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Annual Report to the University

Fiscal Year 1978

Laboratory for Applications of Remote Sensing
Purdue University West Lafayette, Indiana 47906 USA
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PURDUE UNIVERSITY
LABORATORY FOR APPLICATIONS OF REMOTE SENSING

1977-78 Report to the University

The Laboratory for Applications of Remote Sensing

We are pleased to transmit to you this report on the research and educational activities at LARS for the past fiscal year.

This past year saw the successful launch of Landsat-3, the third and last in this series of first generation satellites. With six years experience with these satellites, the technology associated with them continues to flow into practical uses on the national scene. Accordingly, at LARS we have continued to pursue programs of training, attempting to transfer the technology as rapidly but thoroughly as possible to the user community.

This past year has also seen the letting of contracts to industry by NASA for the final design and construction of Landsat-D, the first of a second generation sensor system which is to be launched in 1981. We earlier had the opportunity to have input into the specifications for this system. Because the data it delivers will be much greater in both quantity and complexity, it will require more complex processing procedures and will permit much more advanced applications. Thus during the past year we have increasingly turned our attention to research into advanced methods and basic understanding to form the basis of a second generation technology. Initial research results of this new emphasis are outlined herein. It is expected that the momentum of the national program and therefore of ours will continue to move in this direction for the next several years.

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

Respectfully submitted,

David A. Landgrebe

David A. Landgrebe
Director

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ANNUAL REPORT TO THE UNIVERSITY

FISCAL YEAR 1978

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SCIENTIFIC CONTRIBUTIONS OF LARS IN THE FIELD OF REMOTE SENSING

I. Introduction

Scientists working within the LARS organization during the 12 years since the inception of the Laboratory have been forerunners not only in the development of remote sensing technology but in its applications to such uses as the inventorying of earth resources and the non-invasive diagnosis of diseases in people. Successful accomplishments are apparent in the record for Fiscal 1978 for all of the five program areas which are involved in research.

The Laboratory has been deeply involved in research which has contributed substantially to a capability to make early estimates of world-wide wheat production, to use satellite data as an aid in the field mapping of soils and to understand the basic principles of radiation from such targets as plants, soils and water. It has also been involved through the year in advancing the technology of remote sensing in the areas of sensor improvement and data analysis and interpretation. Particularly worth noting is the design and development of a light weight, accurate, inexpensive radiometer capable of being used in the field and also the design and application of special equipment for diagnosing problems of human health.

It has become evident to LARS scientists that currently there is not sufficient understanding of the interrelationships of energy and surface features in spite of the past large effort in remote sensing research. Few adequate, accurate data sets are available which also provide timely and descriptive data of the field scene or "target". The LARS Crop Inventory and Measurements team is working to correct these deficiencies. As a step in standardizing the acquisition and calibration of spectral data an effective, operational field radiometer such as being developed at LARS will be invaluable.

New research projects acquired by Ecosystems Research area personnel are providing a basis for further development of fundamentals and their application to real problems. These include cooperative research with the North Central Experiment Station on the improved use of Landsat data in surveying natural resources, a study of the effects of topography on spectral reflectance and a cooperative project with a paper company to explore the utility of Landsat data in securing data helpful in the management of large timber holdings.

During the past year a capability to describe mathematically the geometric differences between images was perfected and the results incorporated into operational procedures for requesting remote sensor imagery. These advances are serving as necessary prologue to meeting a rapidly growing demand for a technology and operational procedure for a computer-implemented global data storage and retrieval system, a data bank, for natural resources, especially those impacting food production, distribution and consumption.

II. Contributions by Research Program Areas

A. Crop Inventory Systems Research Program

This program area has carried much of the leadership in the effort to develop ways to use satellite data to make accurate, early predictions of the world-wide production of grain crops, particularly of wheat. Impetus for such studies arise from the growing need for adequate food production and distribution to meet the demands of the rapid population growth occurring in many parts of the world. A 1976 report by the National Research Council estimates the present four billion world's population will grow to six billion by 2000 A.D. despite marked reductions in birth rate in some areas. Although most countries forecast and estimate their crop production, relatively few have reliable methods for gathering the necessary data.

The benefits of improved crop information include: 1) increased price stability resulting from accurate estimates, 2) timely and accurate forecasts of production which allow governments to plan domestic and foreign policies and actions, and 3) optimal utilization of storage, transportation, and processing facilities based on accurate forecasts. Conversely, the socio-economic costs of not having accurate and timely information available are substantial. During the past decade, considerable evidence has shown that remote sensing from aerospace platforms can provide quantitative data, providing much needed information on crop production.

During FY78, the Crop Inventory Systems Research program area continued to work with other program areas of the Laboratory, particularly Data Processing and Analysis Research and Measurements Research on the analysis of data from Landsat and field research projects. These projects are in support of the Large Area Crop Inventory Experiment (LACIE) currently being conducted by USDA, NASA, and NOAA. The LACIE is to develop, test, and demonstrate the feasibility of global crop inventories, with multispectral remote sensing data acquired by Landsat as one of the major inputs. The large-scale experiment is expected to lead to an operational remote sensing-based crop inventory system.

1. LACIE Field Measurements

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

Data were acquired for three crop years for test sites in Kansas, South Dakota, and North Dakota. The remote sensing data include measurements made from truck-mounted spectrometers, a helicopter-borne spectrometer, an airborne multispectral scanner, the Landsat multispectral scanner, and aerial photography. Detailed measurements and observations of the crops and soils, and

meteorological measurements are acquired simultaneously as part of each remote sensing mission. An important aspect of the spectral measurements is that the data from the various sensors, sites, and dates are so calibrated that they can be readily compared.

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

2. Analysis of Spectral Data for Physical Understanding

In this project data acquired by the LACIE Field Measurements project are being analyzed. The primary objective of the project is to quantitatively relate measurements of physiological and physical characteristics of wheat canopies to their multispectral reflectance. Several measures of the amount of vegetation, particularly leaf area index, biomass, and percent ground cover, were found to be strongly related to spectral response. Regression models to predict these crop variables were developed. The capability to predict crop variables from remotely sensed spectral data will be an essential component of developing crop condition and yield prediction models.

In another experiment, significant improvement in the capability to predict canopy variables was obtained using the spectral wavelength bands proposed for the sensor to be on Landsat-D. This scanner will have seven bands which are narrower and more optimally located in the spectrum than the four bands on the Landsat-1 and -2 sensors.

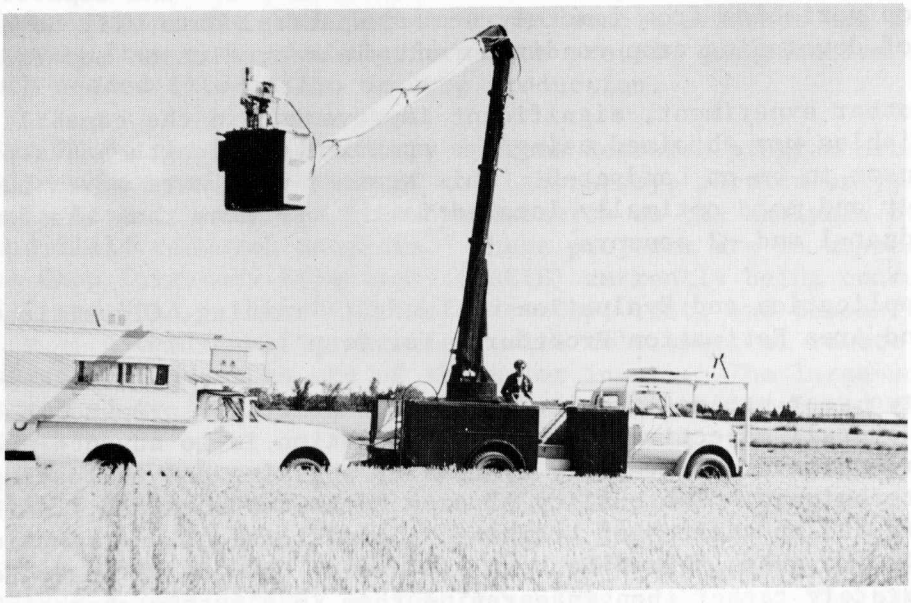
3. Application and Evaluation of Landsat Training, Classification, and Area Estimation Procedures for Crop Inventory

This two-year project resulted from an unsolicited proposal submitted to NASA. The overall objective of this investigation is to advance the development of large area crop inventory systems by applying and evaluating recently developed techniques. The quality of area estimates obtained from Landsat data is affected by choices of training, classification, and sampling procedures. In the past, there has been a tendency to deal with each of these issues separately rather than integrating them in a system approach as this investigation will do. Several types of agricultural scenes in the U.S. Corn Belt will be investigated to assess the scene dependent differences in optimal choices of training, classification, and sampling procedures.

The specific objectives are to evaluate: 1) procedures for selecting the size, number, and geographic location of training areas and for obtaining training statistics from multiple areas; 2) newly developed classification algorithms which utilize temporal and spatial as well as spectral information; and 3) area estimation methods including both a systematic sample of pixels and a sample segment approach.

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

This project, sponsored by NASA, calls for LARS to provide the technical implementation of remote sensing experiments of analogous vegetative areas in the United States and the Soviet Union. This was the second year of a multi-year study and is one of several joint U.S./U.S.S.R. studies on remote sensing of the natural environment. Test sites in South Dakota and the Kursk Oblast of Russia have been selected and data for two crop years have been collected and processed. Several remote sensing systems ranging from ground-level to satellite altitudes are being used. Initially, the study has concentrated on measuring the spectral reflectance of wheat and the agronomic factors affecting its growth and development. Data have been exchanged by the two countries and we are now in the process of analyzing the Soviet data, along with data from the U.S. test site.



LARS staff collecting data from wheat at Williston, North Dakota Agricultural Experiment Station as part of a study to determine the relationship between the agronomic and reflectance characteristics of spring wheat canopies.

B. Earth Sciences Research

1. Spectral Properties of Soils

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

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

A new study was initiated to collect and analyze duplicate samples of 250 surface soils selected from throughout the 48 contiguous states to represent a broad array of climatic and soil variables. The Soil Conservation Service is making a significant contribution to this study by collecting soil samples and providing detailed profile descriptions for each sample. The objective of this study is to define quantitatively the relationships between reflectance (visible and infrared) and physical/chemical properties of soils of significance in agriculture and engineering. The ultimate objective of this research approach is to provide a body of knowledge and interpretive skills which will render remote multispectral sensing a valuable tool for mapping soils, determining land use capabilities and soil productivity ratings, identifying crops, and predicting yields.

2. Soil Classification and Survey

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

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

During the year several briefing sessions were scheduled with administrators of the Soil Conservation Service. The continued development of applications techniques for using Landsat data successfully as a tool in soil survey prompted SCS to create a new fulltime position at LARS to be funded by the national office in Washington, D.C. A cooperative two-year plan of work was developed for the LARS-SCS remote sensing/soil survey program.

Frank Kirschner, USDA Soil Scientist/Remote Sensing Specialist, assigned to LARS by the Soil Conservation Service, checks satellite data against ground survey map.

C. Data Processing and Analysis Research

Research in data preprocessing and data analysis methods are being directed toward the enhancement and broadened applicability of remote sensing data processing technology.

1. Data Analysis Research

In late 1977 LARS was requested and funded by Control Data Corporation to investigate the feasibility of implementing an agricultural data center based on an advanced image processing system. This project involved assessment of potential markets for the technology, both in terms of various applications and world locales. Advanced systems such as the Control Data Cyber Ikon are becoming of increasing importance as the volume of available earth resources remote sensing data continues to increase.

Statistical design and statistical evaluation of analysis results are also of increasing importance as the technology is more widely applied. Sampling techniques, for specifying the economical collection of "ground truth", selection of areas to be analyzed, and extrapolation of sampled results to inferences about large areas clearly are vital tools. Support of the laboratory-wide application of statistical techniques has become a substantial component of the data analysis research effort.

2. Data Handling

Over the past several years research has been conducted on methods of geometrically aligning multiple images of the same scene to enable multivariate analysis and analysis of temporal changes in the images. Research addressed the problem of automatically correlating image pairs to find the geometric misalignment between them. The problem of mathematically describing the geometric differences between images was also researched and the results have been incorporated into operational procedures at LARS for registering remote sensor imagery. The capability for registering remote sensor data is being widely applied to Landsat satellite imagery in support of applications research in all of the disciplines embraced by LARS.

In the past year the registration concept has been broadened from image-to-image registration to encompass the registration of map and tabular data of many types to support the analysis of remote sensor data. These other data types can be considered "ground truth" or reference data and include variables such as topographic elevation and slope, soil type, land use, zoning, political boundaries and others. Research has been conducted on methods of converting maps to digital image form and several applications have been investigated. In one case the effects of slope, elevation and direction of slope on spectral response was studied in the San Juan Mountain area of Colorado using topographic map data registered with Landsat data. In a research project funded by the National Science Foundation, geophysical data as well as topographic map data are being registered with Landsat data to aid in exploration for minerals using remote sensing techniques. Also, research was begun recently under a contract with the NASA Wallops Island Laboratory to study methods of registering radar imagery with Landsat data to enable these data types to be analyzed together. This research is expected

to lead to a wide range of applications of computer-based methods where many remote sensing and ground-collected data variables must be analyzed together to obtain maximum benefit from the remote sensing data.

3. Aiding Technology Transfer

To aid in disseminating the data processing technology to the potential user community, members of the data processing and analysis research staff participate in, and in some cases organize, the development of educational materials and programs. In addition to making regular contributions to a monthly short course at LARS on the basics of remote sensing, the staff presented a five-day course on "Advanced Topics in the Analysis of Remote Sensing Data." The success of this latter course makes its annual presentation a likelihood.

D. Measurements Research

Measurements research at LARS has emphasized field instrumentation development and basic research into the physical aspects of remote sensing. Recent efforts have stressed development of improved data acquisition techniques, novel spectral data, preprocessing and handling capabilities, spectral data display techniques and the application of remote sensing technology to application areas other than earth resources.

During FY78 the following activities were pursued in the Measurements Program Area:

1. Field Data Acquisition System

For the past three years the LARS Field Data Acquisition System has been deployed at the North Dakota State University Agricultural Research Station at Williston, North Dakota. The system acquired spectral data as a part of the Field Measurement Research Project which supported the NASA Large Area Crop Inventory Experiment (LACIE). The data acquisition phase of that project is now complete. The spectral data have been interleaved with a large volume of ancillary data that was acquired as a part of the project experimental plan. All of the data have been calibrated, correlated and verified and placed in a computerized data library that will be available for retrieval and analysis by the remote sensing community. A data handling and display system was developed to permit researchers to interact easily with this unique spectral data base. The data library has been designed so that spectral data from other sources may be formatted and inserted into the library in a facile manner. The data library contains data from six sensors, all of which have been calibrated, verified, correlated with ancillary data and reduced to a compatible format. The data were acquired from sensors mounted on both ground-based and airborne platforms.

2. Instrument Development

A previously developed low cost field spectroradiometer was equipped with specially designed auxillary optical systems which enabled it to be used in a wide variety of spectral reflectance measurements applications. The instrument can be used to measure the spectral reflectance of botanical and biological specimens producing calibrated spectral reflectance data in a format that is compatible with the LARS spectral data library.

A four-band radiometer was integrated into an instrumentation that permits rapid acquisition of field spectral data. Special equipment was developed which permits attaching the radiometer to a lighweight vehicle. Special reflectance calibration standards were designed and developed which allow moving the multiband radiometer rapidly among experimental test sites. This facilitates acquiring moderate spectral resolution data over a wide variety of test sites in a relatively short period of time. In this manner the spectral data can be acquired at several times during the day thus promoting a detailed investigation of sun angle effects as well as a study of

stress development during the day. Although the spectral resolution of the multiband radiometer is not nearly as high as that of the primary data acquisition system operated by LARS it nevertheless represents a valuable adjunct to the array of spectral data acquisition equipment available.

Special electronic equipment was also designed and constructed that is capable of digitizing the video output signals of the Laboratory's thermal scanner. LARS now has the capability of acquiring high quality calibrated thermal imagery and accurately converting it into digital form for analysis by the powerful LARSYS software system. The digital-thermal scanner is being used in both field and biomedical work.

The measurements group is currently designing a special ten-band radiometer and compatible field data handling system that is intended for general use by the remote sensing community. This activity is intended to continue into fiscal year 1979.

Low-cost field radiometer system designed by LARS engineers which will allow spectral measurements to be economically acquired over a wide variety of crop and soil field experiments.

3. Thermal Band Remote Sensing of Crops

This activity was concluded during the current fiscal year but will be reinstituted during fiscal year 1979 as part of a stress detection experiment. The digital-thermal scanner mentioned above was used to acquire radiance temperature data over spring wheat at the Williston, North Dakota test site. The data were used to evaluate a simplified radiation model that permits accurate correlation of the crop geometry to its effective radiance temperatures. The experimental procedures developed are expected to aid materially in the interpretation of thermal band data from the Landsat-3 and Landsat-D satellites. It was concluded that the thermal band contains significant information concerning crop stress and crop geometry.

4. Application of Remote Sensing Technology to Biomedical Engineering

The non-contact characteristics of remote sensing technology make an attractive diagnostic tool in medicine where non-invasive diagnostic techniques are welcome. Also, the technology shows promise as a non-invasive system for evaluating the efficacy of medical devices. Several projects are underway in the Measurements Program Area which are centered upon the adaption of the instrumentation procedure to a particular problem in medicine or bio-medical engineering so that the powerful data analysis procedures that have been developed for earth resource applications can be brought to bear upon these medical problems. A technique has been perfected whereby the digital-thermal scanner is used to evaluate the performance of electrosurgical dispersive electrodes. The electrodes were applied to human volunteers and activated with conventional electrosurgical equipment. Calibrated digital temperature difference maps of the surface skin obtained after the electrodes had been removed were prepared and used to assess the amount of heating that takes place underneath and around the dispersive electrode. The results have been used to evaluate the performance of the electrodes and to improve significantly their design. The research has also lead to a basic understanding of the current distribution under and near the dispersive electrodes. This work has been done in cooperation with the Biomedical Engineering Center at Purdue.

The digital thermal system has also been used to evaluate the effectiveness of hyperthermia (tissue heating using radio frequency energy) in cancer eradication experiments on animals. This work was done in cooperation with the School of Pharmacy at Purdue. An experimental procedure is being designed in the use of the digital-thermal equipment in evaluating the tissue temperature in hyperthermia therapy on human subjects in the radiation therapy clinic at the Indiana University Medical Center in Indianapolis.

The spectroradiometer with the special optical system mentioned earlier has been used in a project involving the correlation of erythema (sunburn) to skin cancer incidence in humans. This same equipment has also been used in a project using skin reflectance measurements as a means of assessing the degree of jaundice in newborn infants.

E. Ecosystems Research

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

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

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

a. Coastal Zone Management Project

LARS, working with the Indiana Division of Forestry, completed a forest inventory for the 150,000 hectare watershed of Lake Michigan in northern Indiana. Computer-aided Landsat classifications were provided by LARS and formed the basis for an intensive field inventory. Information on woodland productivity and soil erodability were combined with the forest classifications to identify and map areas of management potential.

The Division of Forestry has been measurably impressed with the results of the inventory and have proposed additional work in southern Indiana. Additionally, the Division is suggesting the next state-wide forest inventory utilize Landsat technology.

b. Wetland Mapping and Habitat Evaluations

Working with the Indiana Division of Fish and Wildlife, LARS staff are developing a program to utilize remote sensing to map Indiana's wetland resources. Using computer-aided analysis techniques LARS will attempt to identify and map important wetland types from Landsat data. Classification results will be further evaluated to determine habitat potential and waterfowl carrying capacity for specific wetland areas.

2. Inventory of Derelict Lands

The Indiana Division of Reclamation contracted the Laboratory to provide a survey of derelict lands associated with coal strip mining. LARS staff working under guidelines of Public Law 152 Acts of 1976 conducted a photo-interpretation survey of a 20-county area in southwestern Indiana. Using small scale color infrared imagery, LARS was able to provide the Division with maps and acreage tabulations for gob, slurry and barren spoil areas that have not been reclaimed and may pose a threat to the environment.

The publication of the final report provided the Division with timely information regarding the status of derelict areas. This study has placed Indiana in a unique position ahead of other states where surface mining of coal is prevalent.

3. Forest Service Cooperative

LARS staff in the Forestry and Natural Resources Department are working on a cooperative agreement with the North Central Forest Experiment Station of the U.S. Forest Service. LARS will assess the feasibility of using computer analyzed Landsat data to supply information on forest acreage to the National Forest Survey. The Landsat data attributes of repetitive and timely coverage combined with quantitative data analysis techniques can have a significant impact on how the Forest Service conducts future state surveys.

4. NASA Funded Forestry Research

a. Forest Resource Information System

NASA is providing funding to LARS to work together with the St. Regis Paper Company to develop a Forest Resource Information System (FRIS). The system would utilize results from computer-analyzed Landsat data in combination with other forest inventory information to provide management with timely information regarding the status of the forest resource.

The project is significant in that it represents the first joint effort involving the academic, industrial and government sectors working together in an earth resources applications program. The results from this three-year study which began in October 1977, are expected to have an impact on how forest inventory is done in the future.

b. Forest Topography

Dating to the launch of Landsat-1 in 1972, LARS staff have been interested in pursuing research in the effect topography has on spectral response. A two-year study was funded by NASA to specifically investigate how physiography can be utilized when classifying Landsat data.

CONTRIBUTIONS OF LARS TO PROFESSIONAL AND ACADEMIC EDUCATIONAL PROGRAMS

I. Introduction

LARS reputation as a center for education and research in the application of remote sensing to real problems continues to grow as evidenced by the continually growing number of requests from technical people over the world for the privilege of working and studying at the Laboratory.

Countries preparing to use satellite data to secure resource data to guide national resource management, conservation and planning programs are selecting LARS as one of the major training centers to educate their scientists in the technology. During the past year of 22 scientists enrolled in the LARS Visiting Scientist Program, several countries used LARS as a place to train cadres which would serve as nuclei of newly forming remote sensing programs. Examples are a team of four from Bangladesh who combined training at the EROS Data Center, Sioux Falls, South Dakota with a three-week visiting scientist program at Purdue. This was the result of an earlier request from the Bangladesh government for help from LARS in training their professionals. Also as a result of an invitation from the Inter American Development Bank to submit a plan for developing a cadre of remote sensing specialists in each of five Central American countries, a long-time program was initiated with the arrival of two from each country in late March 1978 for a four-month training as LARS visiting scientists. These are the first of an expected series of trainees. In addition, the Ministry of Agriculture and Water of Saudi Arabia has asked LARS to submit a proposal for a thorough training program for their technical people.

LARS provides an excellent opportunity for many academic staff members at Purdue to become proficient in remote sensing technology through participating in research projects. These professors also gain much of value in their teaching activities through participating with scientists from various disciplines who are active in the interdisciplinary environment which exists at LARS. This kind of interaction has resulted in the initiation and development of several formal credit courses in academic departments at both the undergraduate and graduate level.

In addition to sponsoring the specific programs described in detail in the following pages, the Laboratory also:

A. Provides a funded research program and facility for 25 academic and 43 professional staff of the University who add to their teaching the knowledge gained in their remote sensing activities.

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

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

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

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

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

G. Directly supports with Laboratory resources, the educational activities for approximately 25 academic staff members who directed graduate thesis research in problems involving remote sensing in FY78. In the spring semester the Laboratory contributed to the salaries, fringe benefits and overhead of 25 academic staff members at an annual rate of $637,500 and supported the same costs for graduate assistants at an annual rate of $203,000. There were 43 graduate degree candidates, 10 of whom were granted an advanced degree, who were advised by LARS staff members in FY78. In addition to advising students on staff appointments, LARS academic staff members also advised graduate degree candidates in their home departments. Six formal university courses dealing with remote sensing are offered in three different schools by professors who gained their expertise at LARS. In addition, the content of several other courses in Agronomy, Forestry, Civil Engineering, Electrical Engineering and Nuclear Engineering include parts dealing with current remote sensing technology.

II. Specific Educational Programs

Since its initiation in FY74 the Technology Transfer Program has grown rapidly in scope under Professor John C. Lindenlaub. Further growth came during FY78 when Dr. Luis Bartolucci was appointed Technical Director of Training. In response to growing awareness of and demand for up-to-date information in remote sensing, the major components of Technology Transfer activities in FY78 were:

A. Remote Terminal Project

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

- to provide a training facility to potential remote sensing researchers and users, and

- to facilitate the communication of new remote sensing technology to remote sensing researchers and users.

During FY78, there were 30 line communication ports for access to the computer in operation, consisting of 7 card reader/printers, 18 typewriter terminals and 5 dial-up terminal ports. Each of the following locations had one or more card reader/printers and typewriter terminals: NASA/Goddard Space Flight Center, Maryland; NASA/Wallops Island, Virginia; NASA/Johnson Space Center, Texas; and Indiana State University, Indiana.

B. Visiting Scientist Program

The Visiting Scientist Program at the Laboratory for Applications of Remote Sensing, Purdue University, has been developed to meet the specialized needs of scientists who wish to become intimately acquainted with the remote sensing technology developed at Purdue. It provides an opportunity for personalized individual study at the Laboratory during a period of residence of length determined on a case-by-case basis.

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

The trainee or his sponsoring agency is expected to pay the cost of his training program. The cost is variable, depending on the duration of the training period and the amount of computer time used. The trainee or sponsoring agency must also provide for travel and subsistence expenses. During the first half of FY78 this program was under the direction of Professor John C. Lindenlaub; during the second half of FY78 it was under the direction of Dr. Luis A. Bartolucci.

Since FY73 there have been a total of 68 visiting scientists involved in applying remote sensing technology to problems in the 24 different foreign countries which they represented. During FY78 there were 22 visiting scientists involved in applying remote sensing technology to problems in 11 different foreign countries. Also during FY78 a 24-page document describing the program was published entitled, "The LARS Visiting Scientist Program", (LARS Information Note 070777) by John C. Lindenlaub and Douglas B. Morrison.

C. Short Courses

Short courses offered during FY78 included "Remote Sensing Technology and Applications" and "Advanced Topics in the Analysis of Remote Sensing Data." The former, a monthly short course, which had been initiated during FY76 was better attended in FY78 than previously with a total of 96 paid attendees, 38 of whom also participated in the extra computer option.

As in the previous year, the participants were a heterogenous group coming from federal government agencies (22%), state and local agencies (1%), foreign (49%), business and industry (13%), Purdue (1%), other universities (10%), and others (4%).

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

The nucleus of the course was a series of workshops in the analysis of multispectral data obtained from the Landsat satellites using the LARS software system as a prototype of digital remote sensing processing systems. Approximately 40 percent of the participants exercised the additional "Hands-On" option which gave them interactive experience in utilizing the computer to analyze a data set in a selected project.

The five-day advanced short course was offered in April 1978. Twenty-nine people attended coming from state and federal governmental agencies, industry, and universities. Of these, five were from foreign countries, three being from Mexico and one each from Canada and Germany. The course was under the direction of Dr. Philip H. Swain, assistant professor of Electrical Engineering, and was taught by Dr. Swain, Dr. Marvin E. Bauer, Barbara Davis, Dr. David A. Landgrebe, Dr. John C. Lindenlaub, and Dr. Clare D. McGillem. Subjects presented included Supervised and Unsupervised Analysis, Data Processing Methods, Multitemporal Analysis, Spatial Analysis Techniques, System Design and Data Transformations.

D. Educational Materials on Remote Sensing

1. FOCUS Series

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

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

2. The Fundamentals of Remote Sensing, a Minicourse Series

Instructional units of this series consist of printed study guides, a set of 35mm color slides and an audio tape. In addition, several of the units include tangible items which the student uses as he progresses through the minicourses. The series is aimed at the introductory or fundamental principle level. Persons with a background in elementary biology, physics and mathematics can understand and work with the basic concepts and ideas presented in the series. A 35mm slide projector and audio cassette player are required special aids for use with the minicourses. The minicourse series is funded by the Division of Conferences and Continuing Education Administration and presently marketed by them. As of April 20, 1978, 1,562 minicourses had been sold. Several LARS short course participants advised that their organization had purchased this series and that they had reviewed some of these individual courses prior to visiting LARS. List of Minicourse titles:

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

3. The LARSYS Educational Package

The LARSYS Educational Package is a set of instructional materials initially developed to train people to analyze remotely sensed multispectral data using LARSYS, a computer software system developed at Purdue/LARS. A variety of media is used depending on the nature of the subject matter and objectives of each unit. Reinforcement of certain basic concepts, such as the multispectral concept and the multidimensional statistical approach, is interwoven throughout the package. The units preceeded by an asterisk were developed during FY78. List of existing Educational Package Units:

An Introduction to Quantitative Remote Sensing
LARSYS Software System - An Overview
Demonstration of LARSYS on the 2780 Remote Terminal
*Demonstration of LARSYS on the Data 100 Remote Terminal
The 2780 Remote Terminal: A "Hands-On" Experience
*The Data 100 Remote Terminal: A "Hands-On" Experience

LARSYS Exercises
Guide to Multispectral Data Analysis Using LARSYS
A Case Study Using LARSYS for Analysis of Landsat Data
*A Case Study Using ECHO for Analysis of Multispectral Data

4. Simulation Exercises

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

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

Determining Land Use Patterns through Man-Machine Analysis of Landsat Data

5. The Videotape Series

The videotapes in this series "capture" a subject matter specialist's discussion of a remote sensing topic. The tapes are often refinements of a seminar or series of lectures given by the authors. Each tape runs about 30 minutes. Student viewing notes have been compiled for most of the videotapes. One new videotape was created during FY78. List of Videotape Titles:

Introduction to Quantitative Remote Sensing
Quality of System Types and the Multivariant Approach
System Parameters Fundamental to Information Extraction
Introduction to Pattern Recognition for Remote Sensing Applications
Statistical Characterization of Pattern Classes
Derivation of Discriminant Functions
Feature Selection
Cluster Analysis and Sample Classification
Introduction to Radiation in Remote Sensing
Reflectance in Remote Sensing
Emission in Remote Sensing
Fundamentals of Remote Sensing Instrumentation
Mapping Sudan's Resources from Space
*The Landsat Scanners (57 minutes)

6. Color Booklet Slide Set

A slide-tape presentation based on the booklet "Remote Sensing of Agriculture, Earth Resources and Man's Environment" was developed during FY78. This presentation, prepared for a general audience, reveals the role remote sensing has played and will play in monitoring and analyzing earth's resources.

E. Academic Credit Courses with Definite Emphasis on Remote Sensing

Agronomy

498 Inventorying Agronomic Resources
cr. 3 - Prof. Baumgardner and Dr.'s Bauer and Weismiller

Electrical Engineering

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

Forestry

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

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

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

Geosciences

518 Aerogeology and Remote Sensing
cr. 3 - Prof. Levandowski

F. Courses Related to Remote Sensing

Agronomy

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

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

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

Civil Engineering

503 Photogrammetry
cr. 3 - Prof. Mikhail

567 Airphoto Interpretation
cr. 3 - Prof. Miles

603 Advanced Photogrammetry
cr. 3 - Prof. Mikhail

667 Advanced Airphoto Interpretation
cr. 3 - Prof. Miles

Electrical Engineering

644 Communications I
cr. 3 - Communications Sciences Staff

645 Communications II
cr. 3 - Communications Sciences Staff

661 Image Processing
cr. 3 - Prof. Huang

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

Forestry

557 Aerial Photointerpretation
cr. 3 - Prof. Miller

III. Growth of World-Wide Interest in LARS as an Educational Center.

From its beginning LARS has attracted visitors from over the world interested in learning the technology being developed at the Laboratory. Short courses and symposia were offered early in the program. By 1971 the visitor load had grown to a dimension calling for special provisions to accomodate it (Figure 1). A plan was developed at that time to permit visiting scientists to work at the Laboratory on a cost-recovery basis.

By 1974 the demand from large numbers of scientists from over the world wishing to visit LARS resulted in the creation of the present Technology Transfer Program Area. The number of visiting scientists since that time has shown steady growth except for 1977 (Figure 2). Recognition of LARS as a world-wide center for education in applications of remote sensing is apparent in Figures 3, 4 and 5.

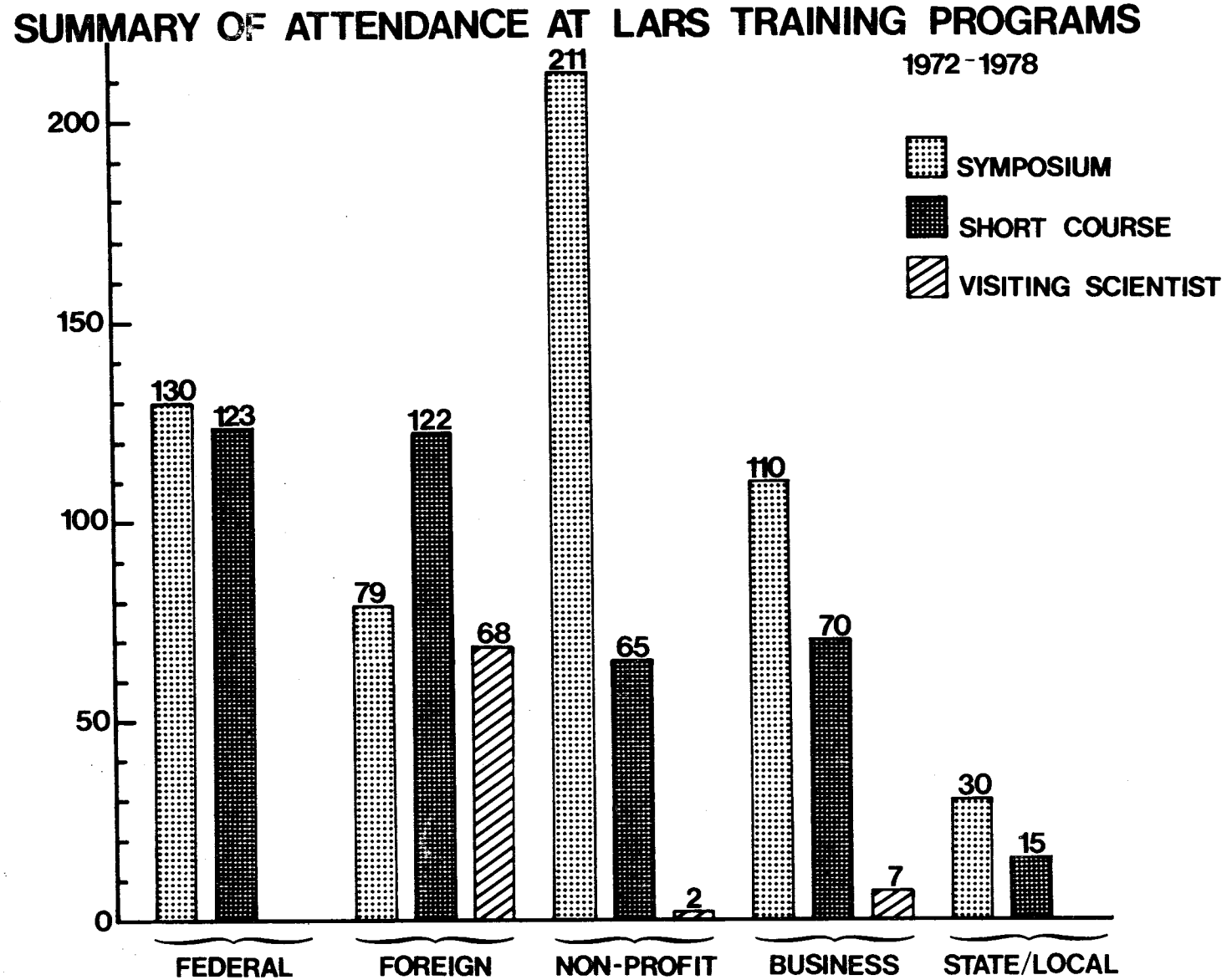

SUMMARY OF ATTENDANCE AT LARS TRAINING PROGRAMS
1972-1978
SYMPOSIUM
SHORT COURSE
VISITING SCIENTIST
200
150
100
50
0
130
123
79
122
68
211
65
2
110
70
7
30
15
FEDERAL
FOREIGN
NON-PROFIT
BUSINESS
STATE/LOCAL

Figure 1

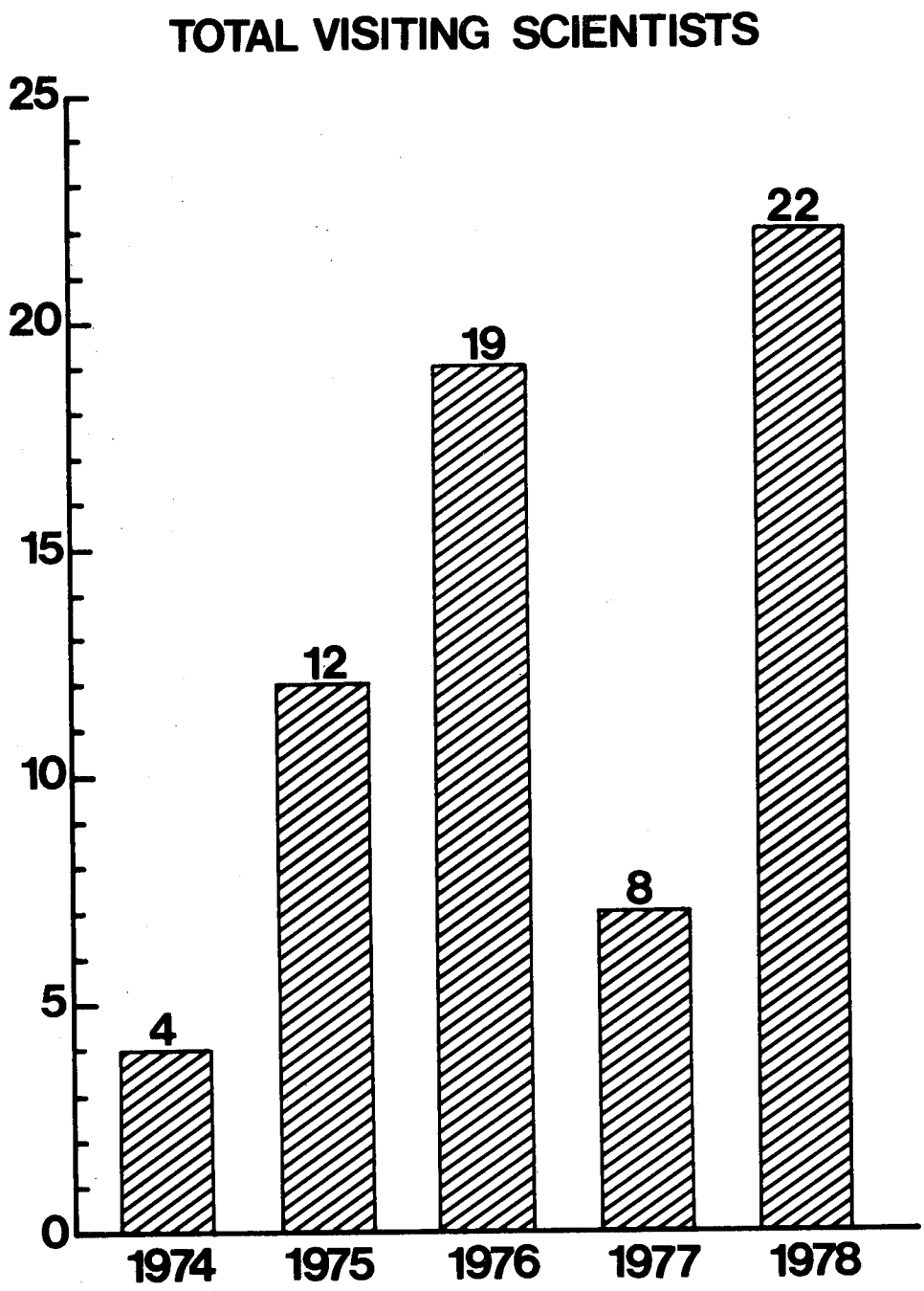
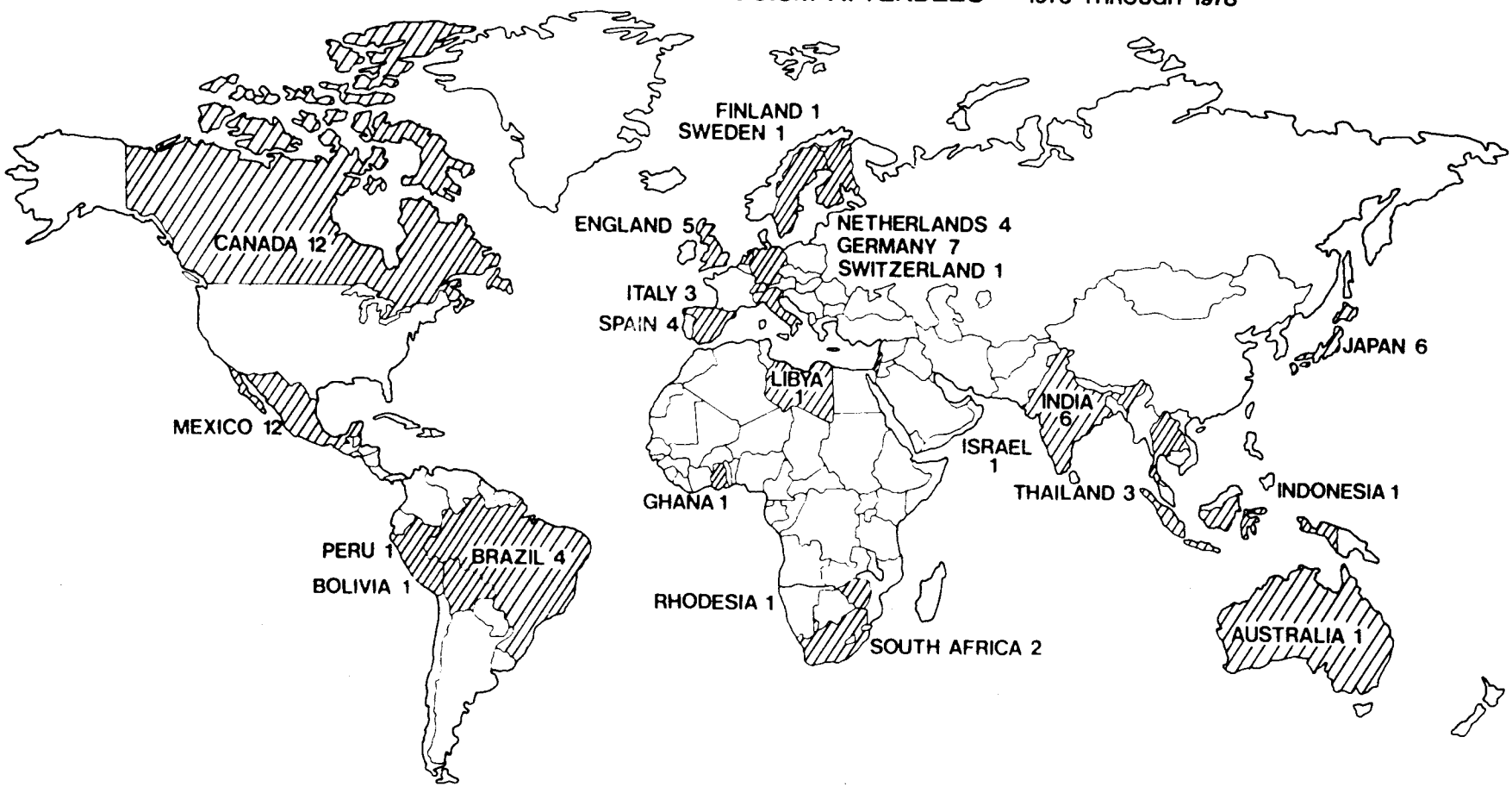

TOTAL VISITING SCIENTISTS
25
20
15
10
5
0
4
12
19
8
22
1974
1975
1976
1977
1978

Figure 2

79 TOTAL **FOREIGN SYMPOSIUM ATTENDEES** 1973 THROUGH 1978



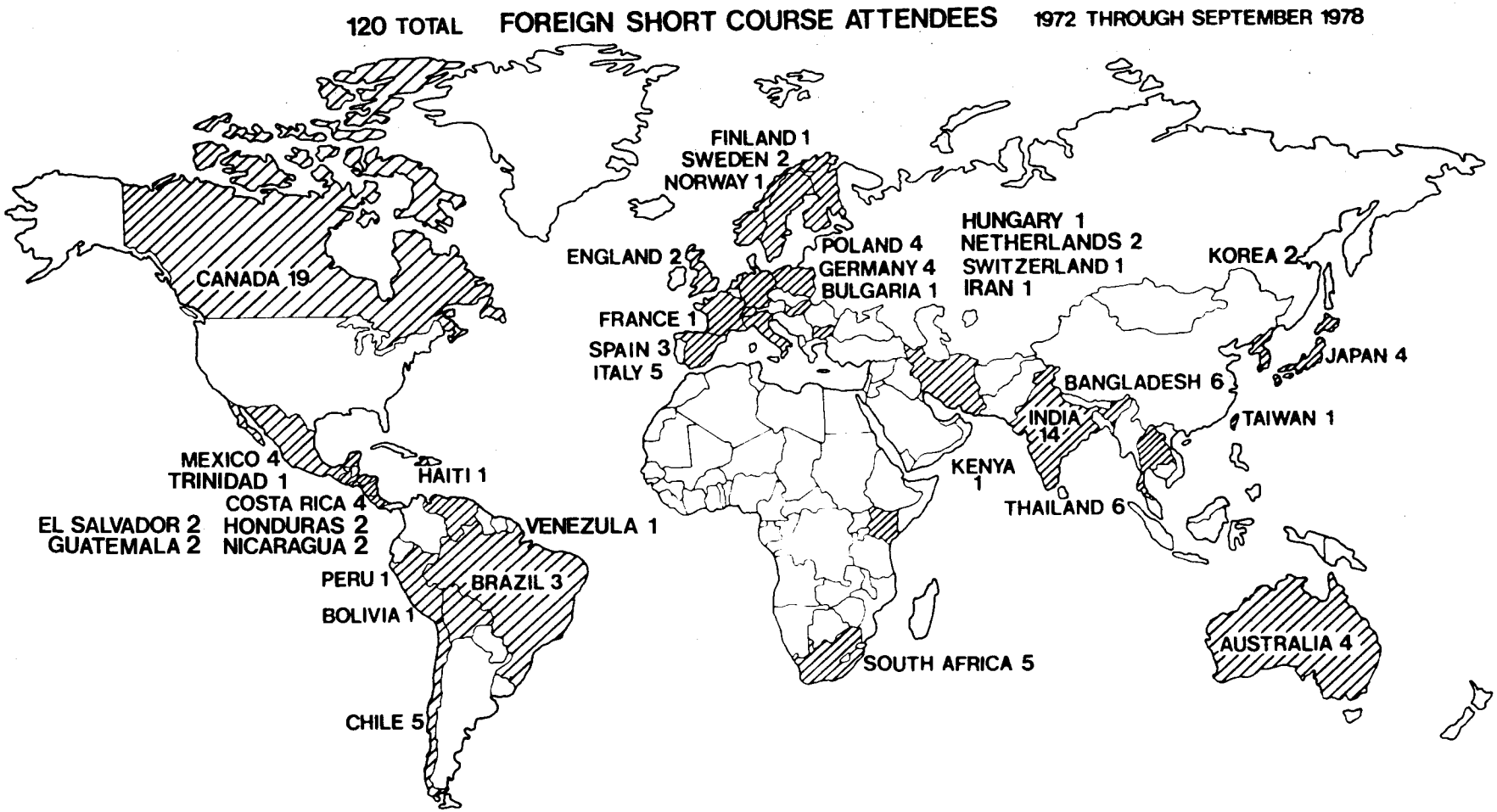
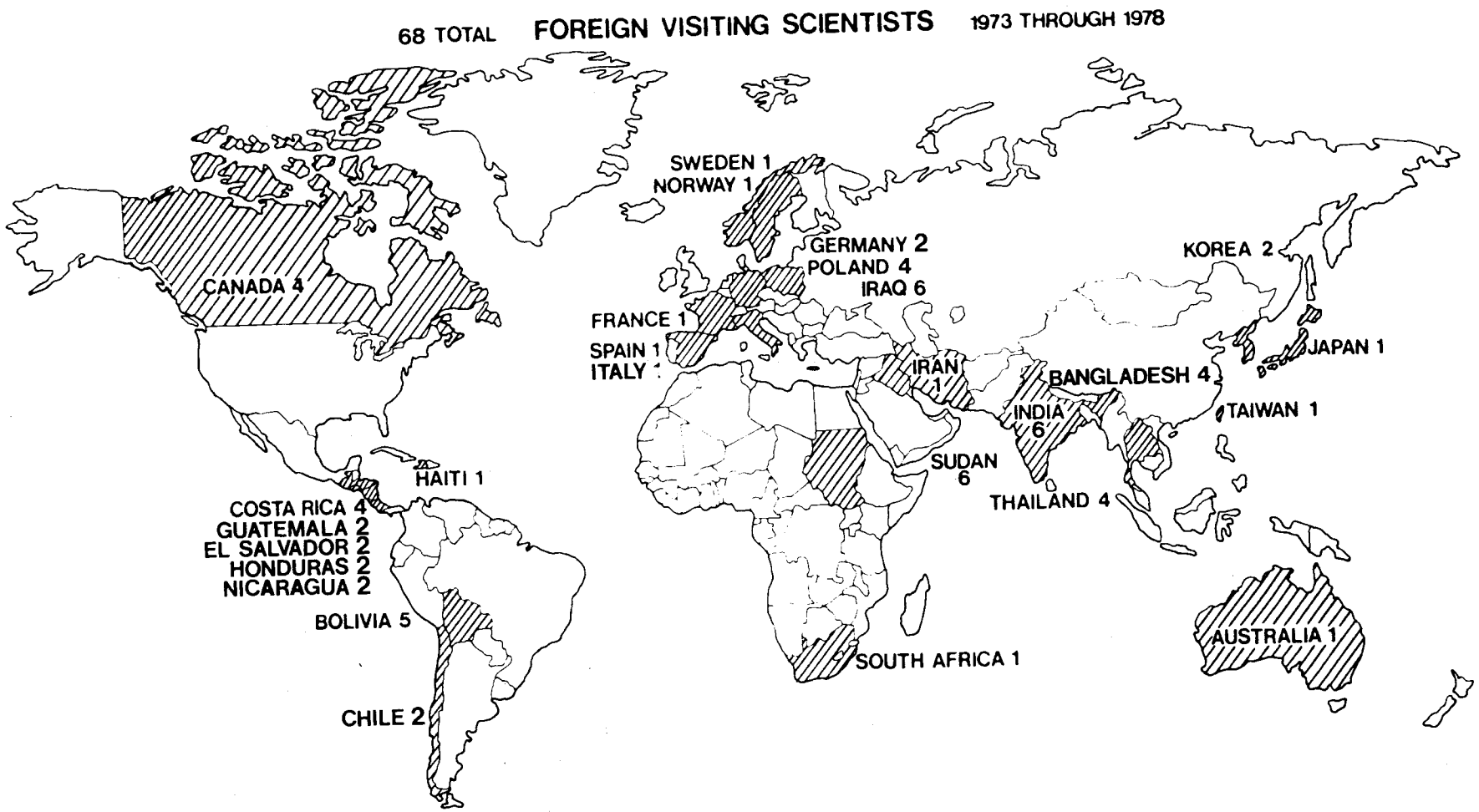

120 TOTAL FOREIGN SHORT COURSE ATTENDEES 1972 THROUGH SEPTEMBER 1978
FINLAND 1
SWEDEN 2
NORWAY 1
HUNGARY 1
NETHERLANDS 2
SWITZERLAND 1
IRAN 1
POLAND 4
GERMANY 4
BULGARIA 1
ENGLAND 2
KOREA 2
CANADA 19
FRANCE 1
SPAIN 3
ITALY 5
JAPAN 4
BANGLADESH 6
INDIA 14
TAIWAN 1
KENYA 1
MEXICO 4
TRINIDAD 1
HAITI 1
COSTA RICA 4
EL SALVADOR 2
HONDURAS 2
GUATEMALA 2
NICARAGUA 2
VENEZULA 1
THAILAND 6
PERU 1
BRAZIL 3
BOLIVIA 1
AUSTRALIA 4
SOUTH AFRICA 5
CHILE 5

Figure 4


68 TOTAL FOREIGN VISITING SCIENTISTS 1973 THROUGH 1978
SWEDEN 1
NORWAY 1
GERMANY 2
POLAND 4
IRAQ 6
KOREA 2
CANADA 4
FRANCE 1
SPAIN 1
ITALY 1
IRAN 1
JAPAN 1
BANGLADESH 4
INDIA 6
TAIWAN 1
SUDAN 6
HAITI 1
COSTA RICA 4
GUATEMALA 2
EL SALVADOR 2
HONDURAS 2
NICARAGUA 2
THAILAND 4
BOLIVIA 5
AUSTRALIA 1
SOUTH AFRICA 1
CHILE 2

IV. Graduate Training with LARS Staff and Facilities

A. Degree Candidates FY78

Ahlrichs, John, M.S., Agron., M.E. Bauer, "Relation of Crop Canopy Variables to the Multispectral Reflectance of Spring Wheat."

Caruso, P., M.S., ME, Prof. D.P. DeWitt, Non-thesis option.

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

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

Ernst, L., Ph.D., For. and Nat. Resources, Prof. R.M. Hoffer, "Extraction of Information Useful for Wetland Habitat Evaluated from Remote Sensing Data."

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

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

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

Hanley, E., M.S., ME, Prof. D.P. DeWitt, "Non-invasive Medical Diagnostics through Multispectral Scanner Reflectance Analysis: Jaundice Detection and Drythema Assessment."

Hinzel, E., M.S., Agron., R.A. Weismiller, Thesis title not yet assigned.

Jordan, S., Ph.D., Geosc., Prof. D. Levandowski, Thesis title not yet assigned.

Kaminsky, S., M.S., Agron., R.A. Weismiller and Prof. B.O. Blair, "An Investigation of Analysis Techniques of Landsat Multispectral Data Designed to Aid the Soil Survey."

Keh, E., Ph.D., CS, D. Freeman, Thesis title not yet assigned.

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

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

L'Heureux, D., Ph.D., Geosc., Prof. Levandowski, Thesis title not yet assigned.

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

McMeekin, J., M.S., CS, J. Etheridge, Non-thesis option.

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

Moore, G., Ph.D. EE, Prof. P.H. Swain, Thesis title not yet assigned.

Muasher, M., M.S., EE, Prof. D.A. Landgrebe, Non-thesis option.

Nash, L., M.S., Agron., Prof. M.F. Baumgardner, "Spectral Analysis of Soil-Vegetation Complexes."

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

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

Pearce, J., Ph.D., EE, Prof. L.A. Geddes, Thesis title not yet assigned.

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

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

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

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

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

Walburg, G., M.S., Agron., M.E. Bauer, Thesis title not yet assigned.

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

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

B. Degrees Granted FY78

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

Chu, N.Y., Ph.D., EE, Prof. C.D. McGillem, Methods and Performance Bounds for Constrained Image Restoration.

Crecelius, D., M.S., Agron., M.E. Bauer, The Time of Day Effect on the Reflectance of Spring Wheat Canopies in the Four Landsat Multispectral Bands.

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

Mobasseri, B.G., Ph.D., EE, Prof. C.D. McGillem, A Parametric Multiclass Bayes Error Estimator for the Multispectral Scanner Spatial Model Performance Evaluation.

Overmeyer, K., M.S., ME, Prof. D.P. DeWitt, Modeling the Electronic and Thermal Performance of Electrosurgical Dispersive Electrodes.

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

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

Sabagopan, Sowmya, M.S., IE, Prof. A. Ravindran, Ranking the Extreme Points of Convex Polyhedra.

Traxler, D., M.S., ME, Prof. D.P. DeWitt, Non-thesis option.

C. Other Graduate Students Advised by LARS Staff Members

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

Franz, S., M.S., Education, Prof. J.C. Lindenlaub, Non-thesis option.

Kaiser, S., M.S., EE, Prof. D.A. Landgrebe, Non-thesis option.

Seubert, C., Ph.D., Agron., Prof. M.F. Baumgardner, "Assessing Erosion-Sedimentation Phenomena by Spectral Measurements."

Sontirat, V., M.S., Agron., Prof. M.F. Baumgardner, "Land Use Classification of the Bangkok, Thailand Area by Digital Analysis of Landsat Multispectral Data."

APPENDIX I

Visitor Summary

A. Overall Summary

1.	Federal Agencies	40
2.	State and Local Agencies	29
3.	Other State and Local Agencies	9
4.	Purdue University	58
5.	Other American Universities	35
6.	Industry	50
7.	Foreign	64
8.	Miscellaneous	23

B. Visitors by Affiliation

1. Federal Agencies

a.	National Aeronautics and Space Administration	13
b.	U.S. Department of Agriculture/Statistical Reporting Service	2
c.	U.S. Geological Survey	1
d.	United Nations Aid Study	1
e.	U.S. Forestry Service	3
f.	U.S. Army	1
g.	U.S. Department of Agriculture/ARS	3
h.	U.S. Department of Agriculture/ASCS	1
i.	U.S. Congress	3
j.	Department of Interior, Bureau of Land Management	2
k.	U.S. Department of Agriculture/Soil Conservation Service	7
l.	Defense Mapping Agency	2
m.	Naval Coastal Service	1

2. State and Local Agencies

a.	Indiana Geological Survey	12
b.	Tippecanoe Soil and Water Conservation	10
c.	Indiana State Highway Department	5
d.	State Planning Services	1
e.	Indiana Natural Resources	1

3. Other State and Local Agencies

a.	Colorado	1
b.	Florida	1
c.	Illinois	6
d.	Virginia	1

4. Purdue University 58

5.	Other American Universities	35
6.	Industry	50
7.	Foreign Countries	
	a. Australia	1
	b. Bangladesh	4
	c. Belgium	1
	d. Bolivia	1
	e. Canada	7
	f. Chile	1
	g. Costa Rica	2
	h. El Salvador	2
	i. France	2
	j. Guatemala	2
	k. Honduras	2
	l. Hungary	1
	m. India	4
	n. Iran	1
	o. Italy	1
	p. Japan	4
	q. Malaysia	2
	r. Mexico	4
	s. Nicaragua	4
	t. Norway	3
	u. Peru	1
	v. Saudi Arabia	1
	w. South Africa	1
	x. Spain	2
	y. Thailand	2
	z. Turkey	2
	aa. Venezuela	1
	bb. Wales	2
	cc. West Germany	3
8.	Miscellaneous	23

APPENDIX II

Publications and Talks by LARS Staff

A. Technical and Educational/Descriptive Publications

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

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

022277 A Mathematical Basis for the Detection of Jaundice by Skin Reflectance Analysis by E. J. Hanely. The objective of this study is to provide a physical basis for the method of optically detecting jaundice. The skin is treated as a homogeneous scattering medium in which bilirubin is dispersed. The model determines in what manner the optical properties of the bilirubin affect the observed reflectance of the skin.

The research reported in this paper was supported by the National Institute of Health, National Institute of Arthritis, Metabolism and Digestive Diseases, Grant Number 1 RO1 AM18871-01.

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

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

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

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

062277 Evaluation of Change Detection Techniques for Monitoring Coastal Zone Environments by R.A. Weismiller, S.J. Kristof, D.K. Scholz, P.E. Anuta and S.M. Momin. Development of satisfactory techniques for detecting change in coastal zone environments is required before operational monitoring procedures can be established. In an effort to meet this need a study was directed toward developing and evaluating different types of change detection techniques, based upon computer-aided analysis of Landsat multispectral scanner data, to monitor these environments.

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

063077 Crop Identification and Area Estimation by Computer-Aided Analysis of Landsat Data by M. Bauer, M. Hixson, B. Davis and J. Etheridge. This report describes the results of a study involving the use of computer-aided analysis techniques applied to Landsat MSS data for identification and area estimation of winter wheat in Kansas and corn and soybeans in Indiana. Key elements of the approach included use of aerial photography for classifier training, stratification of Landsat data and extension of training statistics to areas without training data, and classification of a systematic sample of pixels from each county. Major results and conclusions are: (1) Landsat data was adequate for accurate identification and area estimation of winter wheat in Kansas, but corn and soybean estimates for Indiana were less accurate; (2) computer-aided analysis techniques can be effectively used to extract crop identification information from Landsat MSS data, and (3) systematic sampling of entire counties made possible by computer classification methods resulted in very precise area estimates at county as well as district and state levels.

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

*070777 The LARS Visiting Scientist Program by J.C. Lindenlaub and D.B. Morrison. The LARS Visiting Scientist Program is described and illustrated by means of a number of example programs and a description of the types of services provided. Participant's qualifications and instructions for applying to the program are given, necessary financial arrangements are explained and advanced planning requirements are given. Appendices provide the reader with an advance planning check list, application form, guidelines for estimating costs and a listing of current visiting scientist rates.

This report was sponsored by the Visiting Scientist Program.

072277 The Decision Tree Classifier: Design and Potential by P.H. Swain and H. Hauska. This paper presents the basic concepts of a multistage classification strategy called the decision tree classifier. Two methods for designing decision trees are discussed and experimental results are reported. The relative advantages and disadvantages of each design method are considered. A spectrum of typical applications in remote sensing is noted.

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

*Educational and Descriptive Material

081777 Techniques for Estimating Scales and Areas for Landsat Data by Pierre-Marie Adrien and Vern Vanderbilt. The report describes mathematically the scaling processes used in both the optical and digital techniques applied to Landsat data. The following numerical properties of each method are summarized as a function of scale in two tables: Landsat pixels/square centimeter of image, surface area represented by each square centimeter of image (in hectares, acres, and square kilometers), number of pixels represented by each displayed data point, and surface area represented by each displayed data point (in hectares, acres, and square kilometers).

The work reported in this paper was sponsored by the InterAmerican Development Bank under the Visiting Scientist Program.

082377 Error Estimation and Separability Measures in Feature Selection for Multiclass Pattern Recognition by S.J. Whitsitt and D.A. Landgrebe. The ability to estimate pattern classifier error rates a priori is important in processing steps such as feature selection, algorithm and system design and other phases of information systems design and operation. This work reports several new results on this problem; these results include methods for reducing the variance in error estimation when Monte Carlo simulation techniques are used, the use of separability measures which approximate rather than bound the error rates, use of optimum linear reduction transforms, and empirical tests of these procedures.

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

082477 Comparing Soil Boundaries Delineated by Digital Analysis of Multispectral Scanner Data for High and Low Spatial Resolution Systems by S.J. Kristof, M.F. Baumgardner, A.L. Zachary and E.R. Stoner. Aircraft and Landsat data were used with computer-aided techniques to delineate soil patterns of a field of 40 hectares. The limited spatial resolution of the satellite scanner made difficult to delineate those soil features with widths less than the spatial resolution of the scanner. However, spatial resolution of the aircraft scanner was adequate to recognize each soil type boundary in the test site.

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

*090177 A Case Study Using ECHO for Analysis of Multispectral Scanner Data by D. Scholz, J. Russell, J. Lindenlaub and P. Swain. This case study is a component of the LARSYS Educational Package. It is designed to introduce the ECHO processing function which may be implemented on a variety of computer systems. The typical steps in the analysis of remotely-sensed data using ECHO are illustrated through discussion, an illustrative example and exercises. The exercises have been written for implementation of a computer using LARSYS; however, they may be modified for other analysis systems.

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

*Educational and Descriptive Material

090777 Land Use Classification of the Warsaw, Poland Area by Digital Analysis of Landsat Data by Z.T. Bochenek and W.A. Madej. Landsat data collected over the central part of Poland were analyzed by computer-implemented techniques to evaluate the usefulness of these data for land-use classification. Several land use classes were identified with reasonably good accuracy. Computer-aided analysis proved to be useful in discrimination of many subclasses.

The work reported in this paper was sponsored by the Institute of Geodesy and Cartography, Warsaw, Poland.

090677 Computer-Aided Analysis of Landsat Data for Surveying Texas Coastal Zone Environments by S.J. Kristof and R.A. Weismiller. A study was conducted to determine the feasibility of using machine-aided processing of Landsat data to inventory environmental units within the Texas coastal zone. The analysis was conducted on Landsat data collected on November 27, 1972 and February 25, 1975 over the Matagorda Bay area of the Texas coastal estuarine system. The following terrestrial and aquatic environments were discriminated: alternating beach ridges, swales, sand dunes, beach birms, deflation surfaces, land-water interface, urban, spoil areas, fresh and salt water marshes, grass and woodland, recently burned or grazed areas, submerged vegetation and waterways.

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

091577 A Simplified Design Procedure for Image Restoration and Enhancement Filters by C.D. McGillem and N.Y. Chu. A method for simplifying the design procedure of image restoration filters is presented. The procedure is extended to include optimal interpolation-restoration processing for sharpening and enlarging Landsat images. Preliminary experimental results are included.

The results reported in this paper were supported by the National Science Foundation under Contract No. ENG-7614400.

092377 Soil Map Unit Composition Assessment by Digital Analysis of Landsat Data by F.R. Kirschner, S.A. Kaminsky, R.A. Weismiller, H.R. Sinclair, and E.J. Hinzel. Digital Analysis of Landsat MSS data collected June 9, 1973 was used to prepare a spectral soil map of a 430-hectare area in Clinton County, Indiana. Spectral identification of soil drainage characteristics enabled soil map units, inclusions, and complexes to be readily identified and quantified.

The work reported in this paper was sponsored by the National Aeronautics and Space Administration, Office of University Affairs under Grant NGL-15-005-186.

*092177 A Satellite View of Indiana by R.W. Weismiller and D.K. Scholz. Indiana mosaic and narrative.

The work reported in this paper was sponsored by the National Aeronautics and Space Administration, Office of University Affairs under Grant NGL-15-005-186.

*110577 The LARSYS Educational Package: Instructor's Notes for Use with the Data 100 by J.C. Lindenlaub and J.D. Russell. The LARSYS Educational Package is a set of instructional materials developed to train people to analyze remotely sensed multispectral data using LARSYS. A computer software system developed at LARS/Purdue. The materials included in this volume have been designed to assist LARSYS instructors as they guide students through the LARSYS Educational Package. All of the materials have been updated from the previous version (Information Note 110574) to reflect the use of a Data 100 Remote Terminal.

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

*110677 Demonstration of LARSYS on a Data 100 Terminal - Student's Notes by J. Lindenlaub and Staff. This unit provides the student with an introduction to the remote terminal hardware he will be using and introduces him to some aspects of the LARSYS software system. The demonstration requires an instructor to present the material and guide the student. The student's notes provide objectives and activities to reinforce the concepts presented.

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

*110777 Data 100 Remote Terminal - A Hands-On Experience - Student's Notes by J.D. Russell. In this unit the student is instructed in the use of the terminal by means of an audio-tape accompanied by these student notes. Details concerning interactive use of a CRT or typewriter console and a Data 100 Remote Terminal are presented.

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

110877 In Perspective: Meeting the Image Processing Challenge for Remote Sensing by P.H. Swain. Image processing technology as applied to remote sensing of earth resources has been evolving for more than a decade. After outlining the unique aspects of the problem, this paper surveys the progress which has been made in developing computer-based techniques for image enhancement, image analysis, and the formatting, storage and retrieval of results. Needs for the future are also discussed.

111477 Delineating Salt-affected Soils in the Ganges Plain, India, by Digital Analysis of Landsat Data by A.N. Singh, S.J. Kristof and M.F. Baumgardner. A study was conducted to determine the feasibility of delineating salt-affected soils using computer-aided analysis of Landsat-1 data in an area of the Ganges Plain, Meerut district, India. The multispectral scanner data were obtained on the 2 December 1972 pass. Both supervised and unsupervised classification techniques were used. Four spectral classes of salt-affected soils were separated. The results indicate that Landsat data can be successfully used for differentiating salt-affected soils.

The work reported in this paper was sponsored by UNDP under Contract No. TE323-IND/76/018.

*Educational and Descriptive Material

112277 Computer-Aided Analysis Techniques for an Operational System to Map Forest Lands Utilizing Landsat MSS Data by M.D. Fleming and R.M. Hoffer. The objective of this research was to define an effective and efficient computer-aided analysis technique that can be utilized to map natural resources, particularly forest lands, in areas of rugged terrain using digital multispectral scanner data collected from satellite altitudes. Six alternative procedures for developing training statistics were defined and tested. The results indicated that the "Multi-Cluster Blocks" approach was optimal since it required the smallest amount of support data, required relatively few man-hours of analyst time, reduced computer time (CPU) and resulted in the highest overall classification accuracy. This approach was tested and evaluted on six additional test sites and with both Landsat and Skylab data. The various steps involved in the Multi-Cluster Blocks procedure, which include the selection of heterogeneous blocks of MSS data, individual clustering of each block identifying cluster classes, and pooling spectral classes into informational classes, are described in detail in this report.

The work described in this report was sponsored by NASA under Contracts NAS9-13380, NAS5-21880 and NAS5-20948.

121277 Detection of the Green and Brown Wave in Hardwood Canopy Covers Using Multidate, Multispectral Data from Landsat-1 by B.O. Blair and M.F. Baumgardner. Phenologic events which may be related to yields of economic plant species in humid and subhumid temperate regions are difficult and expensive to observe and measure. Sequential multispectral reflectance data obtained by an orbiting satellite (Landsat-1) over 14 preselected sites in central and eastern United States during a 14-month period were examined. Analysis of data from four reflectance bands (0.5 to 1.1 μm) indicated that foliage color, leaf sensescence, and regrowth differences among hardwood timber stands can be detected and quantified. The results suggest the need for continued development of these monitoring techniques for use in detecting and quantifying conditions of economic plants which may affect yield.

The work reported in this paper was sponsored by Purdue Agricultural Experiment Research Station under Project No. NE-69 under Contract No. NAS5-21781.

010478 Estimating Agricultural Production by the Use of Satellite Information: An Experiment with Laotian Data by R. Hooley, R. Hoffer, and S. Morain. Developing countries need information on the level and composition of agricultural production. Existing methods of measuring the level of agricultural activity leave much to be desired when applied to Least Developing Countries (LDCs). The use of satellite data can make an important contribution to the speed with which data on areas under cultivation are available, to improve cost effectiveness, and hence to a shortening of the length of the reporting period. Relatively simple, manual interpretation techniques can be utilized to provide many LDCs with methods that are relatively cheap and that do not require the availability of very highly specialized computer processing capabilities. This paper reports the results of one study in the country of Laos.

The work reported in this paper was sponsored by the Asia Foundation.

011278 Landsat, Computers and Development Projects by P.M. Adrien and M.F. Baumgardner. Data provided by earth-orbiting satellites and analyzed through specific computer techniques are rapidly providing policy-makers around the world with new information on the location and extent of their countries' renewable and nonrenewable resources. This paper describes new data acquisition and analysis techniques and provides numerous examples of how this new technology may be used to survey and monitor the land, vegetation, water and mineral resources of the world.

011678 Optimum Filter for Minimization of Image Registration Error Variance by C.D. McGillem and M. Svedlow. The problem discussed is the design of an optimum filter for registration of two images of the same scene. The optimum filter was previously shown to be a matched filter. This report shows that in addition to being optimum in the sense of maximum signal to noise ratio at the match position it also minimizes the variance of the registration error.

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

011778 Measurements of Temperature Distribution at Electrosurgical Dispersive Electrode Sites by K.M. Overmyer, J.A. Pearce and D.P. DeWitt. The superficial temperature distribution for various types of dispersive electrodes applied to human subjects and a surrogate medium are presented. Typical temperature distributions on the human thigh display a high temperature perimeter and cooler central area, with the temperature extremes and contours peculiar to the electrode design. These patterns persist for several minutes after electrode removal. A series of experiments were conducted on a surrogate medium to determine the extent of volumetric (ohmic) heating, to evaluate influence of media properties on the temperature distribution, and to evaluate the use of the medium for simulation of the human system. It was found that volumetric heating is appreciable and that appropriate alteration of the medium resistivity with depth produced patterns having similar characteristics to those obtained with the same electrode on a human thigh. A simplified model to analytically predict the temperature distribution is presented and the results are similar to those observed on human subjects.

The work reported in this paper was funded by NDM.

022478 Origins of the Land Grant Philosophy and Its Influence on Agronomic Education by J.B. Peterson. Agronomic education today reflects an evolution in educational philosophy at the college level that was developing as early as the late 1700's. This was, in effect, a belief that practical people who engaged in mechanical and/or agricultural occupations would profit from advanced learning in science, technology, and cultural subjects. This view was not broadly implemented until the passing of the Morrill Act in 1862. The number of agricultural colleges grew steadily following the Civil War. Agronomy as a discipline became a part of this development. In this century agronomic education has reflected the steady advances in agronomic science, and a parallel advance in educational methods, particularly the audiotutorial approach. The changes in national interests and falling proportion of farm families in the population are having an effect on agronomic education. Many persons are studying agronomic subjects because of their interest in the environment and women and urban students are electing phases of agronomy as careers.

030178 Bayesian Classification in a Time-Varying Environment by Philip H. Swain. This paper deals with the problem of classifying a pattern based on multiple observations made in a time-varying environment. The identity of the pattern may itself change. A Bayesian solution is derived, after which the conditions of the physical situation are invoked to produce a "cascade" classifier model. Experimental results based on remote sensing data demonstrate the effectiveness of the classifier.

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

*042778 Purdue/LARS Organization. This document provides a photo and brief resume for each of the LARS Program Leaders and principal administrative personnel.

*Educational and Descriptive Material

B. Contract Reports

082977 SR&T Quarterly Report, June 1, 1977 to August 31, 1977 by D. A. Landgrebe. This report summarizes progress on the three tasks of the contract which are:

2.1 Agricultural Scene Understanding
2.2 Processing Technique Development
2.3 Large Area Crop Inventory Design

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

090277 Annual Report to the University, Fiscal Year 1977 by D.A. Landgrebe. The annual report includes detailed descriptions of the research, technology transfer and fiscal activities. The research is described for each of the program areas. The steps taken by the Laboratory for the rapidly increasing demand for training are outlined.

This report was sponsored by General Funds.

090377 Annual Financial Report to the University, Fiscal Year 1977 by D. A. Landgrebe. The annual fiscal report includes a description of fiscal activities for FY77.

This report was sponsored by General Funds.

091977 Digital Mapping of the Santa Cruz Integrated Subregion Using Landsat Multispectral Scanner Data by L.A. Bartolucci and R.M. Hoffer. This study was primarily concerned with the assessment of computer-aided techniques to analyze Landsat satellite multispectral data for applications to regional mapping of natural resources in the Santa Cruz Integrated Subregion of Bolivia.

The LARSYS computer-aided processing and analysis software was utilized to produce cover type maps and tabulated areal extent information for six provinces in the Santa Cruz Integrated Subregion. The analysis was performed on a province-by-province basis and the final multispectral classification maps (at scales of 1:25,000 and 1:50,000) and tabular results were previously made available to the Bolivian ERTS Program Office.

After the processing and analysis was completed at LARS, a team of Bolivian and LARS scientists conducted a field evaluation of the computer-generated cover type maps. The results of this evaluation indicated that in general, the multispectral classification maps represented accurately most of the ground cover types present in the test site. Specifically, the three major types of forest cover in the region were correctly identified and mapped. However, the identification of the agricultural crops was very difficult because at the time the Landsat data were gathered (September 16, 1975), most of the agricultural crops had been harvested, and in the few instances in which there was sugar cane in the fields, they were spectrally confused with tall natural grasses which are very similar to the sugar cane plant.

The work reported in this paper was sponsored by a cooperative research project between the ERTS Bolivian Program Office and the Laboratory for Applications of Remote Sensing.

112677 Agricultural Scene Understanding by M.E. Bauer, L.F. Silva, R.M. Hoffer and M.F. Baumgardner. Results of four investigations, all related to agricultural remote sensing are described. The four tasks are: (a) LACIE Field Measurement, (b) Thermal Band Canopy Modeling, (c) Forestry Applications Project, and (d) Soil Classification and Survey.

A. The LACIE Field Measurements project report describes the rationale for the experiment, the data acquisition, processing, and storage/retrieval by LARS. Results of the sensor correlation and data verification studies are discussed, along with the rationale and procedures for calibration of reflectance measurements. Analytical results of initial analyses relating spectral and agronomic measurements are described. The report concludes with recommendations for future field measurements investigation.

B. The thermal Band Canopy Modeling results demonstrate the relationship between geometric parameters of wheat canopies, environmental variables and radiance temperature.

C. The Forestry Application Project report describes investigations of (1) the acceptability of Landsat area estimates as inputs to forest inventory, (2) definition of an efficient and cost effective method of developing optimal Landsat training statistics for mapping forest cover, and (3) a comparison of five different classification techniques in terms of cost, accuracy, and output products.

D. The Soil Classification and Survey report describes the results of (1) field experiments relating spectral reflectance measurements to dark and light soils at two surface moisture levels and two amounts of surface residue, and (2) classification for soil survey of multiple dates of Landsat data covering the same scene.

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

112777 Processing Techniques Development by B.J. Davis, J.C. Lindenlaub, T.L. Phillips, C.R. Sand and P.E. Anuta. Work reported in this volume includes implementation of the LIST (Label Identification by Statistical Tabulation) method under the Technology Development subtask; the support of the NASA/JSC remote terminal, development of instructional materials, and planning for future technique interchange between NASA/JSC and Purdue/LARS under the Technology Interchange System Development subtask; and, under the Scanner System Parameter Selection subtask, evaluation of a classification error prediction algorithm and development of scanner system models by information, theoretic and Karhunen-Loeve approaches.

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

112877 Test of Spectral/Spatial Classifier by J.L. Kast and B.J. Davis. This report provides the final results of the subtask to test the spectral/spatial classifier (ECHO). This document reports on:

1. the programming of the nonsupervised ECHO algorithms,

2. tests of the effects of the input parameters on six performance measures, and

3. comparison of the nonsupervised ECHO classifier with the supervised ECHO classifier and the perpoint classifier.

The nonsupervised ECHO classifier identifies objects without the benefit of class statistics. Statistics of the objects thus identified may be of value in training for the classifier. The supervised ECHO classifier demonstrates superior classification accuracy, reduced variability of classification results, and requires less CPU time when compared to the perpoint classifier. The nonsupervised ECHO processor requires less CPU time and produces less variable classification results than the perpoint classifier, but does not produce classification results which are superior to the perpoint classifier.

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

112977 Requirements of a Global Information System for Corn Production and Distribution by M.F. Baumgardner, M.E. Bauer, M.A. Martin and R.M. Peart. As information technology continues to advance, it becomes increasingly important that users of agricultural resources information provide guidelines for the design of improved global information systems. To that end a study was conducted to define the information needs of a global information system for the production and distribution of corn. The approach was to compile as complete a list as possible of the decision-makers and policy-makers involved in the production and distribution of corn. The next step was to identify the important decisions which are made by the decision-makers and then to define the kinds of information needed in each decision-making process. Two techniques were used in the study. One was a two-day workshop involving twenty-five Purdue scientists and twenty-five representatives from industry, corn producers, international development organization, other universities and government agencies. The major focus of the workshop was on the information needs for corn production and distribution. The other technique was interviews with a broad array of decision-makers involved in the production and distribution of corn.

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

011578 Crop Spectra from LACIE Field Measurements by M. Hixson, M. Bauer and L. Biehl. The LACIE Field Measurements project has acquired and assembled one of the most comprehensive data sets for agricultural remote sensing research. The purpose of this document is to briefly describe the data sets and to introduce potential investigators to the spectral data through a series of examples illustrating major sources of variation in the reflectance of wheat and several of its confusion crops.

The research described in this report was sponsored by NASA under Contracts NAS9-14970 and NAS9-15466.

021678 The Feasibility of Using a Cyber-Ikon System as a Nucleus of an Experimental Agricultural Data Center by J.L. Kast, P.H. Swain, and T.L. Phillips. This report documents the menu of remote sensing applications which are currently possible, identifies potential remote sensing markets, and suggests a strategy for the international marketing of the technology in the context of Control Data Corporation hardware and software. The objective of the study is to assess the feasibility of using a Cyber-Ikon System as the nucleus of an experimental agricultural data center and present the system design of such a center. A complete system design in terms of hardware, software, and educational requirements is presented for data centers to be located in developing countries.

The research described in this report was sponsored by the Control Data Corporation under Contract No. 009457.

022378 Status of Derelict Land Associated with Coal Mining in Southwestern Indiana - 1977 by R.A. Weismiller and R.P. Mroczynski. Atlas detailing the results of a photo-interpretation project which was conducted during the summer of 1977. This work was done for the Indiana Department of Natural Resources, Division of Reclamation. The results identify derelict lands associated with the mining of coal in southwestern Indiana.

The second volume is a photo-interpretation handbook which identifies methodology.

022878 Research in Remote Sensing of Agriculture, Earth Resources and Man's Environment by D.A. Landgrebe. This report provides tentative and preliminary results and summarizes progress for the current quarter on the four tasks of the subject contract which are:

2.1 Agriculture Scene Understanding
2.2 Processing Techniques Development
2.3 Crop Production Statistics
2.4 Computer Processing Support

The research described in this report was sponsored by NASA under Contract No. NAS9-15466.

033178 Geophysical Remote Sensing Data Evaluation Study by P. Anuta, D. Levandowski, H. Hauska and W. Hinze. A proprietary data set gathered by the Cities Services Minerals Corporation required analysis for copper mineral exploration purposes.

Geophysical remote sensing data including magnetics, gamma ray and induced pulse transient data were digitized, registered and analyzed using multivariate techniques.

Cluster maps were prepared for a number of combination of variables including Landsat and geophysical data. The data sets, report and interpretation results are proprietary and cannot be released either within LARS or outside LARS or the University.

The research described in this report was sponsored by the Cities Services Minerals Corporation.

042178 Application of Remote Sensing Technology to the Solution of Problems in the Management of Resources in Indiana by R.A. Weismiller and R.P. Mroczynski. Semi-annual status report for June 1, 1977 - November 30, 1977.

The work described in this report was sponsored by NASA/Office of University Affairs under Grant No. NGL 15-005-186.

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APPENDIX III

A Brief Statement of the Accomplishments of Purdue/LARS

Purdue University through its Laboratory for Applications of Remote Sensing has made a number of contributions to the nation's earth resources survey program. These contributions have been in the devising of instrumentation and computer data processing procedures for remote sensing and the development of ways of using them in the application disciplines.

During the first portion of this work (1964-1971) the effort was entirely of a research nature. Specific contributions during this period were:

- Single and multiband level slicing techniques on multispectral data demonstration (1966)
- Multispectral pattern recognition methods for crop discrimination demonstrated (1966)
- Digital image registration system for multispectral data developed (1967)
- Soil, water quality, and forest classifications demonstrated in a multispectral machine-implemented fashion (1968)
- Feature selection algorithms to select the best subset of spectral bands for a given analysis created (1968)
- Crop identification capability via satellite (Apollo IX) data and machine processing methods demonstrated (1969)
- Full frame (10,000 sq. miles) computer analysis of satellite data for geologic purposes demonstrated (1969)
- Clustering in classifier training developed (1970)
- Data compression techniques for multispectral image data demonstrated (1970)
- Machine implemented multitemporal analysis demonstrated (1970)

This period of effort culminated in the 1971 Corn Blight Watch Experiment, involving 17 federal and state agencies and more than 1,000 people. This was the first time all components of such a remote sensing system had been assembled and tested in a quasi-operational environment. In this work it was shown that by remote sensing means, not only could crops be identified but a specific disease condition could be evaluated by both manual and machine implemented methods. Purdue/LARS played a leadership role in this experiment.

In response to the program need, the second phase of the Purdue/LARS effort (1971-present) has, in addition to the research function, concentrated on demonstrating the technology to the user community and on technology transfer. To accomplish this Purdue/LARS has:

- Tested and demonstrated the previously developed computer processing methods using Landsat and Skylab data on application problems from many disciplines

- Operated a computer remote terminal system to make the technology conveniently available to users and to aid in technology transfer

- Thoroughly documented and distributed the computer software system, LARSYS, a user oriented system for classifying multispectral data

- Created, used, and distributed training materials on remote sensing, conducted monthly short courses and a visiting scientist program

- Assisted in the establishment of the Large Area Crop Inventory Experiment (LACIE)

In addition to this concentration on demonstration and technology transfer, a number of significant research milestones have also been achieved during this period. Examples are:

- Development of a machine classifier utilizing spatial as well as multispectral scene variations

- Multitemporal analysis of satellite data

- Development of procedures for the geometric correction, interpolation and registration of satellite data for large areas

- Registration of various types of ancillary data (e.g. topography) onto Landsat data for increasing identifiability of earth surface materials

- Techniques for facilitating detailed soil survey from Landsat data

- Investigation of practical change detection techniques for Landsat data

- Engineering of instrumentation and collection of a large calibrated field spectra data base

- Investigation of in situ factors which influence the reflectance and emitance characteristics of crops

Purdue endeavors to maintain a high degree of innovation and attention to national needs. This is accomplished by incorporating the unique ingredients present at a large research oriented Lands Grant University into an effective team-oriented, goal-directed research organization.

APPENDIX IV

Staff, Fiscal and Facility Summary

Staff Summary

During FY78 there were 210 people (85.59 FTE) from 15 departments in 5 schools assigned to LARS projects. The following table shows a further break down of this information:

Staff Summary by School

	Agriculture	Consumer & Family Science	Engineering	Humanities Social Science & Education	Science	# of Employees	Full Time Equivalent
Faculty	6		14	1	4	25	7.02
Professional	8		33	1	1	43	29.29
Clerical			21			21	13.29
Service			5			5	3.16
Graduate Students	14	1	23		5	43	15.68
Undergraduates			75			75	17.15
						210	85.59

Professorial Staff

1. Agriculture

   a. M.F. Baumgardner - Professor of Agronomy and LARS Program Leader
   b. R.M. Hoffer - Professor of Forestry and LARS Program Leader
   c. F.R. Kirschner - Adjunct Professor of Agronomy
   d. M.A. Martin - Assistant Professor of Agricultural Economics
   e. R.M. Peart - Associate Professor of Agricultural Engineering
   f. J.B. Peterson - Professor of Agronomy (Post-retirement appointment) and Associate Director of LARS

2. Engineering

   a. R.E. Bailey - Professor of Nuclear Engineering
   b. N.Y. Chu - Post-doctoral Fellow of Electrical Engineering
   c. D.P. DeWitt - Associate Professor of Mechanical Engineering
   d. L.A. Geddes - Professor of Electrical Engineering (Biomedical)
   e. R.E. Hanneman - Visiting Professor of Chemical Engineering
   f. D.A. Landgrebe - Professor of Electrical Engineering and Director of LARS
   g. J.C. Lindenlaub - Professor of Electrical Engineering and LARS Program Leader
   h. C.D. McGillem - Professor of Electrical Engineering
   i. R.D. Miles - Professor of Civil Engineering
   j. B.G. Mobasseri - Post-doctoral Fellow of Electrical Engineering
   k. A. Ravindran - Associate Professor of Industrial Engineering
   l. L.F. Silva - Professor of Electrical Engineering and LARS Program Leader
   m. P.H. Swain - Assistant Professor of Electrical Engineering and LARS Program Leader
   n. V.C. Vanderbilt - Post-doctoral Fellow of Electrical Engineering

3. Humanities, Social Science and Education

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

4. Science

   a. V.L. Anderson - Professor of Statistics
   b. D.W. Levandowski - Professor of Geoscience
   c. K.S. Pillai - Professor of Statistics
   d. T.R. West - Professor of Geoscience

Professional Staff

1. Agriculture

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

2. Engineering

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

3. Humanities, Social Science and Education

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

4. Science

   a. M.M. Hixson - Research Statistician

Staff Involvement at LARS in Number of Staff

July 1, 1977 - June 30, 1978

Department	Faculty (Page 55)	Professional (Page 56)	Graduate* Students (Page 15)	Undergraduate Students	Service	Clerical
Agriculture						
Agricultural Economics	1					
Agricultural Engineering	1					
Agronomy	3	6	9			
Forestry	1	2	5			
Consumer and Family Sciences						
Housing, Equip., and Env. Design			1			
Engineering						
Chemical	1					
Civil	1					
Electrical	9	3	16			
Experiment Station		25		75	5	18
Industrial	1		1			
Mechanical	1	1	4			2
Bio-Medical		4	2			1
Nuclear	1					
HSSE						
Education	1					
Communications		1				
Science						
Computer Science			2			
Geoscience	2		2			
Statistics	2	1	1	—	—	—
TOTAL	25	43	43	75	5	21

*Includes only those graduate students on the payroll. The total including all graduate students is 48. (See Pages 15 & 28)

Fiscal Summary

July 1, 1977 to June 30, 1978

Funds Available:

General Funds	$ 134,380	
Research Funds	2,176,568	
Other Funds	39,160	
Total Funds Available		$2,350,108

Facility Summary

Capital equipment accumulation in excess of $1,250,000

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

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

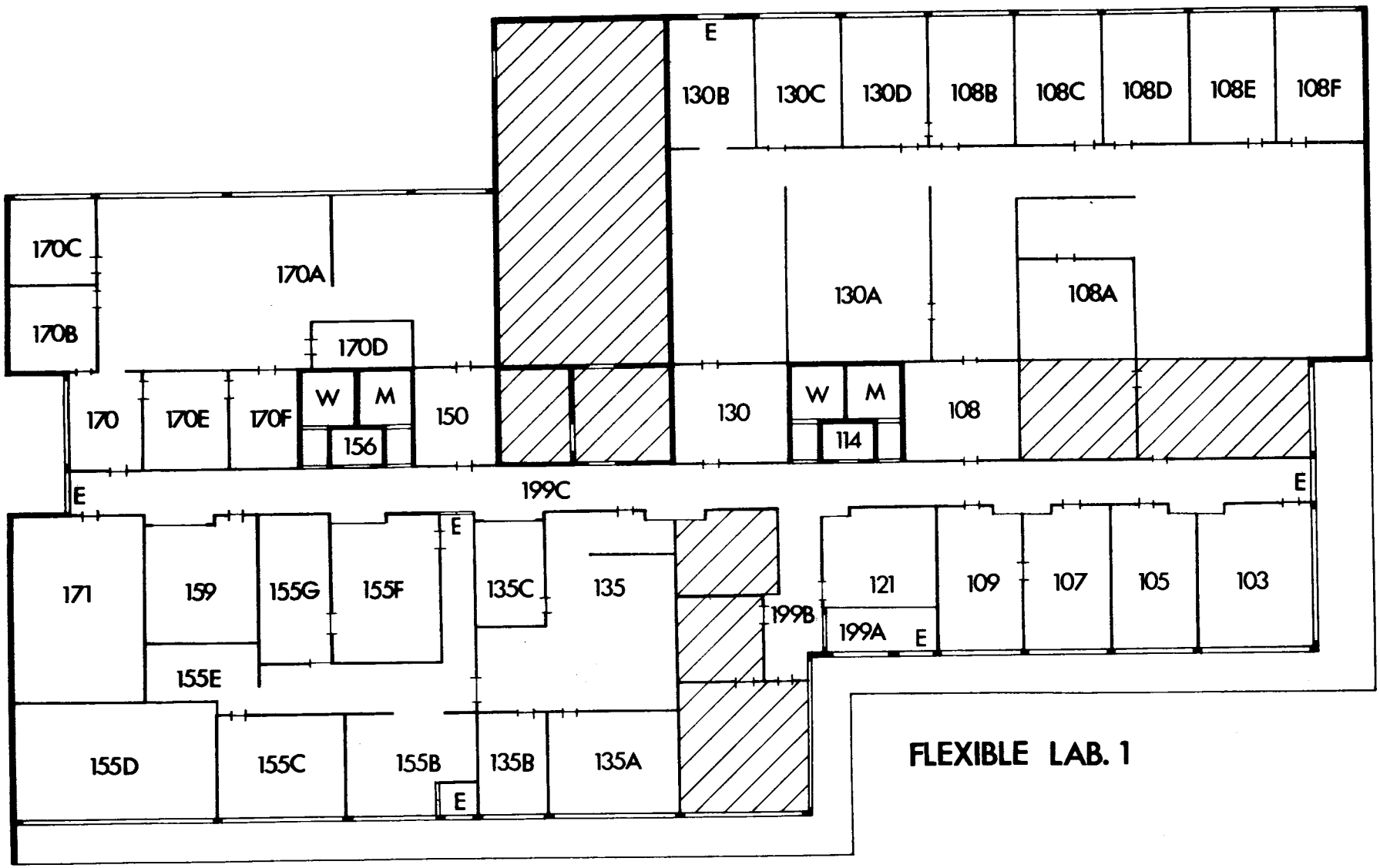
Utilities are paid by Physical Plant

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

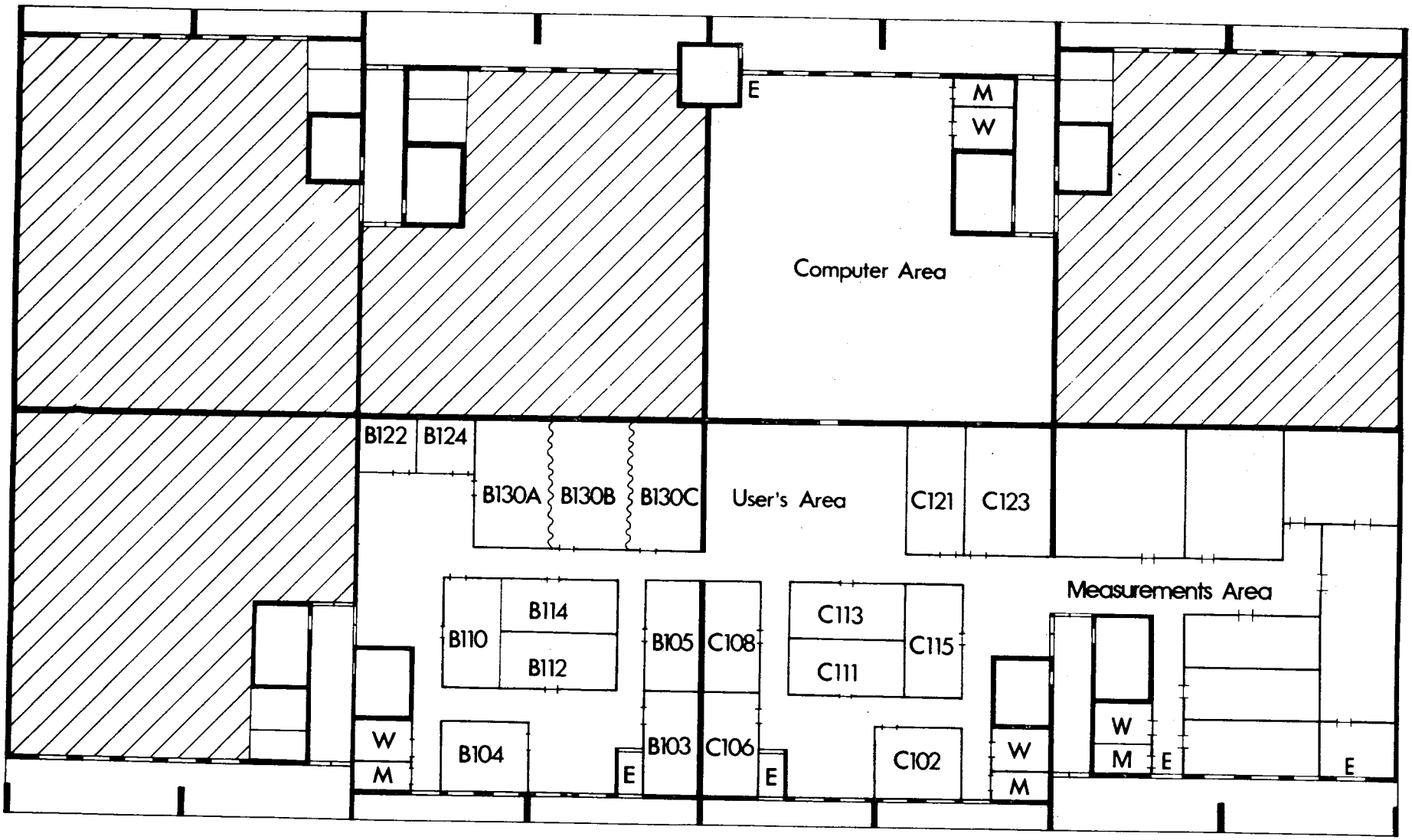
Funds for telephone rental are provided to LARS via general fund allocations

SPACE

Building	Sq. Ft.
Flex Lab I	10,754
Flex Lab II	
Unit B	3,885
Units C and F	6,994
Unit D	3,170
	24,803



FLEXIBLE LAB. 1



FLEXIBLE LAB. 2