LABORATORY FOR APPLICATIONS OF REMOTE SENSING

Annual Report to the University

Fiscal 1974

Purdue/LARS
1220 Potter Drive
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PURDUE UNIVERSITY
LABORATORY FOR APPLICATIONS OF REMOTE SENSING
TO AGRICULTURE, EARTH RESOURCES, AND MAN'S ENVIRONMENT
PURDUE INDUSTRIAL RESEARCH PARK
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WEST LAFAYETTE, INDIANA 47906

1973-74 Report to the University
The Laboratory for Applications of Remote Sensing

This report covers the period July 1, 1973 through June 30, 1974. It provides a summary of research and development activities and the training functions carried out with contract funds. It also documents the amount of staff and student involvement and the manner in which funds were expended as a function of academic unit. It is appropriate to compare these activities with the currently approved statement of LARS objective which is

> To support the major objectives of the university by attacking in an interdisciplinary environment, specific problems of current national interest in the areas of the earth's resources, physical measurements, and the machine processing of data, and in the process, to provide relevant research topics for both faculty and students.

Based upon this objective, not only are research accomplishments important to us, but also the degree of faculty and student involvement in the effort. By this measure it has been another most productive year.

David A. Landgrebe
Director

Distribution:

The President
The Provost
The Policy Committee
The Management Committee
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The Division of Sponsored Programs

LABORATORY FOR APPLICATIONS OF REMOTE SENSING

ANNUAL PROGRAM REVIEW

FISCAL 1974

LARS PROGRAM REVIEW
FOR FISCAL YEAR 1974

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RESEARCH ACCOMPLISHMENTS

I. INTRODUCTION

Research during FY74 at the Laboratory for Applications of Remote Sensing (LARS) built heavily on earlier accomplishments by the Laboratory. Reacting to the obvious future need for methods of handling large quantities of data expected from satellite systems LARS personnel as early as 1964 concentrated on methods of processing data by machine. Aircraft scanner data missions in the early years were utilized to develop high speed analysis techniques. In 1964 it was demonstrated that film data of nine different wavelengths could be used to separate visually green vegetation, bare soil and water.

These results prompted a quantitative approach with three major endeavors:

1. Pattern recognition techniques.

2. Digital data handling methods.

3. An interdisciplinary approach using both physical scientists and life scientists in devising and utilizing a suitable analysis system.

By the end of 1970 the use of multispectral scanner data and machine analysis techniques to identify spectrally and delineate features of the landscape was greatly improved.

The leadership which the LARS staff gave to the 1971 Corn Blight Watch Experiment demonstrated the capability of remote sensing for inventorying surface features over large areas. Techniques developed in that study led readily into research by the Laboratory staff in the application of data from ERTS-I to important resource problems on earth. Research in FY74, as in FY73, heavily utilized ERTS-I imagery as a basis for research not only in the applications of remote sensing but also in improving the techniques of mechanically processing, analyzing and presenting multispectral scanner data.

By the time ERTS-I was launched research in remote sensing had produced several machine processing algorithms useful for both preprocessing and analysis of data. Some of these algorithms were embodied into a software system known as LARSYS, a system which was thoroughly tested using aircraft scanner data. Thus, an important task with the launch of ERTS-I was to test this

processing method relative to the high volume, high quality data which ERTS-I was designed to produce. Also, an important purpose of these studies was to test the rapid turn-around possibilities of the analysis and the quality of the data being produced by the satellite. This type of research, initiated in FY73, was continued through FY74.

The success of ERTS-I over the last two years and the prospects of launching ERTS-II have led remote sensing research into three main areas.

One involves the improvement and applications of ways to use temporal data. Previous successful research into methods for image data registration coupled with the ready availability of data from repetitive coverage of the earth by ERTS-I provided the opportunity for research in deriving additional information from such data.

A second has to do with the growing necessity to develop methods for successful data analysis without a great reliance on on-the-ground in situ observations. This effort is stimulated by the ability of satellites to gather data over such large areas in such short times.

The third and largest area of attack at LARS is in the application of remote sensing technology to real problems, particularly those of relating to natural resources on earth.

II. WORK IN PROGRESS

A. DATA PROCESSING AND ANALYSIS RESEARCH

Research at LARS in processing and analysis of remotely-sensed data has led to basic concepts and capabilities which today are widely accepted and are being utilized in a broad range of both research-oriented and near-operational earth resources data processing systems. Work continued through FY74 to improve the effectiveness and efficiency of using spectral, spatial and temporal content of earth observation data.

1. Data Analysis Research

Utilization of Temporal Information.

A systematic study of the extraction and utilization of temporal information was pursued. An analysis was made of the value of the temporal dimension for crop species classification and urban change detection. ERTS-I MSS data from several dates were digitally registered and analyzed, using multispectral pattern recognition techniques. The results were encouraging, indicating that temporal data may significantly improve crop series classification. Equally impressive results were obtained in applying this method to general land use mapping.

Spectral Class Definition.

Characterization of spectrally discriminable classes is crucial to the practical application of machine processing methods to remote sensing data. Research has continued in the improvement of cluster analysis, a powerful technique in spectral characterization, the potential of which has not been fully developed. It is a particularly important technique where in situ ground observations are limited.

Research through FY74 was aimed at refinement, implementation and evaluation of both feature space and parameter space clustering algorithms. Refined procedures were developed for applying cluster analysis to remotely-sensed data, particularly with emphasis on defining "distinguishable clusters." This year's results contributed to automation of remote sensing data analysis by providing the user with a new and useful tool.

Extraction and Analysis of Spatial Information.

Multispectral information alone is not always sufficient for the characterization of ground cover classes of interest. An example has been the tendency for data clearly within urban areas to be classified as wheat. As a step in classification, an algorithm was developed which implemented partitioning of a digitized multispectral image into parts corresponding to objects being sensed. A common approach has been to classify each image point separately using the reflectance of each point in various spectral bands. Such a classification using point-by-point methods has been successful in many applications. However, in some cases classification accuracy has been too low. The method as developed was found to give accurate results in classifying agricultural areas and extracting urban areas.

2. Data Handling Research

Multispectral Image Registration.

Advances in the techniques for registration of multiple images of the same scene have enhanced the utility of multispectral and multitemporal data sets. The existing implementation of the algorithms for such registration is suitable for highly correlated images but not for relatively uncorrelated ones. For the latter type manual techniques are necessary. Effort has continued to research and evaluate algorithms for improved image registration.

Geometric Correction of MSS Data.

Research was directed to develop techniques to improve the geometric quality of the ERTS digital data for research

purposes. Interfacing of remote sensing data with maps and other forms of ground data is still an important step in the application of such data to the terrain areas.

ERTS-I multispectral scanner data is received from the satellite by NASA, processed, and delivered to users, recorded on computer compatible tape and in photographic form. The computer tape form of the data is calibrated and line length adjusted by NASA but no geometric corrections are applied. The system-corrected photographic products are corrected for many geometric distortions including earth rotation effects in addition to the above two corrections. Also, these images are rescaled so that the horizontal and vertical scales are the same. Thus, the digital form of the MSS data contains many geometric distortions and users of these data are faced with the problem of compensating for these errors.

Two procedures were studied, theoretical geometric correction and geometric correction using ground control points. Correction by the theoretical transformation uses no reference points. It is an affine transformation based on estimated values of digital aspect ratio, orbit inclination and satellite velocity. By application of the nearest neighbor rule an average of about 20M or 66 feet of position error is introduced. The overall accuracy of the correction is about 1 per cent.

Geometric correction using ground control points was applied to images which were first corrected for scale, rotation and skew by the theoretical transform. When the recorrected data were overlayed on a USGS 7 1/2 minute quad no error could be visually observed and the estimate of error using a quadratic polynomial was .6 of a resolution element RMS or about 48 meters. This approach is promising for accurately correcting ERTS type data to map coordinates, albeit still involving laborious manual checkpoint finding process.

Preprocessing Algorithms.

An optimum procedure for correcting for the effect of finite size of the instantaneous field of view in scanning sensors has been developed. This procedure includes special design for the scanner instantaneous field of view (IFOV) and an associated preprocessing algorithm.

B. MEASUREMENTS RESEARCH

1. Reflective and Emissive Properties of Natural Materials

The Measurements Research Program at LARS continued to concentrate on the development of specialized instrumentation for the acquisition of *in situ* spectral reflectance data. Work continued on the improvement of the field spectroradiometer system previously designed, developed and constructed at LARS. Measurement techniques were improved by the development of a procedure for the rapid acquisition of bi-directional reflec-

tance factor data distributed over a hemisphere of observation angles for agricultural fields. Also, a high intensity source goniometric device which enables the field spectroradiometer to be used indoors as a large sample spectral reflectometer during the winter months was designed, constructed and implemented. Calibration procedures were improved by the design and construction of field operable sources capable of calibrating the response of the instrument in the visible, near infrared and thermal infrared portions of the spectrum. Improved calibration and instrumentation procedures have made possible the application of spectral-temporal data to such questions as crop maturity and yield..

Basic studies to determine the quantitative relationships between spectral and emissive properties of vegetative canopies and their geometric characteristics were continued. It was shown that geometric effects dominate the response of a non-systemic stressed corn canopy in the spectrum from 0.4 to 14 micrometers and that a thermal channel contributes significantly to the use of aircraft multispectral scanner data in the classification of stressed vegetation. Digitized photographs and multispectral data from Skylab and multispectral data from ERTS were compared in a machine-aided land use analysis of Lawrence County, Indiana. In this study it was found that a spectral band in the region of 1.5 to 2.0 micrometers could significantly aid in the classification of multispectral scanner data gathered from space.

2. Electrical Measurements of Available Soil Moisture Profile

Theoretical research continued through the year has indicated that the available soil moisture profile can be inferred from surface measurements with a VHF source and a magnetic (or electric) field measurement. In addition, previous work has related the electrical properties of the soils under study to their available soil moisture content.

3. Atmospheric Modeling

Studies were made of the atmospheric effects upon aircraft sensing of Earth surface properties and correction of ERTS MSS data.

A detailed model of atmospheric scattering and absorption properties was employed in order to relate energy reaching the aircraft or satellite to that leaving the earth's surface. Results indicated from 0 to 12 per cent range of error in surface reflectivities over natural vegetation surfaces could be expected.

ERTS MSS measurements were found to be particularly sensitive in the near infrared to variations in atmospheric water vapor content. These results emphasize that spatially variable meteorological information will be required, in addition to spectrally variable properties in order to improve existing classification techniques.

C. CROP PRODUCTIVITY INVESTIGATIONS

In response to the current great need for information on world crop production, scientists at LARS began concentrating in FY74 on developing a remote sensing capability to achieve such information on a world wide scale. Remote sensing is potentially a useful tool for obtaining both acreage and yield information, the two kinds of knowledge essential to accurate estimation of production.

The feasibility of crop identification by analysis of MSS data has been clearly demonstrated. In the 1971 Corn Blight Watch Experiment major crop species were accurately identified using aircraft scanner data. More recently ERTS MSS data collected over northern Illinois were successfully classified as corn, soybeans or other. Classification accuracies were similar to those previously obtained from aircraft data. Of most significance, areas as large as 2,000 miles were successfully classified in one analysis.

Encouraged by these advances, LARS in FY74 in cooperation with scientists from the NASA Johnson Space Center, Houston, Texas, began a research program to develop a capability to inventory world wide wheat production, known as the Large Area Crop Inventory Project (LACIE). Plans were developed to improve techniques for converting classification data to area estimates and to obtain crop yields by other than conventional ground level surveys.

1. Crop Identification

Research to quantify the classification performance for crop identification from ERTS data was initiated. ERTS data collected over six Indiana and Illinois test sites during the 1973 growing season have been classified. Evaluation of the results is now underway.

2. Crop Acreage Estimation

Research was initiated to perfect a method of converting crop identification data obtained from classifications of satellite data to acreage estimates. Research has been designed and is underway to develop improved methods to replace the few simple techniques currently available.

3. Crop Yield Prediction

Little work has been done on crop yield prediction, an essential element of a capability to predict crop production. Field research was undertaken in FY74 to determine the effect of major factors affecting corn and soybean yield on the

spectral reflectance of crops. Planting date, plant population, nitrogen deficiency and moisture stress were studied. The data have been collected and analysis has begun. The results may lead to a capability to assess crop condition with reflectance measurements made from satellite sensors. Work will be continued to relate the measured spectral reflectance of the crop to its expected yield.

Plans were laid for an extensive research effort to develop and evaluate procedures for assessing crop condition and predicting yield.

D. SOIL RESOURCES RESEARCH

1. Soil Survey

Research at LARS in FY74 resulted in a capability for interfacing soils maps and ERTS multispectral imagery. This was done by producing a rectified ERTS multispectral image on the digital image display and making a hard copy. The soils map was then reduced or enlarged photographically to the scale of the ERTS image and overlayed on the ERTS image as a transparency. The resulting product permitted for the first time, a precise comparison of soils maps and ERTS imagery.

Procedures developed in the past year have formed the basis for current research on a four-state program in cooperation with the Soil Conservation Service, USDA, in which ERTS imagery will be used exclusively. The purpose will be to determine the best procedures for using ERTS imagery as an aid to soil survey and its relative efficiency and effectiveness.

2. Spectral Properties of Soils

Advances were made through the year in relating spectral properties of soils to their other physical characteristics. ERTS-I data obtained during 1972 and 1973 over test sites in the central United States were used in identifying and mapping differences in soil patterns, species and condition of cultivated crops and conditions of rangelands. Multispectral scanner data from multiple ERTS passes made possible studying temporal changes in the scene. Also, geometric correction of the digital data for several dates and several test sites facilitated the task of comparing analytical results with other maps and data sources.

Mapping Soils and Rangelands by Machine Analysis of Multi-temporal ERTS-I Data.

Multispectral classifications delineating soils boundaries in different test sites compared well with existing soil association maps prepared by conventional means. Furthermore, multispectral analysis of ERTS-I data were found to provide patterns in rangelands which can be related to soil differences, range management practices, and the extent of infestation of the range with mesquite (Prosopis fuliflora) and juniper (Juniperus spp.).

Machine-Aided Analysis of Land Use - Land Form Relations From ERTS-I MSS Imagery in Sand Hills Region, Nebraska.

Machine-aided analysis of ERTS-I MSS data obtained over the Sand Hills of Nebraska indicates that reasonably accurate soils maps can be produced automatically. Interpretation of spectral class, spatial contribution and statistical character allows confident assignment of soil and cover type names to computer classes. Correlation between computer maps and USDA soils maps of the same areas was high. Interpretation of machine maps yields information concerning land use, physiographic, soil and hydrologic patterns of the region.

Research further indicated that information on soils can be incorporated into the sampling strategy to reduce the variability of signatures from vegetative ground cover types. Stratification on the basis of soils information is expected to permit decreased sample size and increased accuracy in recognizing cover types.

3. Engineering Soils Mapping

The relationships between spectral responses of soil and soil textural groups, engineering soils groups and land forms were studied. Non-supervised analysis failed to show a consistant relationship between land form type and soil spectral class.

Supervised analysis results showed a strong relationship between soil texture and soil spectral class and a moderately strong tie between engineering soils groups and their respective spectral classes. A weak association existed between land form type and soil spectral class.

E. LAND USE

1. Land Use Classification of Marion County, Indiana By Spectral Analysis of Digitized Satellite Data

Multispectral scanner data, obtained over Marion County (Indianapolis), Indiana at an altitude of 915 kilometers, were analyzed by computer-implemented techniques to evaluate the utility of satellite data for urban land use classification. Several land use classes, such as commerce/industry, single-family (newer) residential, trees, and water exhibited spectrally separable characteristics and were identified with greater than 90 per cent accuracy. Difficulties were encountered in the spectral separation of grassy (open) agricultural areas and multi-family (older) housing. The confusion between these two classes was largely eliminated, however, when spectral characteristics of samples (instead of individual data points) were considered. Another solution to the problem consisted of spatially dividing the data into urban and rural land uses prior to classification. Over 95 per cent accuracy of recognition may be achieved by this "preprocessing" step in an analysis.

2. Land Use Inventory of the Great Lakes Watershed with Multispectral Data From ERTS-I

One of the major developmental type of research activities initiated in FY74 is a pilot study of a capability to map with remote sensing techniques land use for 85 million acres in eight states which drain into the Great Lakes. Besides testing the capability to make such a survey the end product will be useful in a joint United States-Canada effort to clean up the lakes. By processing data from ERTS-I, LARS is classifying each four-acre plot of the 191 counties involved into first level urban, agriculture, forest, or no-major-use (lakes, streams) areas. A second classification level is delineating eight sub-categories.

The project is successful. Useful data is being supplied to the Environmental Protection Agency, sponsor of the program through the USDA.

3. Urban Land-Use Mapping by Machine Processing of ERTS-I Multispectral Data: A San Francisco Bay Area Example

Computer-maps of a large segment of the San Francisco-Oakland and San Jose Urbanized Areas have been produced at a scale of 1:24,000 using a segment of an ERTS-I frame re-

formatting to correct skewness and scale. An area of some 4,500 square kilometers was also mapped at 1:48,000 (a one-fourth sample). For both scales, urban areas were separated from rural.

Classification was achieved by grouping twenty-eight spectral classes into eleven functional classes. Reliability was checked by comparing computer results to contemporaneous high-altitude color air photographs on a pixel-by-pixel basis. Performance results are high considering the grossness of the data and the complexity of the urban landscape.

F. ECOSYSTEMS RESEARCH

1. Interdisciplinary Analysis of Colorado Rocky Mountain Environments Using Automatic Data Processing (ADP) Techniques

The objective of this research was to determine if remotely sensed data and computer aided analysis techniques could be utilized to study natural resources of the mountainous environment. Previous research at LARS had determined that the data collected over relatively flat areas could be analyzed accurately and rapidly using computer aided analysis techniques. However, some question had occurred as to whether these techniques could be used in an area of high relief. In addition, cover types were known to be more complex, i.e. heterogeneous in area and in cover types present.

Ecological Inventory

Classification accuracies of 90 to 95 per cent were obtained in areas of other relief on a regional basis for general cover types (coniferous and deciduous forest, grassland, crop land, air rock, soil and water) using computer-aided analysis techniques and ERTS-I multispectral scanner data. The classification accuracies for more detailed cover types rapidly decreased to 70 to 80 per cent when attempted. This decrease in accuracy was due to the complexity of the cover types and the topographic influences on spectral response of the cover types present.

Areal estimates for Level I cover types using Computer-Aided Analysis Techniques (CAAT) were highly accurate, as shown by correlation coefficients greater than 0.973 when computer derived acreages were compared to acreage estimates obtained by standard photo-interpretation techniques.

Statistical analysis showed that in mountainous areas, spectral response of Level II forest cover types is significantly (0.99 level) influenced by variations in stand density, aspect, and slope, as well as differences between species.

Hydrological Features Survey.

Snow cover in a mountainous environment was accurately and rapidly mapped by using existing techniques and by overlaying and geometrically correcting the data to scale. Snow cover and clouds could not be reliably differentiated on the basis of spectral response of the ERTS-I data due to the detector saturation and available spectral range. The freeze-thaw sequence of mountain lakes were successfully monitored by computer aided analysis of ERTS data.

The freeze-thaw study of mountain lakes and the study of temporal changes in the areal extent of the snow pack both indicated that an 18-day data collection cycle was not adequate, particularly during the spring runoff. The ability to collect data only every 18 days was restricted by cloud cover problems which often decreased frequency of data collection to 36 or 54 days, a frequency which is unacceptable for many hydrological purposes.

Geomorphological Analysis.

Geological features such as sedimetry and igneous rocks were mapped by computer-aided analysis techniques. However, intrusive and extrusive rocks of similar chemical composition could not be spectrally differentiated by present techniques. Geomorphological features such as hogbacks, shell valleys and other earth forms were easily mapped by manual interpretation from data which had been spectrally classified.

Interpretation Techniques.

This investigation demonstrated that, in topographically complex mountainous areas, spectral reflectance is significantly related to elements of the terrain, primarily aspect, slope, and elevation.

Data Collection Platform.

The Data Collection Platform at 5036 meters on Niwot Ridge performed excellently in spite of environmental extremes. The data collected from this platform included temperature measurements at various elevations, wind, solar energy and other environmental parameters.

2. An Interdisciplinary Analysis of Multispectral Satellite Data for Selected Cover Types in the Colorado Mountains, Using Automatic Data Processing Techniques

Analysis of these data is underway to date and has resulted in successful mapping of a recent forest fire in the Mesa Verde National Park. This research resulted from cooperative effort between LARS personnel and the staff of the National Park Service at Mesa Verde National Park. All analysis and documentation is tentatively scheduled to be completed by May 31, 1975.

3. Comparison of Computer-Aided Analysis Techniques and Photo-Interpretation Methods for Inventorying Forest Lands (U. S. Forest Service and LARS)

The objective of this cooperative research between U. S. Forest Service personnel and the LARS staff was to evaluate data collected by ERTS over South Dakota, Colorado and Georgia. The results and analysis procedures of the investigation were turned over to the U. S. Forest Service personnel for evaluation. LARS methods will be compared to various existing photo-interpretation methods and other computer-aided analysis techniques to determine the advantages and disadvantages to the LARSYS approach.

4. Evaluation of Surface Water Resources From Machine-Processing of ERTS Multispectral Data

Research was 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.

All surface water bodies over 0.5 hectare were identified accurately from ERTS multispectral analysis. Five distinct classes of water were identified and correlated with parameters which included 1) degree of water siltiness; 2) depth of water; 3) presence of macro and micro biotic forms in the water; 4) presence of various chemical concentrations in the water. The results demonstrated that the machine-processing of ERTS spectral data used alone or in conjunction with conventional sources of hydrological information can lead to the monitoring of 1) area of surface water bodies; 2) estimated volume of selected surface water bodies; 3) differences in degree of silt and clay suspended in water; and 4) degree of water eutrophication related to chemical concentrations.

5. Improvements in Remote Sensing Techniques

A "modified clustering" computer-aided analysis technique was developed as an effective procedure for obtaining training statistics and was documented as an operational approach for analysis of satellite scanner data. Relatively small portions of the total data set were found to be necessary to provide adequate sets of training statistics. Only 1,177 ERTS resolution elements were used in 16 cluster areas to train the computer for the classification of the 2,170,000 resolution elements contained in the San Juan Mountain test. Less than 1/10 of 1 per cent of the total data set could be utilized for training statistics and yet a Level I classification accuracy of over 90 per cent was obtainable.

LARS' Educational Activities

I. Introduction

Although LARS' primary activity is to provide an interdisciplinary research facility for the analysis and application of remote sensing data, a corollary activity involves transferring the new technology to others interested in it, both within Purdue University and outside of the University. 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 36 academic professional staff of the University, who add to their teaching the knowledge gained in their remote sensing research activities.

B. Provides funding for salaries, equipment, operational expenses and thesis research for graduate students from many areas of the University. (There were 41 graduate students in FY 73-74.)

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

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

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

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

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

II. Graduate training expedited by LARS staff and facilities.

A. Graduate students funded by LARS during fiscal year 1973-74.

Agricultural Economics	1
Agronomy	6
Civil Engineering	1
Computer Sciences	6
Electrical Engineering	13
Forestry & Conservation	4
Geosciences	9
Nuclear Engineering	1
Total	41

B. Degrees granted to graduate students using LARS facilities and under guidance of LARS staff members in fiscal year 1973-74.

Agronomy

P. N. LeBlanc	M.S.

Electrical Engineering

Ravindra Kumar	M.S.
Thomas Robertson	Ph.D.
Martin Svedlow	M.S.

Forestry and Conservation

Michael Coggeshall	M.S.

Computer Sciences

Scott Sinnock	M.S.

Geosciences

Luis Bartolucci-Castado	M.S.
James A. Henderson	M.S.
William L. Murray	M.S.
Chester L. Parsons	M.S.
Stanley Woodring	M.S.

Graduate Students
Degrees Completed
In FY 1974

Bartolucci-Castado, Luis A., M.S., Geos., Prof. T. R. West and R. Hoffer, "Computer-Aided Processing of Remotely Sensed Data for Temperature Mapping of Surface Water from Aircraft Altitudes."

Coggeshall, Michael, M.S., Forestry and Conservation, Prof. R. M. Hoffer, "Basic Forest Cover Mapping Using Digitized Remote Sensor Data and ADP Techniques."

Henderson, James A., M.S., Geos., Prof. Ned Smith, no thesis title assigned.

Kumar, Ravindra, Ph.D., EE, Prof. LeRoy Silva, "Emission and Reflectance from Healthy and Stressed Natural Targets with Computer Analysis of Spectroradiometric and Multispectral Scanner Data."

LeBlanc, P.N., M.S., Agron., Prof. Johannsen, "Land Use Clarification Utilizing Remote Multispectral Scanner Data and Computer Analysis Techniques."

Murray, William, M.S., Geos., Prof. G. M. Jurica, "The Atmospheric Effect in Remote Sensing of Earth Surface Reflections."

Parsons, Chester, M.S., Geos., Prof. G. M. Jurica, "Correction of Earth Resources Technology Satellite Multispectral Scanner Data for the Effect of the Atmosphere."

Robertson, Thomas V., Ph.D., EE, Prof. K. S. Fu, "Multispectral Image Partitioning."

Sinnock, Scott, M.S., C.S., Prof. W. Melhorn, "Interpretation of ERTS-I Data by LARSYS and Manual Techniques."

Svedlow, Martin, M.S., EE, Prof. C. D. McGillem, "Image Registration: Some Iterative Algorithms and a Measure for Data Overlay Quality."

Woodring, Stanley M., M.S., Geos., Prof. T. R. West, "Engineering Soils Mapping from Multispectral Remote Sensing Data Using Computer Assisted Analysis Techniques."

Graduate Students

Degree Candidates

Beck, Robert, M.S., Agronomy, Prof. J. McFee, "Soils in Relation to Land Use in Waste Management."

Benson, Ray, M.S., C.S., Prof. Paul Anuta, no thesis title assigned.

Berkebile, John, Ph.D., For. & Con., Prof. Roger Hoffer, no thesis title assigned.

Biehl, Larry, MSE, EE, Prof. LeRoy Silva, no thesis title assigned.

Borger, Robert, M.S., Geoscience, Dr. R. Roy, no thesis title assigned.

Clevenger, John, Ph.D. EE, Prof. LeRoy Silva, "Low Cost Field Spectroradiometer for Remote Sensing."

Donahue, Stephen, Ph.D., Agron., Prof. Rhykerd, "Causes of Stand Reduction in Orchard Grass Under High Nitrogen Regimes."

Fleming, Michael, M.S., For. and Cons., Prof. Roger Hoffer, no thesis title assigned.

Frater, James, M.S., Geos., Prof. William Melhorn, no thesis title assigned.

Freeman, David, M.S., C.S., Supervisor, William Simmons, no thesis title assigned.

Gill, Joseph, M.S., Ag. Econ., Prof. William Miller, "Soil Loss in Wabash Basin."

Hitchcock, Harry C., Ph.D., For. and Cons., Prof. Roger Hoffer, no thesis title assigned.

Kardos, Christopher, M.S., N.E., Prof. Robert Bailey, "Modeling and Mapping of Thermal Discharges into Moving Bodies of Water Using Multispectral Scanning Techniques."

Kettig, Robert, Ph.D., EE, Prof. D. Landgrebe, "The Application of Sample Classification Techniques to Remotely Sensed Multispectral Data."

Lehman, Terry, M.S., Geos., Prof. D. W. Levandowski, "Remote Sensing From a Space Platform of Domal Features as Guides to Ores and the Localization of Ores."

Mapes, Kathleen, M.S., C.S., Prof. Terry Frederick, no thesis title assigned.

McDonald, Ellen, M.S., C.S., Prof. Howard Grams, no thesis title assigned.

Mobasseri, Bijan, M.S., EE, Prof. Clare McGillem, "Image Processing."

Montgomery, Oscar L., Ph.D., Agron., Prof. M.F. Baumgardner, "The Effects of the Physical and Chemical Properties of Soils on the Spectral Reflectance of Soils."

Mundy, Steve, M.S., Civil Eng., Prof. K. Curtis, no thesis title assigned.

Riemer, Terry, Ph.D., EE, Prof. Clare McGillem, "A Linear Shift-Invariant Image Preprocessing Technique for Multispectral Scanner Systems."

Seberger, Lewis, M.S., C.S., Prof. Paul Anuta, no thesis title assigned.

Stockton, John, Ph.D., Agronomy, Prof. M. F. Baumgardner, "Crop Identification in a Semi-Arid Environment."

Stohr, Christopher J., M.S., Geos., Prof. T. R. West, "Sink-hole Delineation and the Influence of Topography on Multispectral Response."

Vanderbilt, Vern. Ph.D., EE, Prof. LeRoy Silva, "Geometric Effects and Spectral Reflectance of Vegetative Canopies."

Walker, Carl, M.S., Agron., Prof. Baumgardner, "Land Use Mapping by Machine Processing of Satellite Acquired Multispectral Scanner Data."

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

Wu, Chai-Lin, Ph.D., EE, Prof. D. Landgrebe, "The Decision Tree Approach to Classification."

Yam, Eric, Ph.D., EE, Prof. J. Y-S Luh, "Robotic Visual Perception.

Zalusky, James T., Ph.D., EE, Prof. Floyd Schultz, "Electrical Methods of Determining Soil Moisture Content."

III. Specific Educational Programs

During FY74 a new program area was established, Technology Transfer Programs, with Professor John C. Lindenlaub as Program Leader. This arrangement resulted from the growing demand from scientists over the world for information and training regarding remote sensing technology. Several definite sub-programs are now handled by this new program area.

A. Visiting Scientists Program

The Visiting Scientists 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 Scientists 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 the training program. The cost is variable, depending on the duration of the training period. The trainee or sponsoring agency must also provide for travel and subsistence expenses. The program is under the direction of Professor John C. Lindenlaub.

The fee is based on a $130 fixed preparation cost, plus a gradually reducing per trainee-day rate, plus $280 per hour for any necessary computer usage. For ten trainee days (one man for 10 days or 10 men for one day, etc.) the current rate is about $1,000 on the average.

B. 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 educational:

- 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 FY74 remote terminals were in operation at six locations: two at LARS (Flex Lab I); one each at NASA/Goddard Space Flight Center, Maryland; NASA/Wallops Island, Virginia; and NASA/Langley, Virginia; two at NASA/Johnson Space Center, Houston, Texas and three at the state offices of Texas, Austin, Texas. Recently, arrangements have been concluded to install one at Indiana State University, Terre Haute, Indiana and one at Sioux Falls, South Dakota.

Educational materials geared to individual study were developed at LARS and are currently being used by new remote terminal users. These materials, which constitute the LARSYS Educational Package, use a variety of media to familiarize new users with both the principles supporting the analysis techniques and with the details of the analysis procedure itself.

A "site expert" at each remote terminal location is a key figure in helping meet the educational goals of the remote terminal project. The "site expert" spends anywhere from several days to several weeks at LARS, going through the training materials, working with a remote terminal, and observing the operations in the computation center. He is responsible for giving educational guidance to staff members at the remote site.

In addition, the people at Texas, with the aid of Carl Walker from LARS, developed an educational course involving a week of preliminary seminars, training in LARSYS using the Purdue/LARS Educational Package, and preliminary research on ERTS data from the Texas area. Students from many of the state agencies participated in the course.

C. Short Courses and Symposia

As a result of the demand from over the world from people in many scientific fields to learn the techniques of remote sensing as developed by LARS personnel, the Laboratory has been offering a series of short courses and symposia.

1. Short Courses

The Laboratory offered a Short Course on Machine Processing of Remotely Sensed Data June 3-7, 1974. The limit of fifty enrollees was readily met by scientists from over the world.

This short course was designed for persons who wished to learn how to analyze remotely sensed data such as from systems like the ERTS and Skylab satellites and to discuss potential applications using these analysis techniques.

The course was intended for those with a professional background in remote sensing or related fields. These participants represented federal, state, and local governmental agencies as well as private industry and educational institutions and represented a variety of disciplines: agriculture, land use planning, engineering, environmental quality control, forestry, geology, the natural sciences, etc.

The week began with discussions on radiation theory and energy-matter interactions, the physical basis of remote sensing technology. Presentations on measurement systems and the concept of digital data formats concluded the background material required for the study of numerical analysis techniques.

The nucleus of the course was a series of workshops on the analysis of multispectral data using the LARS software system as a prototype of digital remote sensing processing systems.

2. Symposia

Two hundred eighty scientists attended the symposium on Machine Processing of Remotely Sensed Data offered by the

Laboratory October 16-18, 1973. The following subjects were presented in eight Technical Sessions:

a. Data Management and Processing Systems
b. Image Registration and Calibration
c. Land Use Planning Application
d. Geometrical Transformations and Mapping
e. Earth Resource Measurements and Applications
f. Classification and Feature Selection I
g. Special Systems and Techniques
h. Classification and Feature Selection II

Forty-three papers were presented covering the central theme of theory, implementation and applications of machine processing of remotely sensed data. The symposium was designed to provide an opportunity for researchers in the fields of data processing and data utilization to present recent research results, describe new technological developments, and discuss various applications of existing processing techniques. Because of the demand, a second similar symposium will be offered June 3-5, 1975.

IV. Formal University Courses Dealing with Phases of Remote Sensing.

A. Courses with definite emphasis on remote sensing.

Electrical Engineering

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

Forestry

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

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

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

Geosciences

591R Aerogeology and Remote Sensing
cr. 3. Prof. Levandowski

B. Courses related to remote sensing.

Agronomy

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

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

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

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

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

I. Staff, Equipment and Funds Summary - FY 1973-1974

. Staff includes 165 people from 19 departments in four schools

. Had an operating budget of just under $2,000,000 expended as follows:

A) Research Expenditures

Salaries:		
Engineering	$416,013.42	
Agriculture	99,698.39	
Science	87,119.84	
H.S.S.E.	1,575.00	
Total Salaries		$ 605,405.65
Fringe Benefits		85,215.24
Overhead		434,572.24
Supplies and Capital		765,227.60
Total Research		$1,889,420.73

B) General Fund Support

Salaries	21,573.35	
Supplies and Expense	18,699.89	
Total Expenses		40,273.24

C) University Support Via Cost Sharing 39,495.84

Total Resources $1,969,189.81

II.All Accounts Expenses by Department and School

July 1, 1973 - June 30, 1974

Agriculture

	Ag. Econ.	Ag. Info.	Hort.	Agr.	Fors.	Tot. Ag.
All Sal.	$ 9,533.63	$ 8,900.04	$5,339.31	$125,312.87	$ 50,612.54	$ 99,698.39
F.B.	840.88	908.10	692.73	14,921.99	7,203.13	24,566.83
O.H.	5,987.14	5,683.33	3,536.11	80,297.36	32,847.97	128,361.91
C.S.	490.86	456.51	106.40	4,896.10	1,429.42	7,379.29
Total	$16,852.51	$15,947.98	$9,674.55	$225,428.32	$ 92,103.06	$ 260,006.42

Engineering

	Aero	Civil	M.E.	E.E.	Nuclear	E.E.S.	Tot. Eng.
All Sal.	$ 3,080.00	$ 600.00	$3,182.50	$ 97,731.07	$ 2,102.20	$ 309.317.65	$ 416,031.42
F.B.	413.00	.81	637.40	8,578.34	150.67	46,397.55	56,177.77
O.H.	1,934.24	376.80	2,094.56	62,508.35	1,351.72	204,155.51	272,421.18
S.&E.						765,227.60	765.227.60
C.S.	150.57	29.33	55.42	3,527.46	108.14	27,395.49	31,266.41
Total	$ 5,577.81	$ 1,006.94	$5,969.88	$172,345.22	$ 3,712.73	$1,352,493.80	$1,541,106.38

	Geo. Sci.	Comp. Sci.	Stat.	Bio. Sci.	Tot. Sci.
All Sal.	$70,645.21	$15,006.51	$ 768.12	$ 700.00	$87,119.84
F.B.	4,331.70	18.94	.80	3.74	4,355.18
O.H.	22,156.51	9,681.66	482.38	479.50	32,800.05
C.S.	553.94	178.27	37.54		769.75
Total	$97,687.36	$24,885.38	$1,288.84	$ 1,183.24	$125,044.82

	H.S.S.E.
All Sal.	$ 1,575.00
F.B.	115.46
O.H.	989.10
C.S.	80.39
Total	$ 2,759.95

1973-1974

17-FUNDS

BUDGET

Salaries			
Lea Thomas	100%		
Vic Fletcher	100%		
D. A. Landgrebe	30%		
Total			$24,832
Supplies, Expenses, Capital			
A) Telephone		$7,341	
B) Copy Center		3,925	
C) Other		6,542	
1. Physical Plant Services			
2. Equipment Repair and Maintenance			
3. Common Shay Tools			
4. Central Machine Shop			
5. Materials for Fabrication			
6. Operation and Maintenance of One Vehicle			
7. Building Maintenance			
8. Office Supplies			
9. Campus Travel			
10. Vehicle Insurance			
11. Office Equipment and Furniture			
Total Supplies & Expenses			$17,808
TOTAL BUDGET			$42,640

LARS Research Staff
As of May 31, 1974

Faculty	Number
Nuclear	1
Electrical	4
Civil	2
Mechanical	1
Engineering	8
Agronomy	7
Forestry & Conservation	1
Agricultural Economics	1
Agriculture	9
Statistics	1
Geoscience	6
Science	7
Total Faculty	24

Professional	
Engineering Experimental Station	20
Electrical	4
Engineering	24
Agronomy	6
Forestry & Conservation	2
Agricultural Information	1
Agriculture	9

Communications	1
H.S.S.E.	1
Geoscience	2
Science	2
Total Professional	36

Graduate Students (as of June, 1974)

Nuclear	1
Electrical	6
Civil	1
Engineering	8
Geoscience	3
Computer Science	2
Science	5
Agronomy	4
Forestry & Conservation	3
Horticulture	1
Agricultural Economics	1
Agriculture	9
Industrial Management	1
Total Graduates	23

Undergraduates

Engineering Experimental Station	29
Total Undergraduates	29

Other

Engineering Experimental Station	19
Total Other	19

Professorial and Professional Staff

FY 1973-74

I. Professorial Staff

A. Agriculture

1. M. F. Baumgardner--Professor of Agronomy
2. B. O. Blair--Professor of Agronomy
3. R. A. Boots--Assistant Professor of Landscape Architecture
4. D. P. Franzmeir--Associate Professor of Agronomy
5. R. M. Hoffer--Associate Professor of Forestry and Conservation
6. W. L. Miller--Associate Professor of Agricultural Economics
7. L. Monticello--Visiting Scientist
8. J. B. Peterson--Professor of Agronomy (post-retirement appointmer
9. H. P. Ulrich--Professor Emeritus of Agronomy

B. Engineering

1. R. E. Bailey--Professor of Nuclear Engineering
2. D. P. DeWitt--Associate Professor of Mechanical Engineering
3. D. A. Landgrebe--Professor of Electrical Engineering
4. J. I. Lindenlaub--Professor of Electrical Engineering
5. C. D. McGillem--Professor of Electrical Engineering
6. E. M. Mikhail--Associate Professor of Civil Engineering
7. F. V. Schultz--Professor of Electrical Engineering
8. L. F. Silva--Associate Professor of Electrical Engineering

C. Science

1. V. L. Anderson--Professor of Statistics
2. R. L. Frederking--Instructor of Geoscience
3. G. M. Jurica--Assistant professor of Geoscience
4. D. W. Levandowski--Associate Professor of Geoscience
5. M. Lewellen--Visiting Instructor
6. W. N. Melhorn--Professor of Geoscience
7. T. R. West--Associate Professor of Geoscience

II. Professional Staff

A. Agriculture

1. M. E. Bauer--Research Agronomist in Agronomy
2. T. C. Builta--Technical Editor in Agricultural Information
3. J. E. Cipra--Research Agronomist in Agronomy
4. R. H. Gilbert--Research Agronomist in AGronomy
5. F. E. Goodrick--Data Analyst in Forestry and Conservation
6. S. J. Kristof--Research Agronomist in Agronomy
7. R. P. Mroczynski--Photo-Interpreter in Forestry and Conservation
8. C. F. Walker--Administrative Assistant
9. R. A. Weismiller--Research Agronomist in Agronomy

B. Engineering

1. B. A. Addessio--Applications Programmer
2. P. E. Anuta--Associate Manager of Data Reformatting Research
3. L. T. Barnes--Editor
4. L. L. Biehl--Project Manager/Engineer
5. T. M. Cary--Research Analyst
6. B. J. Davis--Statistician/Analyst
7. S. M. Davis--Editorial Assistant
8. J. B. Etheridge--Applications Programmer
9. D. M. Greeman--Associate Manager of Data Reformatting
10. J. W. Gorsuch--Technical Assistant
11. H. L. Grams--Manager of Computer Operations
12. W. C. Hockema--Computer Operations Supervisor

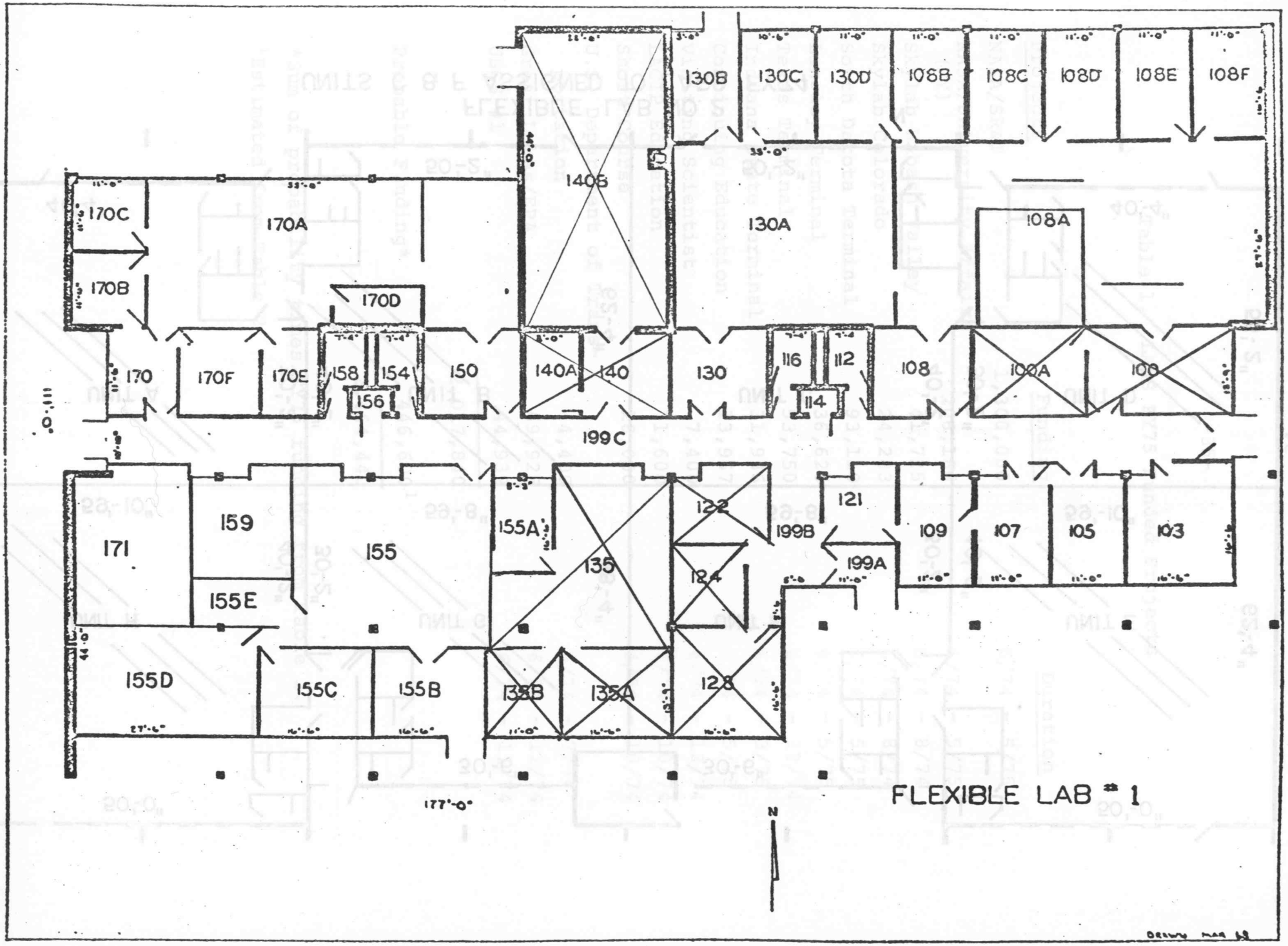
C. Science

1. J. A. Henderson--Research Analyst in Geoscience
2. S. G. Luther--Research Analyst in Geoscience

V. SPACE, Flexible Laboratories I and II

Space	Sq. Ft.	Cost/sq. ft.	Total (annual)
Flex Lab I	9,867	$4.50	$43,959
Flex Lab II	6,994	$3.90	27,276
TOTAL	16,861		$71,235

- The LARS space is rented from PRF 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.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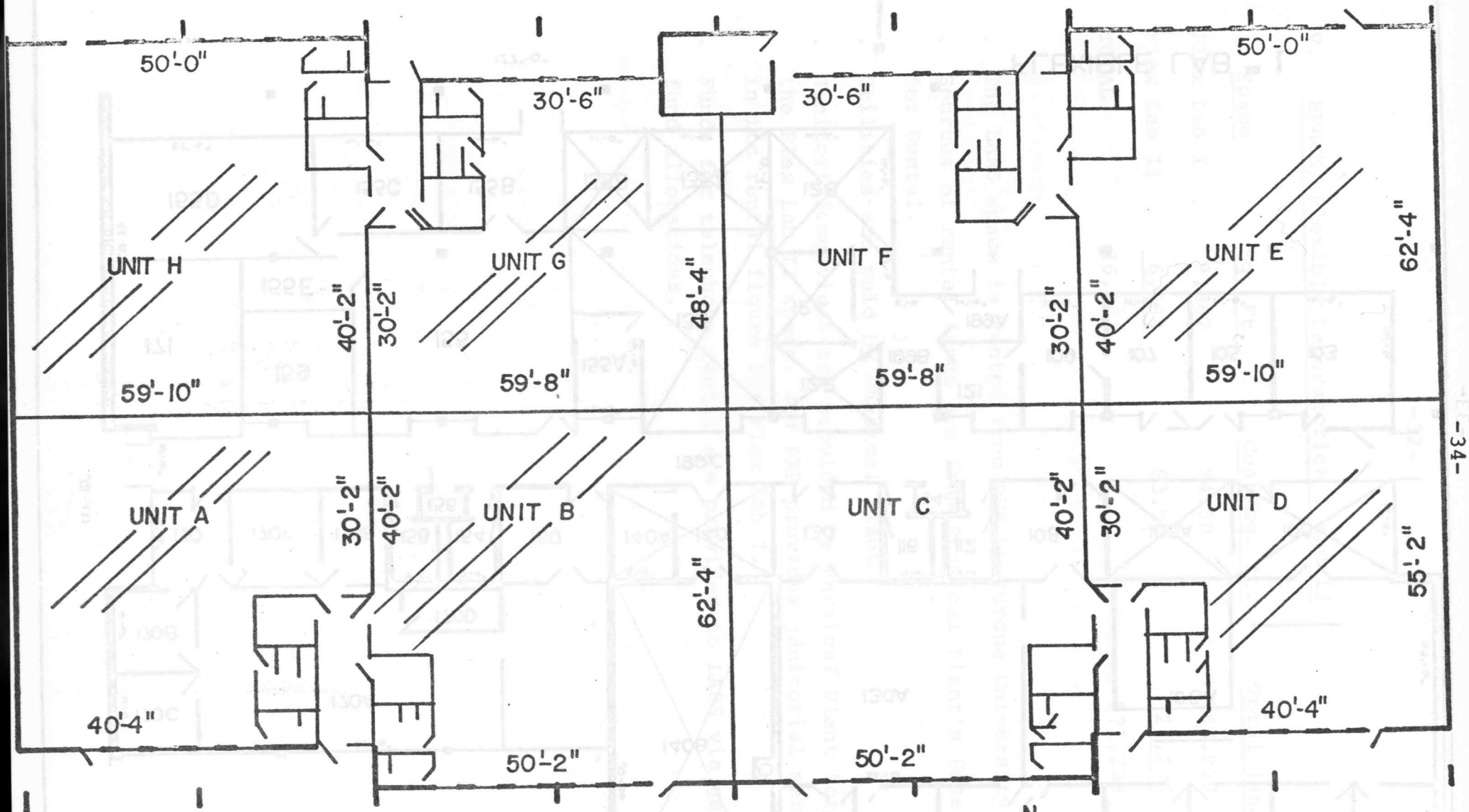
FLEXIBLE LAB # 1



FLEXIBLE LAB NO. 2
UNITS C & F ASSIGNED TO LARS FY74

Table 1. LARS FY75 Funded Projects

Projects	Funding	Duration
NASA/SR&T	1,300,000	6/74 - 5/75
NASA/University Affairs (PY)	206,186	6/74 - 5/75
Skylab Wabash Valley	41,725	6/74 - 8/74
Skylab Colorado	24,283	6/74 - 8/74
South Dakota Terminal	93,110	6/74 - 5/75
Langley Terminal	36,626	6/74 - 5/75
Texas Terminal	53,750	6/74 - 12/74
Indiana State Terminal	31,936	6/74 - 3/75
Continuing Education	13,967	6/74 - 5/75
Visiting Scientist	7,400	6/74 - 12/74
LACIP Education	71,600	7/74 - 10/74
Short Course	18,000	6/74 - 10/74
U.S. Department of Transportation	4,400	6/74 - 7/74
Great Lakes/EPA	69,925	6/74 - 12/74
USGS #1	44,932	6/74 - 11/74
	2,017,840	
Probable Funding*	446,600[1]	
	2,464,440	

*Sum of probability times FY75 funding from Table 2.

[1]Estimated from Table 2.

Table 2. LARS Proposed Projects FY75 - FY76

Project	Probability	Funding FY75	FY76
NASA/University Affairs	1.0	$	$135,000
Skylab Wabash Valley extension	1.0	50,000	
Skylab Colorado extension	1.0	83,000	
USGS #2	.9	50,000	65,000
ERTS-B Crops	.9	50,000	130,000
ERTS-B Colorado	.9	20,000	58,000
Public Service Indiana	.8	36,000	
TRW, Inc.	.8	5,000	
Visiting Scientists	.7	5,000	
NASA/Goddard Terminal	.7	15,000	16,000
NASA/Wallops Terminal	.6	15,000	4,000
NASA/JSC Field Experiment	.5	100,000	
Sudan/FAO	.5	25,000	125,000
LARSYS Training	.4	15,000	
NASA Goddard Preprocessing	.4	48,000	
Chile/AID	.4	50,000	100,000
Bolivia	.4	20,000	30,000
TVA	.3	10,000	
Soil Erosion	.2	30,000	120,000
New Terminal		20,000	30,000
		$647,000	$813,000

Note: Only projects for which some discussion with a potential sponsor has taken place are listed here.

VISITORS TO THE LABORATORY FOR APPLICATIONS OF REMOTE SENSING
July 1, 1973 - June 30, 1974

SUMMARY

FEDERAL AGENCIES	55
STATE AND LOCAL AGENCIES	39
PURDUE	50
OTHER UNIVERSITIES (U.S.)	76
INDUSTRY	30
FOREIGN	26
UNITED NATIONS	3
MISCELLANEOUS	22
TOTAL	301

BIBLIOGRAPHY

Soon after completion research at LARS is published in an Information Note series. This makes possible early release of research results to fellow scientists in a rapidly advancing field. It also provides to the scientific community a unified source of information on the progress of research at LARS not otherwise possible since there is no single journal which serves as a major vehicle for papers in remote sensing.

The following Information Notes for FY74 provide comprehensive coverage of the research compiled during the year. They are identified by a six-digit control number. This number represents the month, day and year on which the manuscript was made available for duplication. For example, Information Note 071373 refers to July 13, 1973.

PUBLICATIONS BY LARS STAFF - FY 73-74

071373 Robertson, T.V. and K.S. Fu. Multispectral Image Partitioning. 96P. Also available as a Ph.D. Thesis and Tech. Report TR-EE 73-26, both from the School of Electrical Engineering, Purdue University, August, 1973. An algorithm is presented that divides a multispectral image into successively smaller parts until all parts larger than a certain minimum size are likely to contain a single target entity. The algorithm is modelled theoretically and shown to produce an arbitrarily good portion of an idealized image. The algorithm is used to recognize crops and cities in remotely sensed images, and to partition a chest radiograph and a photograph of a girl.

072473 Kumar, R. and L. Silva. Emission and Reflection From Healthy and Stressed Natural Targets with Computer Analysis of Spectroradiometric and Multispectral Scanner Data. Also available as Ph.D. Thesis and as Technical Report TR-EE 73-37, both from the School of Electrical Engineering, Purdue University, December, 1973. 427P. The purpose of this research is to study the emission and reflection from healthy and stressed natural targets, with special emphasis on corn plants. The study includes: Infrared Radiometry of Plants, Reflectance Model of a Plant Leaf, Simplified Thermal Emission Model of a Plant Canopy, Field Experiments with Longwavelength Spectroradiometer and Analysis of Multispectral Scanner Data of Blighted Corn Plants in Selected Flightlines.

072673 Mausel, P.W. and C.J. Johannsen. An Application of Remotely-Sensed Data to Agricultural Land Use Distribution Analysis. The Professional Geographer. Vol. XXV, No. 3. August, 1973. PP. 242-247. This paper explores the background, procedures and potentials of computer-aided analysis of multispectral data as applied to a problem of geographic and remote sensing interest. This includes (a) a classification of basic land use classes, (b) a check on the accuracy, (c) a computer-implemented determination of land uses as a function of distances from roads, (d) an analysis of the statistical significance of variations of land use from one location to another and (e) a discussion of selected geographic implications.

091273 Lindenlaub, J.C. The LARSYS Educational Package. Instructor's Notes. 44P.

091373 Lindenlaub, J.C. The LARSYS Software System. An Overview. 135P.

100773 Landgrebe, D.A., F.C. Billingsley, and J.D. Nichols. Machine Processing Methods for Earth Observational Data. Presented at the International Astronautical Federation Congress, Baku, USSR. October 7-13, 1973. A brief review of the development over the last decade of earth resource informations systems is presented. Machine data preprocessing and analysis methods are surveyed and illustrated. These include preprocessing steps intended to modify geometric and radiometric aspects of earth observational image data to enhance the ability of either human interpreters or machine algorithms to extract information from data. Illustrations of processed and analyzed images from spaceborne sensors including the Earth Resources Technology Satellite are discussed.

101073 Levandowski, D.W., T.V. Jennings and W.T. Lehman. Applications of ERTS-1 Imagery to Mapping of Lineaments Favorable to the Localization of Ore Deposits in North Central Nevada. Proceedings of the meeting of the Geologic Society of America and related societies, Nov. 14, 1973. 19P. The purpose of this study is to demonstrate the value of ERTS-1 data as a supplement to mineral reconnaissance techniques. An iso-lineament intersection map prepared from composite color images at north-central Nevada indicates a strong correlation between major intersection areas and domal areas associated with mineral districts. Based on this correlation, two major intersection areas with no known associated ore deposits are integrated to be buried domal areas and potential exploration targets.

101373 Swain, P.H., T.L. Phillips and J.C. Lindenlaub. The Role of Computer Networks in Remote Sensing Data Analysis. Proceedings of the Conference on Machine Processing of Remotely Sensed Data, Laboratory for Applications of Remote Sensing, Purdue University, W. Lafayette, Indiana. October, 1973. IEEE Catalog No. 73 CHO 834-2 GE. PP. 1A-12 to 1A-18. For remote sensing data analysis, a time sharing-based computer network offers several potentially significant advantages over dispersed, unconnected computer facilities. In order to evaluate the merits of such a computer network, a prototype remote sensing data processing system consisting of a central computer located at LARS and terminals at various remote sensing organizations has been established. This paper discusses the rationale for such a system and some of the details of a project designed to provide an indication as to how computer networks might be used in the future to provide data analysis facilities to geographically dispersed users of remote sensing data.

101473 Emmert, R.A. and C.D. McGillem. Multitemporal Geometric Distortion Correction Utilizing the Affine Transformation. Proceedings of the Conference on Machine Processing of Remotely Sensed Data, Laboratory for Applications of Remote Sensing, Purdue University, W. Lafayette, Indiana. October, 1973, IEEE Catalog No. 73 CHO 834-2 GE. PP. 1B-24 to 1B-32. The misregistration between data subsets is

modeled by an affine transformation. The properties of the Fourier transform of a two-dimensional function under the affine transformation are given, and examples of these relations between the spatial and spatial frequency domains are shown. Techniques for the estimation of the coefficients of the distortion model using the spatial frequency information are developed, and an example of the use of this method for the correction of line scanner imagery is given.

101573 Ellefsen, R., P.H. Swain and J.R. Wray. Urban Land-Use Mapping by Machine Processing of ERTS-1 Multispectral Data: A San Francisco Bay Area Example. Proceedings of the Conference on Machine Processing of Remotely Sensed Data, Laboratory for Applications of Remote Sensing, Purdue University, W. Lafayette, Indiana. October, 1973, IEEE Catalog No. 73 CHO 834-2GE. PP. 2A-7 to 2A-22. Classification of ERTS-1 data for urban land-use applications was achieved by grouping twenty-eight spectral classes into eleven functional classes. Reliability was checked by comparing computer results to contemporaneous high-altitude color air photographs on a pixel-by-pixel basis. Performance results are excellent considering the grossness of the data and the complexity of the urban landscape.

101673 Todd, W.J., and M.F. Baumgardner. Land Use Classification of Marion County, Indiana by Spectral Analysis of Digitized Satellite Data. Proceedings of the Conference on Machine Processing of Remotely Sensed Data, Laboratory for Applications of Remote Sensing, Purdue University, W. Lafayette, Indiana. October, 1973. IEEE Catalog No. 73 CHO 834-2GE. PP. 2A-23 to 2A-32. 9 pages. Land use planners would benefit from the periodic updating of data banks by computer analysis of ERTS MSS data. Four bands of digitized, multispectral data collected by ERTS-1 on 30 September, 1972 over Marion County, Indiana were analyzed by machine processing to obtain an urban land use classification. Spectrally separable classes used in the classification scheme, which was tested to be 87 per cent accurate, included commerce/industry, multi-family (older) residential, single-family (newer) residential, grassy (open, agricultural) areas, woodland, water, cloud, and cloud shadow.

101773 Cipra, J.E. Mapping Soil Associations Using ERTS MSS Data. Proceedings of the Conference on Machine Processing of Remotely Sensed Data, Laboratory for Applications of Remote Sensing, Purdue University, W. Lafayette, Indiana. October, 1973. IEEE Catalog No. 73 CHO 834-2 GE. PP. 3A-1 to 3A-10. 10 pages. Geometrically corrected ERTS MSS data collected June 9, 1973 were analyzed by specially developed techniques using the computer. Resulting computer maps from a digital image display were overlayed to existing soil association maps of Tippecanoe County, Indiana. Four soil associations were clearly mapped by the computer analysis, and additional soils information useful to the ongoing USDA Soil Conservation Service soil mapping program was noted.

101873 Robertson, T.V. Extraction and Classification of Objects in Multispectral Images. Proceedings of the Conference on Machine Processing of Remotely Sensed Data, Laboratory for Applications of

Remote Sensing, Purdue University, W. Lafayette, Indiana. October, 1973. IEEE Catalog No. 73 CHO 834-2 GE. PP. 3B-27 to 3B-34. Presented here is an algorithm that partitions a digitized multispectral image into parts that correspond to objects in the scene being sensed. The algorithm partitions an image into successively smaller rectangles and produces a partition that tends to minimize a criterion function.

Supervised and unsupervised classification techniques can be applied to partitioned images. This partition-then-classify approach is used to process images sensed from aircraft and the ERTS-1 satellite, and the method is shown to give relatively accurate results in classifying agricultural areas and extracting urban areas.

101973 Duan, J.R. and P.A. Wintz. Information-Preserving Coding for Multispectral Data. Proceedings of the Conference on Machine Processing of Remotely Sensed Data, Laboratory for Applications of Remote Sensing, Purdue University, W. Lafayette, Indiana. October, 1973. IEEE Catalog No. 73 CHO 834-2 GE. PP. 4A-28 to 4A-35. 7 pages. A general formulation of the data compression system is presented. A method of instantaneous expansion of quantization levels by reserving two codewords in the codebook to perform a folding over in quantization is implemented for error free coding of data with imcomplete knowledge of the probability density function. Results for simple DPCM with folding and an adaptive transform coding technique followed by a DPCM technique are compared using ERTS-1 data.

102073 Gupta, J.N., R.L. Kettig, D.A. Landgrebe and P.A. Wintz. Machine Boundary Finding and Sample Classification of Remotely Sensed Data. Proceedings of the Conference on Machine Processing of Remotely Sensed Data, Laboratory for Applications of Remote Sensing, Purdue University, W. Lafayette, Indiana. October, 1973. IEEE Catalog No. CHO 834-2 GE. PP. 4B-25 to 4B-35. 10 pages. Initially, methods for analyzing earth observational data involved the use of only spectral variations measured from the scene. The work reported in this paper provides a method for making some use of spatial variations as well. The results of some preliminary tests of this new method are presented in this paper.

102573 Mausel, P.W., W.J. Todd, M.F. Baumgardner, R.A. Mitchell and J.B. Cook. Evaluation of Surface Water Resources from Machine-Processing of ERTS Multispectral Data. 15 pages. The acquisition of water resources data is important to metropolitan areas. Four bands of digitized, multispectral data collected by ERTS-1 over Marion County on 30 September, 1972 were analyzed by computer processing to obtain water resources information. Four spectrally separable water classes were used in the classification scheme. The spectral classes of water are related primarily to differences in water depth and turbidity and to amount and type of suspended particles and aquatic growth in the water.

103073 Anuta, P. Geometric Correction of ERTS-1 Digital Multispectral Scanner Data. 23 pages. ERTS-1 MSS data produced in digital form contains geometric distortions which are undesirable for users wishing to relate the data to maps. A digital computer algorithm was developed which performs certain geometric connections to improve the geometric quality of this data. The corrected data has been accurate enough to enable overlay of the ERTS data on 1:24,000 scale topographic maps and the usefulness of the data has been considerably improved by these corrections.

110173 Sharples, J.A. The Corn Blight Watch Experiment Economic Implications for Use of Remote Sensing for Collecting Data on Major Crops. 11 pages. From the Corn Blight Watch Experiment several conclusions can be drawn about the use of remote sensing for estimating the acreage and periodic condition of major crops: (a) the role of remote sensing as a data collection technique appears to be one of augmenting the enumerator in the field rather than replacing him; (b) in the foreseeable future remote sensing should not be expected to lower the cost of collecting traditional information on major crops; (c) a major advantage of using remote sensing is that the output--a photograph or a scanner data tape--acts as a store of information about all features within the geographical area covered by the scanner.

110273 Murray, W.L. and J.E. Jurica. The Atmospheric Effect in Remote Sensing Earth Surface Reflectivities. Also available as an M.S. Thesis, Dept. of Geosciences, Purdue University. August, 1973. 61 pages. Under certain circumstances the presence of the atmosphere can hinder the identification of earth surface features by remote sensing techniques. An accurate model of atmospheric radiation transfer at visible wavelengths has been used to determine the extent of signal modification for differing illumination and atmospheric conditions. Effects equivalent to more than a 10 percent change in surface reflectivity are observed for some conditions.

110873 Anuta, P.E. and M.E. Bauer. A Procedure for Utilizing the Temporal Dimension for Automatic Classification and Change Analysis of Multispectral Imagery. 23 pages. Sequential coverage of the same area by remote sensors and subsequent registration of the data makes time dependent phenomena measurements available for computer analysis. The paper describes methods for analyzing temporally registered remote sensor multispectral imagery for classification improvement and change detection. Results for crop classification, crop change detection and urban change detection were encouraging; however, only one brief example is given.

111473 Sinnock, S. and W.N. Melhorn. Evolution of the Upper Colorado River as Interpreted from ERTS-1 Imagery. Proceedings of the Fourth Annual Conference on Applications of Remote Sensing in Arid Lands. Tuscon, Ariz. Nov. 14-16, 1973. 22 pages. Manual interpretation of ERTS-1 MSS imagery has led to the recognition of anomolous surface patterns on the Uncompahgre Plateau in Southwestern Colorado. These anomolous patterns are interpreted as erosional scars produced by Tertiary fluvial network.

The master stream of this network migrated by lithologic and joint control from the present San Juan Mountains to the present Colorado River location.

111573 Melhorn, W.N., S. Sinnock and R. Mroczynski. Applications of Machine Processed ERTS-1 Data to Regional Land Use Inventories in Western Colorado. Proceedings of the Fourth Annual Conference on Applications of Remote Sensing in Arid Lands. Tuscon, Ariz. Nov. 14-16, 1973. 19 pages. The paper details an investigation of cover-type mapping in arid west-central Colorado as a function of topography, altitude, and climatic zonation. Machine classification of ERTS-1 imagery of selected geographic transects across the Uncompahgre Plateau--Grand Valley area indicates that automatic processing can identify specific zone type assemblages and provide meaningful statistics on the percentage of zones of each assemblage. These percentages are in approximate accord with values obtained by conventional ground-based assessment.

120673 Hitchcock, H.C. Remote Sensing, Computers, and Land Use Planning. This paper briefly describes remote sensing and computer-aided analysis of MSS data. It shows several potential and present areas of application in land use planning.

121073 Hoffer, R.M. and the LARS Staff. Techniques for Computer-Aided Analysis of ERTS-1 Data, Useful in Geologic, Forest and Water Resource Surveys. Proceedings of the Third ERTS Symposium Washington, D.C. Dec. 10-14, 1973. 23 pages. Forestry, geology, and water resource applications were the focus of this study, which involved the use of computer-implemented pattern-recognition techniques to analyze ERTS-1 data. The results have proven the value of computer-aided analysis techniques even in areas of mountainous terrain.

Several analysis capabilities have been developed during these ERTS-1 investigations. A procedure to rotate, deskew, and geometrically scale the MSS data results in 1:24,000 scale printouts that can be directly overlayed on 7 1/2 minute U.S.G.S. topographic maps. Several scales of computer-enhanced "false color-infrared" composites of MSS data can be obtained from a digital display unit, and emphasize the tremendous detail present in the ERTS-1 data. A grid can also be superimposed on the displayed data to aid in specifying areas of interest, such as avalanche tracks or areas of burned-over timberland. Temporal overlays of six sets of data have allowed both qualitative and quantitative analysis of changes in the areal extent of the snowpack.

Computer-aided analysis of the data allows one to obtain both cover-type maps and tables showing acreage of the various cover types, even for areas having irregular boundaries, such as individual watersheds. Spectral analysis of snow and clouds, water and shadow areas, and forest cover of varying overstory density have revealed several important results.

121173 Baumgardner, M.F., J.A. Henderson, Jr. and Staff. Mapping Soils Crops and Rangelands by Machine Analysis of Multi-Temporal ERTS-1 Data. Proceedings of the Third ERTS Symposium. Washington, D.C. Dec. 10-14, 1973. 30 pages. ERTS-1 data, obtained during the period 25 August 1972 to 5 September 1973 over a range of test sites in the Central United States, have been used for identifying and mapping differences in soil patterns, species and conditions of cultivated crops, and conditions of rangelands. Multispectral scanner data from multiple ERTS passes over certain test sites have provided the opportunity to study temporal changes in the scene.

Geometric correction was performed on the digital data for several dates and for several test sites. This made much easier the task of locating specific data points and of comparing the analytical results with other maps and data sources.

Multispectral classification delineating soils boundaries in different test sites compared well with existing soil association maps prepared by conventional means.

Spectral analysis of ERTS data was used to identify, map, and make areal measurements of wheat in western Kansas.

Multispectral analysis of ERTS-1 data provided patterns in rangelands which can be related to soils differences, range management practices, and the extent of infestation of grasslands by mesquite (Prosopis fuliflora) and juniper (Juniperus spp.)

121373 Landgrebe, D.A. and the LARS Staff. An Evaluation of Machine Processing Techniques of ERTS-1 Data User Applications. Proceedings of the Third ERTS Symposium. Washington, D.C. Dec. 10-14, 1973. 30 pages. This paper provides further results on machine processing of ERTS-1 data for user applications. Earlier papers at the first and second ERTS Symposiums gave results in general land use categories, crop classification and urban land use. The current paper gives results in soil association mapping and further urban land use analysis. It also gives results on geometric correction and temporal registration of ERTS data.

011074 Grams, H.L. Purdue/LARS Computer User's Guide. 28 pages.

022274 Henderson, J.A., Jr. M.F. Baumgardner and C. Walker. Preparing Resource Inventories in the Southern Great Plains by Machine-Processing of ERTS-1 Multispectral Data. Proceedings of the Fourth Annual Conference on Applications of Remote Sensing of Arid Lands. Tuscon, Ariz. Nov. 14-16, 1973. 13 pages. Two test sites in the Southern Great Plains, one centered around Lubbock, Texas, and one around Hobbs, New Mexico were used in this resource inventory. Using supervised (training sets) and non-supervised (clustering) computer programs the scenes were separated spectrally and mapped into classes.

Classification results were correlated with ground information and a comparison was made between the results of the Hobbs subframe (where no ground information was available) and the Lubbock Subframe (where a considerable amount was available). Classes of surface features which were successfully identified and mapped spectrally were croplands, rangelands, surface water, broad soil patterns, urban areas, drainage patterns, and major transportation arteries.

022774 Woodring, S.M. and T.R. West. Engineering Soils Mapping from Multispectral Remote Sensing Data Using Computer Assisted Analysis. An analysis procedure for engineering soils mapping by computer of multispectral remote sensing data was developed: 1. Locate cultural features by visual examination of imagery. 2. Produce generalized bare soil-vegetation-water map using non-supervised technique. 3. Outline significant soil fields for computer training using supervised approach. 4. Computer-classify entire area based on these fields.

031274 Phillips, T. and S. Schwingendorf. On the Access to an Earth Resources Data Processing System. 22 pages. The Purdue/LARS Earth Resources Data Processing System is briefly described. The considerations to which an organization would want to give attention before obtaining a remote terminal to this system are discussed. The support of such a terminal which Purdue/LARS is willing to propose is described.

032574 Stohr, C.J. and T.R. West. Delineation of Sinkholes Using Thermal Infrared Imagery. Proceedings of the Third Annual Remote Sensing of Earth Resources Conference, UTSI, Tullahoma, Tenn. March 25-27, 1974. 13 pages. The reported results of several authors concerning the location of sinkholes using only thermal infrared imagery is herein questioned, because of theoretical and empirical considerations. Daytime and nighttime thermal infrared imagery collected in the spring and fall of 1970 over an area near Staunton, Virginia is examined using manual interpretation and computer-assisted analysis. None of these procedures could be used successfully to delineate sinkholes using only thermal imagery, and it is concluded that thermal imagery should be used as a supplementary tool in conjunction with aerial photography.

032674 Hitchcock, H.C. and R.M. Hoffer. Mapping a Recent Forest Fire with ERTS-1 MSS Data. Proceedings of the Third Annual Remote Sensing of Earth Resources Conference, UTSI, Tullahoma, Tenn. March 25-27, 1974. 13 pages. Accurate fire boundary delineation provides essential information to forest managers in allocating suppression costs and planning regeneration efforts. The objective of this study was to test the capability of computer-aided analysis of ERTS-1 MSS data to accurately define the boundary of a recent forest fire and to discriminate spectral classes within the perimeter. Two frames of ERTS-1 MSS data were selected for analysis of the Moccasin Mesa Fire in Mesa Verde National Park. Data sets were collected one-half growing season and one full growing season after the fire. Results indicate that computer-aided analysis of ERTS-1 MSS data has the capability for accurately delineating

fire boundaries and determining acreage of the burned area. Distinct spectral classes may also be defined within the fire perimeter.

032774 Sinnock, S., W. Melhorn and O. Montgomery. Machine-Aided Analysis of Land Use-Land Form Relations from ERTS-1 Imagery, Sand Hills Region, Nebraska. Proceedings of the Third Annual Remote Sensing of Earth Resources Conference, UTSI, Tullahoma, Tenn. March 25-27, 1974. 24 pages. A computer-augmented analysis of ERTS-1 MSS data was performed on a test area in McPherson and Arthur counties in the Sand Hills region of Nebraska. Excellent correlation was obtained between available USDA Soils maps and ground photography, and the machine analysis of differences in soil types, conditions of rangelands, physiography, and location and extent of water bodies and marshlands.

032874 Guernsey, J.L., P.W. Mausel and R.H. Gilbert. Machine Processing ERTS-1 Data in Analyzing Land Use Conflicts in the Indianapolis Metropolitan Area. Land use changes around a water body, a large regional airport, several new subdivisions and an interstate beltline. Both supervised and unsupervised procedures were used to analyze spectral data, and seven land use classes were delineated. Overall accuracy of land use identification for state-wide planning was very encouraging.

032974[1] Jurica, G.M. and C.L. Parsons. Atmospheric Correction of Remotely Sensed Spacecraft Data. Proceedings of the third Annual Remote Sensing of Earth Resources Conference, UTSI, Tullahoma, Tenn. March 25-27, 1974. 13p. This paper reports on application of an atmospheric model to the interpretation of ERTS MSS data. It is concluded that Band 4 (0.80 - 1.00 μm) data are to a high degree influenced by the water vapor content of the atmosphere. Knowledge of the meteorological conditions at the time of an ERTS overpass appears to be necessary in order to achieve maximum classification accuracy of surface features.

033174 Coggeshall, M.E., R. Hoffer and J. Berkebile. A Comparison Between Digitized Color Infrared Photography and Multispectral Scanner Data, Using ADP Techniques. Proceedings of the Fourth Biennial Workshop on the use of color IR photography in the plant sciences. Orono, Maine. July 10-12, 1973. 13p. Computer classification results derived from digitized color infrared photography were compared with similarly derived results for three corresponding wavelength bands of multispectral scanner data. Classification results for 158 test fields indicated 47.5 percent overall correct identification with the digitized color infrared photography as compared to 80.5 percent for the corresponding three channels of multispectral scanner data (and 95.1 percent where all of the available twelve multispectral scanner channels were utilized). Forest cover was particularly difficult to separate from agricultural cover types using the digitized photography, but good separation was obtained with the multispectral scanner data.

[1]This presentation has not been published.

040174 Whitsitt, S.J. and Landgrebe, D.A. Simulation Techniques for Estimating Error in the Classification of Normal Patterns. 30 pages. Methods of efficiently generating and classifying samples with specified multivariate normal distributions are discussed. Conservative confidence tables for sample sizes are given for selective sampling. Simulation results are compared with classified training data. Techniques for comparing error and separability measures for two normal patterns are investigated and used to display the relationship between error and the Chernoff bound.

040474 Davis, S.M. and J. C. Lindenlaub. An Application of Personalized Instruction to Remote Sensing. This paper describes an application of personalized instruction to the training of people using a computer network dedicated to remote sensing technology. It describes the educational challenge posed by the kind of learner to be trained, the instructors available, the physical and administrative conditions, and the rapid evolution of the technology being taught. The LARSYS Educational Package, a 6-module, multi-media sequence developed to meet this challenge, is described in detail. An evaluation of its effectiveness is included.

041574 Davis, B.J. and P. H. Swain. An Automated and Repeatable Data Analysis Procedure for Remote Sensing Applications. Proceedings of the Ninth International Symposium on Remote Sensing of Environment. Ann Arbor, Mich. April 15-19, 1974. 4p. A new multispectral data analysis procedure, based on LARSYS, has been developed which substantially reduces the influence of the analyst. The analysis is automated, including the interpretation of clustering results. The classification results obtained are repeatable and not biased by analyst subjectivity during the analysis.

041674 Miller, W.L. The Economic Impact of Remotely Sensed Data as the Source of Nonpoint Pollution Monitoring and Control. The nonpoint pollution in streams and lakes is a problem. This can be corrected through changes in land use and management practices. These actions have economic costs and benefits. This research examines the costs and benefits of these actions when remotely sensed data is used as the source of part of this information required for the analysis.

041774 Kumar, Ravindra and LeRoy F. Silva. Statistical Separability of Agricultural Cover Types in Subsets of One to Twelve Spectral Channels. The purpose of this study was to determine the statistic separability of several agricultural cover types using multispectral scanner measurements. The data from visible, near, middle, and far infrared channels were studied using the transformed divergence as a quantitative analysis tool. Correlation of separability with classification accuracy on a cover type basis and channel array selection is made.

041874 Hall, F.G., Bauer, M.E. and W. A. Malila. First Results from the Crop Identification Technology Assessment for Remote Sensing (CITARS). This paper describes the objectives, experimental plan, procedures and first results for a crop identification by remote sensing technology assessment project being conducted by NASA, ERIM and LARS.

The following papers were presented at the Annual Meeting of the American Society of Agronomy, November, 1973, Las Vegas, Nevada and are not yet in LARS Information Note form.

Baumgardner, M. F. and C. F. Walker. 1973. Producing a Land Use Inventory by Computer-Implemented Analysis of Multispectral Data from Satellite Altitudes. Multispectral reflectance data were obtained on different dates by the Earth Resources Technology Satellite (ERTS) over a 30,000 Km^2 area of southwestern Michigan. At an altitude of 915 kilometers the resolution of the ERTS multispectral scanner is approximately 0.5 hectare. Detail of this scale provides ample resolution to identify and map land use patterns. Computer-implemented pattern recognition techniques were used to analyze the ERTS data. Level I land use classes were easily identified and mapped with these techniques. Most of the Level II and some sub-categories of Level II classes were delineated and mapped.

Cipra, J. E., D. P. Franzmeier, and G. C. Steinhardt. 1973. Mapping of Soil Characteristics by Computer Analysis of ERTS MSS Imagery. Images from the Earth Resources Technology Satellite (ERTS) were analyzed to determine their usefulness as a source of significant new information on certain soil and landscape characteristics of interest. Two counties in western Indiana were studied, using computer-aided analysis of multispectral scanner (MSS) data and correction of geometric distortions, for data collected in November and May. Comparisons were made of conventionally mapped soil association boundaries and ERTS images. In addition, high-altitude color infrared photography was used to interpret soil characteristics distinguishable on the ERTS imagery. Boundaries between some contrasting soil associations as conventionally mapped were readily apparent on ERTS imagery. Additional boundaries could be distinguished on ERTS imagery when soil association maps were used for reference. Although some apparent discrepancies were found, ERTS imagery, because it gives an overall view of the soil landscape, is a useful new tool to assist in making general soil maps.

Kristof , S. J. and H. P. Ulrich. 1973. Multispectral Data from the Earth Resources Technology Satellite as a Tool for Soil Survey. Multispectral reflectance data were obtained on different dates by the Earth Resources Technology Satellite (ERTS) over Lynn County, Texas in the Southern Great Plains. At an altitude of 915 kilometers the resolution of the ERTS multispectral scanner is approximately 0.5 hectare. This

resolution provides ample detail to identify and map significant soils differences and mapping units. Both photointerpretation and computer-implemented pattern recognition techniques were used to analyze the four spectral bands of ERTS data. In general, soil associations were delineated and mapped with these techniques.

Montgomery, O. L. and S. J. Kristof. 1973. In Situ Evaluation of Soil Surface Characteristics Using a Field Spectroradiometer. Data obtained from an extended wavelength field spectroradiometer were used to evaluate the soil surface characteristics from a number of soil types in the United States. The instrument has the capability of measuring spectral response in the wavelength range of 0.37μm to 14.0μm. The field of view of the instrument is adjustable from 1 degree to 15 degrees for both isolated and spatial viewing. Spectral reflectance characteristics were determined for representative samples of bench mark soils from each of the ten orders defined in the Seventh Approximation. Of the soils examined, many of the orders were easily separable spectrally. Further study is necessary to define spectral variations within orders.

Steinhardt, G. C., D. P. Franzmeier and J. E. Cipra. 1973. Comparison of Indiana Soil Associations and Earth Resources Technology Satellite Imagery. The multispectral scanner on board the Earth Resources Technology Satellite (ERTS) sends back data giving the intensity of radiation reflected from the earth's surface for various wavelengths in the visible and infrared portions of the spectrum. These data are recorded on magnetic tapes which can be used for producing black and white photographs and images on a display screen resembling a TV receiver. Interpretation in a manner similar to that used for aerial photographs of the photographic imagery made from a single wavelength band showed that some soil associations grouped by physiographic position could be consistently separated. False color imagery was produced by multiple exposure of color film through various filters to images in several wavelength bands displayed in black and white on the digital display screen. Compared with black and white imagery this technique gives sharper detail and allows separation of more soil-land use systems.

Stockton, J. G. and O. L. Montgomery. 1973. Reflectance Differences between Mollisols Observed in Data from the Earth Resources Technology Satellite. Multispectral reflectance measurements were obtained over North Dakota, Iowa, Kansas and Texas with the multispectral scanner on the Earth Resources Technology Satellite (ERTS). Computer-implemented pattern recognition techniques were used to analyze the multispectral data. The differences observed in surface reflectance of Mollisols can be related to geographic distribution. Analysis of variance seems to indicate that the differences due to geo-

graphic distribution are significant. The observed differences in reflectance were attributed primarily to climatic differences of the widely ranging geographic locations of the Mollisols examined in this study.

TALKS AND PUBLICATIONS NOT APPEARING IN INFORMATION NOTES

Jurica, G. M., Atmospheric Effects Upon a Remote Sensing Program. Presented to Applied Optics and Radiation Group, Purdue University, March 14, 1974.

Landgrebe, D. A., Information Sources and the Collection of Data (two lectures) and Spectral Analysis and Analysis Methods (two lectures). Summer School on Remote Sensing of Earth Resources, Organized by CNES (French Space Agency) under United Nations leadership, Tarbes, France, August 21 - September 20, 1973

Landgrebe, D. A., Multispectral and Machine Data Processing Methods. U. S. Department of Agriculture and NASA, Washington, D. C., November, 1973.

Landgrebe, D. A., On the Methods for Selecting Spectral Bands for Multispectral Data Classification. Bi-lateral U. S.-U.S.S.R. Meeting, NASA Headquarters, Washington, D.C., May 1, 1974.

Swain, P. H. and R. C. King, Two Effective Feature Selection Criteria for Multispectral Remote Sensing. Proc. Joint International Conference on Pattern Recognition, Washington, D. C., November, 1973.