programs used to access and analyze data obtained by spectrometer or multiband radiometer systems that have been developed for laboratory or field research.

SAS and SPSS (Statistical Analysis System and Statistical Package for the Social Sciences) — computer programs for data analysis including information storage and retrieval, data modification and programming, report writing, statistical analysis, and file handling.

SASGRAPH — programs for high resolution graphics terminals, pen plotters, and/or graphics matrix printers.

IMSL — a set of routines for the development of scientific and engineering applications programs; contains over 400 subroutines covering the general fields of mathematics and statistics; from the International Mathematical and Statistical Libraries.

GCS (Graphics Compatibility System of the U. S. Military Academy) — designed for use in a wide variety of computer graphics terminals.

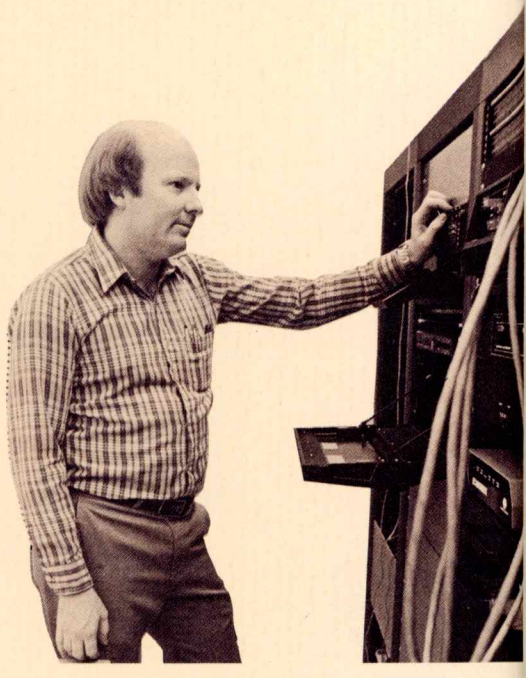
IGL (Interactive Graphics Library) — a structured, modular approach to interactive graphic techniques, capable of working within the concepts of distributed graphics processing and host-and-device independence.

SCRIPT — a word processing system from the University of Waterloo.

ADABAS — a sophisticated data base management system for the support of storage and retrieval systems.

Below left. **A microcomputer-based digitizing system developed by Kay Hunt and Terry Phillips offers analysts a way to prepare ancillary data for further processing.**

Below. **Gary Brammer checks out the communications link connecting users at remote sites to the LARS computer.**



## Gary M. Brammer

**Senior Computer Analyst**
B.S.E.E., M.S.E.E., Texas

Mr. Brammer's activities have focused on the integration of computer systems and on intercomputer communications. He is a member of Eta Kappa Nu and Tau Beta Pi honorary societies and IEEE.

## B. Catherine Kozlowski

**Systems Analyst**
B.A., Knox, Mathematics; M.L.S., Indiana; M.S., Purdue, Computer Science

Ms. Kozlowski's professional interests lie in developing the use of computers to solve research problems. At LARS, she has developed programs to register data from different sensors.

## National Pesticide Information Retrieval System

The National Pesticide Information Retrieval System (NPIRS) is being developed at Purdue University through a cooperative agreement with the U.S. Department of Agriculture.

NPIRS is a computer-based data resource that contains information describing key characteristics of all pesticide products registered by the U.S. Environmental Protection Agency and participating state regulatory agencies. The NPIRS currently operates as a Cooperative Pilot System (CPS) that includes nine states plus the USDA, USEPA, and a manufacturer representing the pesticide industry. The pilot operation makes use of ADABAS implemented on the LARS computer.

The fully operational NPIRS, with up-to-date pesticide information, is scheduled for release in October 1983. The system, which can be accessed through a dial-up computer terminal, will be available on a subscription basis.


## Systems for the Acquisition of Field Data

The LARS field data acquisition capability is based on three instrument systems, the Exotech Model 20C wide-range spectroradiometer, the Exotech Model 100 Landsat-band radiometer, and the Barnes Model 12-1000 Thematic Mapper-band radiometer. The Barnes instrument was developed through a joint effort of LARS, Barnes Engineering, NASA, and USDA.

The spectroradiometer is mounted on a mobile aerial tower and the radiometers are mounted on a specially developed pick-up truck platform. All three systems have been equipped to acquire simultaneous boresighted radiant temperature and photographic data.

Illumination for laboratory studies is provided by a bi-directional reflectance factor reflectometer. The reflectometer includes a 1000 watt lamp for incident illumination from 0.5-2.3 μm. The incident illumination can be rotated from 5 to 55 degrees.

Left. **Luke Kramer monitors the system load from the operator's terminal of the IBM 370.**


### Luke Kraemer

**Data Base Manager for NPIRS project**
B.S., Purdue, Computer Science

Mr. Kraemer's professional interests involve data base systems and computer applications in sports. A member of Phi Beta Kappa, he is a consultant to the Indiana University football team.

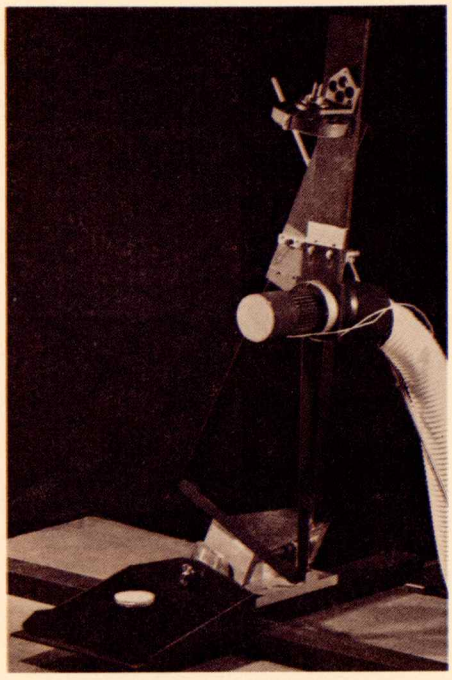
### Eileen M. Luke

**Systems Analyst**
B.S., California-Davis, Mathematics; M.S., Purdue, Statistics

Ms. Luke's professional interests lie in statistical computing and the design of data bases for statistical analysis. She has assisted in the development of a weather data base for NASA's Johnson Space Center and in statistical analysis of leaf-area index. A member of the American Statistical Association, Ms. Luke has provided statistical consulting to research staff in agronomy, entomology, industrial management, animal science, and mechanical engineering.

## Data Base for Field Spectral Measurements

The LARS field research data base includes more than 200,000 spectral observations of crops and soils along with agronomic measurements such as leaf area index and fresh biomass. These radiometer and spectroradiometer data are calibrated, correlated, and verified before being entered into the data base. These data, stored on 29 computer tapes, are available to the remote sensing community by request through the NASA Johnson Space Center. Institutions can also access the data directly via dial-up terminal to the LARS computer and the LARS-developed LARSPEC software.



## Soil Sample Collection

A growing collection of "benchmark" soil samples from around the world is available for research at LARS. They are used for quantitative study of the correlation between reflectance and physical/chemical properties of soils, work which is essential for improving our capability to analyze and interpret satellite-derived scanner data for inventorying and monitoring soil resources.

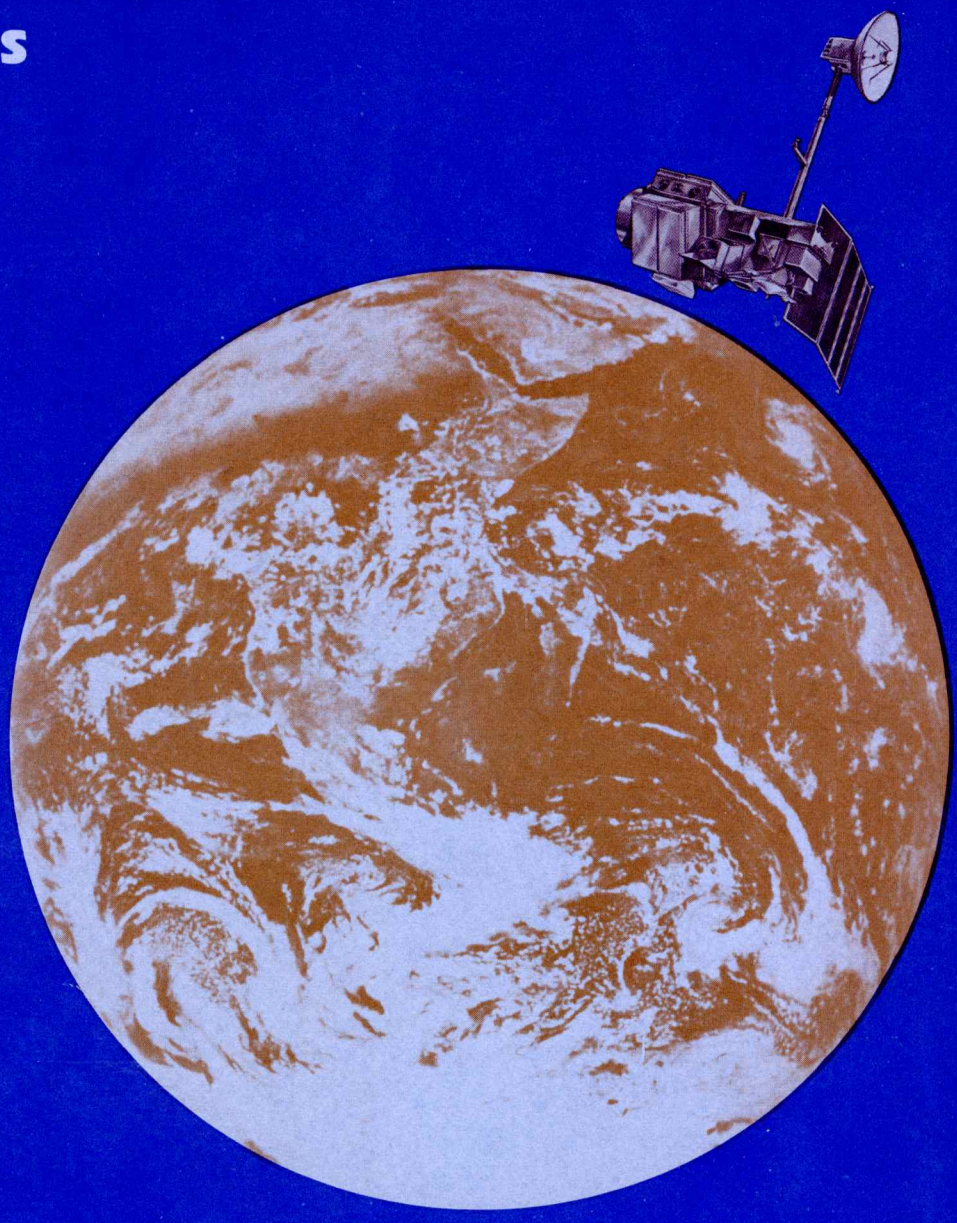
Left. **The bidirectional-reflectance-factor reflectometer for indoor studies includes a 1000-Watt, tungsten-iodine, coiled filament lamp, transfer optics, and a sample stage.**

# Future Programs

Information is a valuable resource. Quantitative information about the current status and the rates of change in global land, water, vegetation, and mineral resources becomes increasingly valuable as demands for these resources multiply. A key to more intelligent utilization and management of earth resources is an improvement in the flow of information to decision-makers and policy-makers.

If current trends persist, remote sensing technology will best be utilized in the future as an essential component of resource information management systems in which data are referenced to specific areas on the earth surface. In the remote sensing research community, increasing emphasis is being placed on the development of geographic information systems (GIS).

Purdue University, with its broad base in the engineering and natural sciences, can continue to play an important role in the development of remote sensing technology and resource information systems. The future will continue to challenge the research community to improve the delivery of useful, accurate, and timely information to resource managers and decision-makers.



**For further information about LARS staff expertise, educational programs, or research activities, contact:**

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