LARS Information Note 052977

The FOCUS Series: A Collection of Single-Concept Remote Sensing Educational Materials

Shirley M. Davis

The Laboratory for Applications of Remote Sensing
Purdue University
W. Lafayette, Indiana
1977

STAR INFORMATION FORM

1. Report No. 052977	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle The Focus Series: A COLLECTION OF SINGLE-CONCEPT REMOTE SENSING EDUCATIONAL MATERIALS		5. Report Date 5/29/77
		6. Performing Organization Code
7. Author(s) Shirley M. Davis, Ed.		8. Performing Organization Report No.
		10. Work Unit No.
9. Performing Organization Name and Address Purdue University Laboratory For Applications of Remote Sensing 1220 Potter Drive West Lafayette, IN 47904		11. Contract or Grant No. NAS9-14970
		13. Type of Report and Period Covered Information Note
12. Sponsoring Agency Name and Address National Astronautics & Space Administration Earth Observations Division/Johnson Space Center Houston, TX		14. Sponsoring Agency Code
15. Supplementary Notes		

16. Abstract

The FOCUS series is a collection of two-page foldout documents each consisting of a diagram or photograph and an extended option of three to four hundred words. The series was developed to present basic remote sinsing concepts in a simple, concise way. Issues currently available are collected in this information note.

17. Key Words (Suggested by Author(s)) Remote Sensing, Multispectral Scanners, Satellite, Pattern Recognition, Landsat	18. Distribution Statement

19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 83	22. Price*

*For sale by the National Technical Information Service, Springfield, Virginia 22161

JSC Form 1424 (Rev Nov 75) NASA — JSC

LARS Information Note 052977
T-1314/4

The FOCUS Series:
A Collection of Single-Concept Remote Sensing Educational Materials

by
Shirley M. Davis

Abstract

The Focus Series has been developed to present basic remote sensing concepts in a simple, concise way. Issues currently available are collected here so that more people may know of their existence.

Recent technological developments in remote sensing and the broadening of its use have quickly caused much of the existing educational material in remote sensing to be outdated. Today only a small body of current, instructional materials on the subject is available commercially. While a person entering the field can readily find numerous technical research reports, he may have considerable difficulty locating materials which describe the basic concepts relevant to remote sensing technology as it is developing today.

In recognition of this need, the FOCUS series was developed as a way to explain and illustrate basic remote sensing concepts. Each pamphlet in the series is designed to illuminate

---

The FOCUS Series was developed under NASA Contracts NAS 9-14016, NAS 9-14970, and Grant NGL 15-005-112. S. M. Davis is Training Specialist at the Laboratory for Applications of Remote Sensing, Purdue University.

a single concept through one page of concisely written text supported by illustrations. Extensive care is taken to minimize the use of technical terms in the descriptions and to include definitions where confusion might occur.

The FOCUS issues on "Remote Sensing", "The Multiband Concept", and "LANDSAT" require no prior understanding of remote sensing; the ones on "Pattern Recognition", "Sample Classification", and "Reformatting LANDSAT Data" assume that the reader has at least a minimal understanding of the nature of remote sensing data. Several other issues in the FOCUS series describe applications of remote sensing: "Snowcover Mapping", "Mapping Soil Characteristics", "Crop Species Identification", and "Regional Land Use Inventories".

The educational aim of the series has affected its design in a number of ways. The format of the pamphlets was designed so that they could be both relatively inexpensive to produce and yet attractive to the potential reader. Secondly, each issue contains a list of suggestions for further reading to guide the student wishing to pursue the topic in greater depth. In preparing these bibliographies, authors give preference to titles which are available in the open literature.

The challenge in preparing a FOCUS issue is to present a complex topic in such a way that it is neither unnecessarily complicated nor in any way misleading to the reader who has no prior understanding of the concept. In order to insure that this requirement is met, each FOCUS issue is subjected to rigorous in-house review by a variety of people: remote sensing specialists, technicians, educationalists, communicators, engineers, and scientists.

Purposely designed to be brief, individual titles in the FOCUS series do not lend themselves to being submitted as technical reports. In order that more people may know of their existence and the rationale behind them, the titles which currently exist are being collected as a part of this Information Note.

Acknowledgments

The author wished to acknowledge the contributions of several LARS' staff members to the present series: to Roger M. Hoffer and John C. Lindenlaub, who identified the need for materials such as these; and to those who have participated in their development: Luis A. Bartolucci, Ronald K. Boyd, Tina K. Cary, David M. Freeman, Roger M. Hoffer, John C. Lindenlaub, Douglas B. Morrison, Terry L. Phillips, Barbara J. Pratt, James D. Russell, C. Royal Sand, Philip H. Swain, Richard Weismiller, and Leslie Wilson.

Titles Available

March, 1977

"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"

LARS - Purdue

FOCUS

Number 1

THE MULTISPECTRAL SCANNER

The Multispectral Scanner

There are many types of sensor systems that can be used in remote sensing. Photographic systems are the most common, but since photographic films are sensitive to energy only from a limited portion of the electromagnetic spectrum (visible and near-infrared wavelengths), they cannot obtain information about the thermal characteristics (temperature and emissivity) of the vegetation, soil, and water on the earth's surface. Scanners sensitive to energy in only the thermal region can accomplish this, but multispectral, optical-mechanical scanners are capable of collecting data in the visible and thermal portions of the spectrum (0.3-15.0 μm). They are usually mounted on aerospace platforms, either aircraft or satellite.

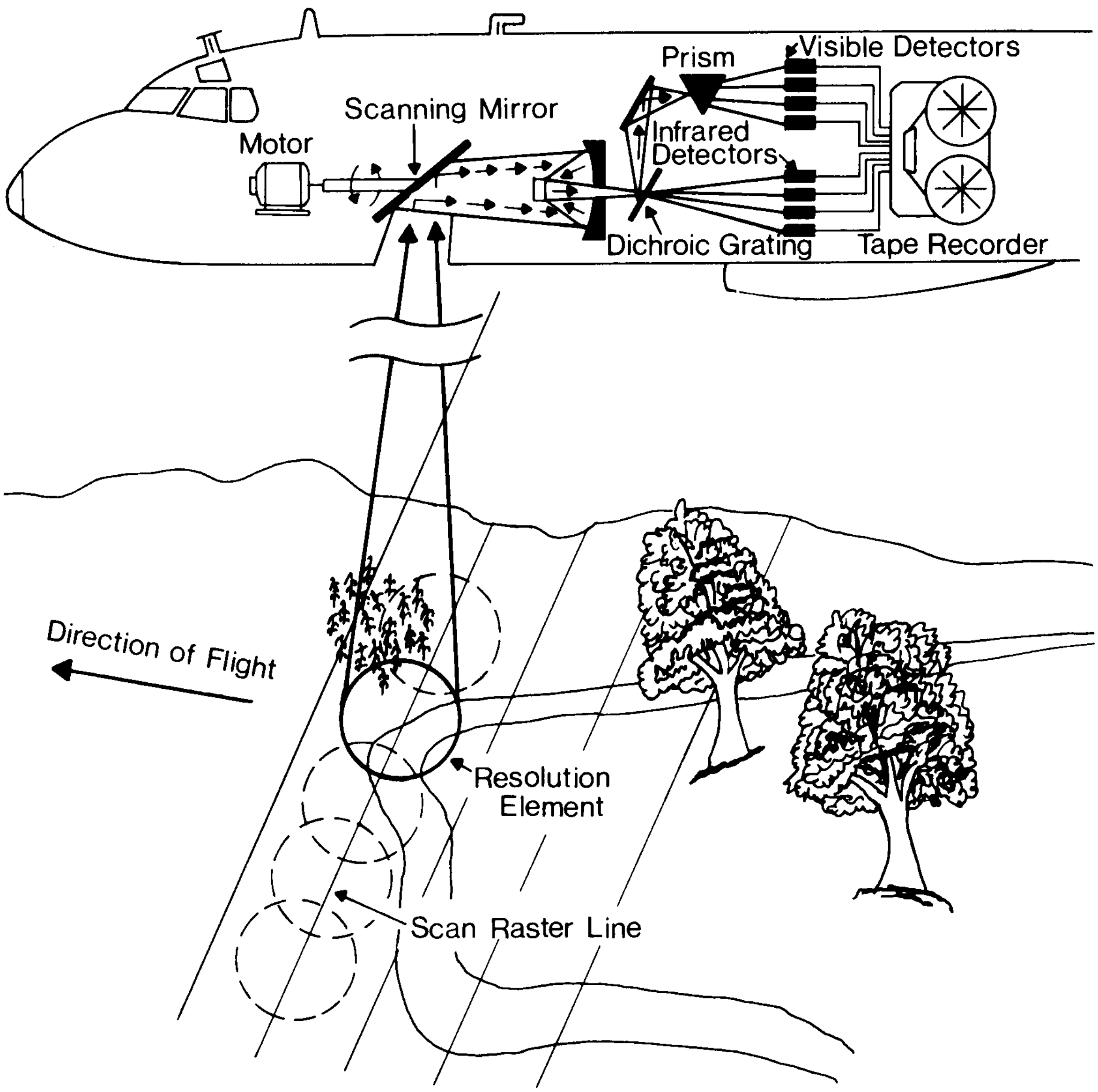
Opposite is a diagram of a typical multispectral, optical-mechanical scanner. The energy reflected and emitted from a small area of the earth's surface is "seen" by the scanning mirror, then is reflected through a system of optics where it is spectrally dispersed. In this example the energy in the visible wavelengths (.38-.72 μm) is spread by a quartz prism; dichroic gratings are used as dispersive devices for the infrared energy (.72-14.0 μm). The detectors, carefully selected for their sensitivity in the various portions of the spectrum, measure the energy in specific wavelength bands. The size of the resolution element, the instantaneous field of view of the scanner, is a function of the scanner configuration and the altitude of the platform.

As the platform passes over an area, the ground surface is scanned in successive strips, or scan lines, by the mirror. While the rotating motion of this mirror allows the energy along a scan line to be measured, the forward movement of the platform, which is perpendicular to the scan line, brings successive strips of terrain into view. Thus, when parameters of the data-gathering system have the proper relationship, a continuous area of the earth's surface can be sensed using several wavelengths bands which can encompass the entire optical portion of the electromagnetic spectrum.

The output signals from the detectors are amplified and then simultaneously recorded on magnetic tape or transmitted directly to the ground. An important feature of this sensing system is that sampling the output of all bands produces single data sets containing all the spectral information available for a given resolution element. This is a convenient way to pack the data for machine processing.

While photographic data collection systems tend to retain better spatial accuracy, optical-mechanical scanner data have better spectral resolution since the parameters of the detectors can be set for much narrower wavelength bands and there is inherent registration between spectral channels. Data reformatting, calibration, and registration need to be performed before the data is ready for analysis.

(smd)



Visible Detectors
Prism
Scanning Mirror
Motor
Infrared Detectors
Dichroic Grating
Tape Recorder
Direction of Flight
Resolution Element
Scan Raster Line

FURTHER READING

R. A. Holmes and R. B. MacDonald
The Physical Basis of System Design for Remote Sensing in Agriculture
Proceedings of the IEEE 57:629-639 (Apr 1969)
Also: LARS Information Note 062667

D. A. Landgrebe and T. L. Phillips
A Multichannel Image Data Handling System for Agricultural Remote Sensing
Laboratory for Agricultural Remote Sensing Annual Report, Volume 3, 1968. Pp. 165-171
Also: LARS Information Note 062667

L. F. Silva
Radiation and Instrumentation in Remote Sensing
In: Course Notes for Remote Sensing Technology and Applications. 1972. 64 pages

Prepared by
The Laboratory for Applications of Remote Sensing
Purdue University, West Lafayette, Indiana 47907

S. M. Davis, General Editor

LARS-Purdue

FOCUS

Number 2

COVER TYPE CLASSIFICATION

Cover Type Classification

In many ecological and agricultural situations there is a need to map various cover types over large geographic areas in a relatively short period of time. The computer-aided classification of data gathered by multispectral, optical-mechanical scanners aboard aircraft or spacecraft can meet this need. It is the differences which exist between the spectral signatures of materials that make this automatic identification possible.

The accompanying illustration shows the results of a computer-aided classification of multispectral data into vegetation, bare soil, and water for an area of central Indiana. The aerial photography on the left, taken ten days before the scanner data were collected, serves as a point of comparison for the accompanying computer printouts.

First, multispectral scanner data were collected from an altitude of 3,200 feet. These data are measurements of reflected energy in specific wavelength bands for each resolution element, or area on the ground viewed in any one instant -- in this case an area of about nine square yards.

The key to the computer-aided analysis of data lies in pattern recognition. In the analysis discussed here, measurements for areas where the cover type was known provided the basis for "training" the pattern recognition categorizer to recognize similar measurements in unidentified areas.

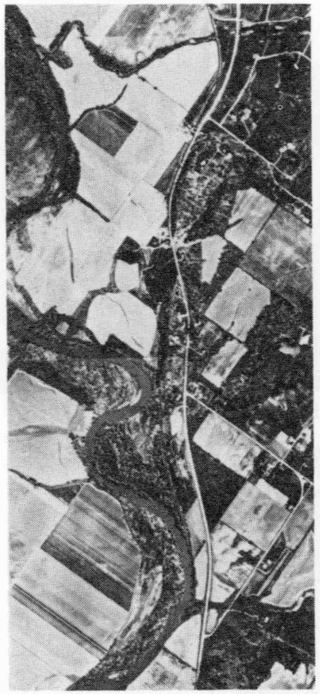
After the three wavelength bands or channels most effective for doing the classification were selected, the processor compared the response pattern of each unidentified resolution element in each of these channels with the measurements for each known cover type and automatically assigned that resolution element to the class it most closely resembled.

The lefthand printout below is a visual representation of the results of the classification. The computer printed an "M" for all areas identified automatically as water; they appear as a dark tone on the printout. Bare soil areas were printed with dashes (light-toned areas), and green vegetation was identified by "I" (intermediate tone).

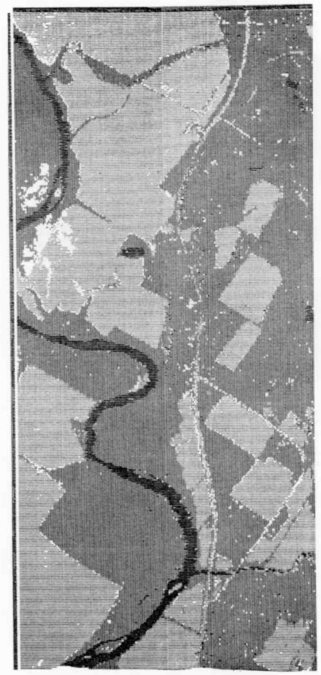
At the right is a printout showing just those areas identified as water. Many of the areas appear rather small and scattered; they are actually ponded areas and water in drainage ditches. It is interesting to note that the computer-aided classification resulted in correct identification of water in several locations which had previously been overlooked on the aerial photographs. Overhanging tree branches or indistinctive color differences between the water and the surrounding materials obscured the water from visible detection; differences in reflectance characteristics in the scanner imagery, however, made the identification possible.

Checking the classification accuracy in 107 randomly selected sample areas revealed that the average accuracy was 99.4% for green vegetation, 98.0% for soil, and 96.7% for water.

(smd)



Photograph



Computer Printout of
Green Vegetation, Soil,
and Water

Computer Printout
of Water Only

FURTHER READING

R. M. Hoffer and F. E. Goodrick
Geographic Considerations in Automatic Cover Type Identification
Proceedings of the Indiana Academy of Science for 1970, Volume 80, 1971
(LARS Reprint 012971)

R. M. Hoffer and F. E. Goodrick
Variables in Automatic Classification over Extended Remote Sensing Test Sites
Proceedings of the Seventh International Symposium on Remote Sensing of Environment, 1971. (LARS Reprint 061571)

R. M. Hoffer and C. J. Johannsen
Ecological Potentials in Spectral Signature Analysis
LARS Information Note 011069. 1969

D. A. Landgrebe
Automatic Classification of Soils and Vegetation with ERTS-1 Data
LARS Information Note 101472, 1972

Prepared by
The Laboratory for Applications of Remote Sensing
Purdue University, West Lafayette, Indiana 47907

S. M. Davis, General Editor

LARS-Purdue

Number 3

PATTERN RECOGNITION

The Role of Pattern Recognition

Pattern recognition can be used as a basis for machine-aided analysis of remotely sensed data. A block diagram of a pattern recognition system is shown in Figure 1. In the LARS context the receptor or sensor which observes "patterns" is a multispectral scanner, and its output is a set of reflectance measurements for an individual resolution element or area of the ground. In the case of the Earth Resources Technology Satellite (ERTS-1), for example, a set consists of measurements of irradiance in four spectral bands (.5-.6, .6-.7, .7-.8, .8-1.1 μm) and may be represented as a four-component vector, $X = (x_1, x_2, x_3, x_4)$.

The decision maker reads the measurement levels from the receptor and classifies the resolution element into one of several possible classes. This classification can be made by various techniques, but in all cases information about the possible classes must previously have been supplied to the decision maker. In practice this information is obtained from training samples.

As a simple example, suppose an area consisting of soil, vegetation, and water is to be classified. Assume that the receptor makes two measurements on each resolution element, i.e., $X = (x_1, x_2)$. To acquire a set of training samples for each class, a set of observations of areas known to be water, vegetation, and soil respectively is obtained. For the observations belonging to each class, the mean or average values for the two measurements, x_1 and x_2, are computed and "decision regions" established (Figure 2). The decision maker can now classify the entire area: when given the measurements for a resolution element of unknown classification, it assigns that element to the class with the closest mean vector. In Figure 2 the unclassified element "U" would be classified as vegetation.

The example uses a very simple method of classification. For improved accuracy, LARS uses techniques which consider not only the means of the training samples but also their variances.

Pattern recognition is especially suited for handling large quantities of data with minimal human involvement. It provides an automatic procedure for decision making which is readily implemented on high-speed data processing equipment.

(eob)

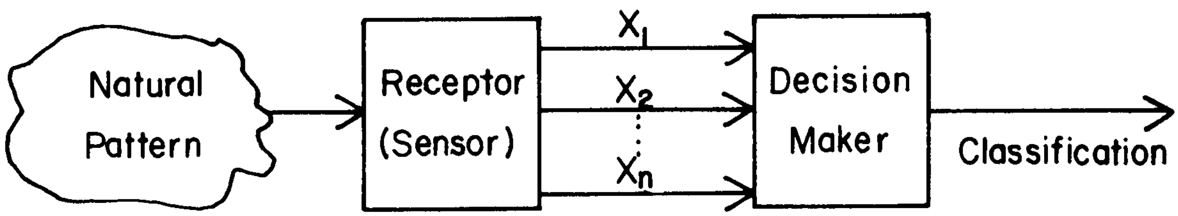


Figure 1. A Pattern Recognition System

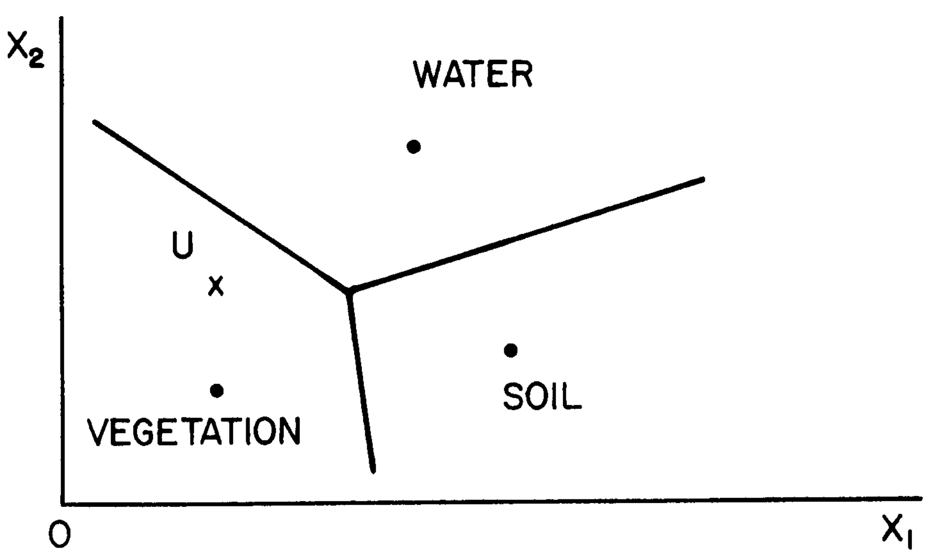


Figure 2. Class Means and Decision Regions

FURTHER READING

G. P. Cardillo and D. A. Landgrebe
On Pattern Recognition
LARS Information Note 101866. 1966.

N. J. Nilsson
Learning Machines
New York: McGraw-Hill, 1965.

P. H. Swain
Pattern Recognition: A Basis for Remote Sensing Data Analysis
LARS Information Note 111572. 1972.

Prepared by
The Laboratory for Applications of Remote Sensing
Purdue University, West Lafayette, Indiana 47907

S. M. Davis, General Editor

LARS - Purdue

MAPPING SOIL CHARACTERISTICS

Mapping Soil Characteristics

Over the years soil scientists have defined meaningful soil categories based primarily on such features as soil texture, parent material, slope, and drainage characteristics. Each year the soils on over 50 million acres of the United States are mapped into these categories by the Soil Conservation Service and other agencies as an aid to the nation's resource management. Conventional mapping techniques involve field mapping with use of black and white aerial photos as map bases. A number of new techniques are being investigated in an effort to accelerate the entire soil mapping program.

Within the past decade, advances in airborne and spaceborne sensor systems have made it possible to obtain vast quantities of spectral reflectance data over large geographic areas in a very short time. Such data-acquisition systems, when coupled with computer-aided analysis, offer the soil scientist another tool for surveying soil characteristics. Gridding and sampling techniques make it possible to correlate precise locations of soil samples with known addresses on the magnetic tapes containing scanner data.

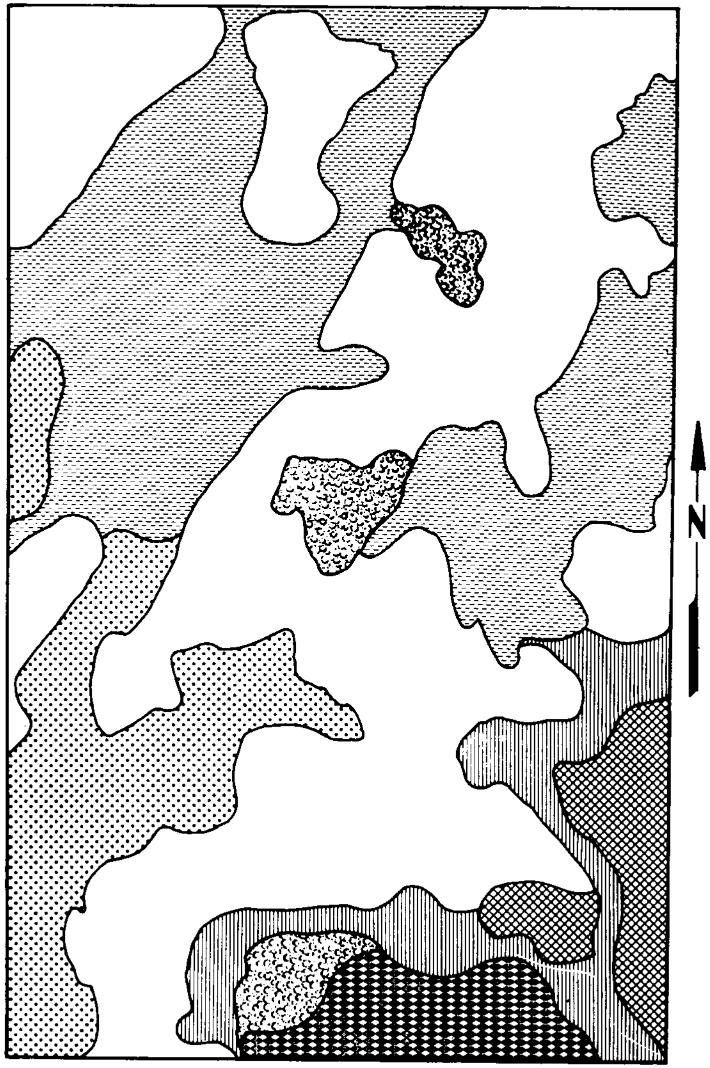
The figure opposite represents one type of soil mapping that can be done by analyzing multispectral scanner data using LARSYS, the computer software system developed at Purdue University specifically for analysis of this data. On the left is a soil survey map of a nearly level area in Tippecanoe County, Indiana. The map was made by conventional field mapping procedures. The computer printout on the right is a visual representation of a classification of the scanner data collected when the soil surface was bare. On the basis of the multispectral reflectance characteristics, it was possible for the soil scientist to discriminate reasonably well between several of the soils types.

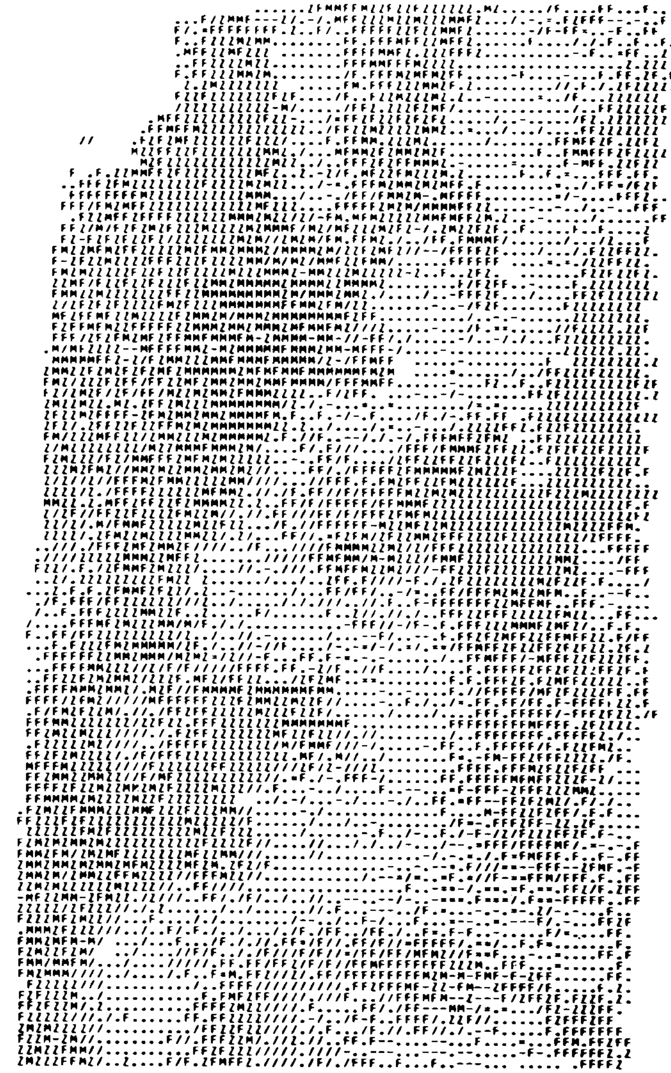
The usefulness of reflectance data for soil mapping is limited by the fact that conventional soil series are differentiated by both surface and subsurface properties; hence, a technique dependent on surface distinctions would not discriminate between soils which themselves are differentiated by subsurface features only. Greatest success in soil mapping has been achieved when variations in spectral response <u>within</u> a soil type are smaller than the variations <u>between</u> soil types.

Maps delineating other soil characteristics such as organic matter content and internal drainage patterns have also been produced using computer-aided analysis of multispectral reflectance data. The production of soil-characteristic maps by this method depends primarily on the degree of correlation between the spectral properties of the soils and the significant physical and chemical soil properties. Soil color has a major influence on the reflectance, but variations in soil moisture and in the surface condition (roughness, crusting or cultural practices) also modify the reflectance; crusted soils have a higher reflectance value than rough, and dry higher than wet.

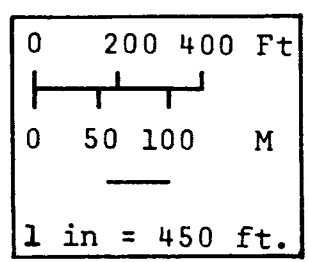
For the soil scientist, the promise of computer-aided analysis of reflectance data lies not so much in achieving a one-to-one relationship with the categories of the traditional soil surveys as in determining broad soil characteristics and soil patterns over wide areas in a short time. There is adequate evidence that reflectance data gathered at satellite altitudes can also be an effective tool for use in soil mapping programs particularly when less detail is desired, as in reconnaissance soil surveys.

(smd)





Ragsdale silty clay loam
Brookston silty clay loam
Brookston silt loam
Toronto silt loam
Crosby silt loam
Celina silt loam
Reesville silt loam



M Ragsdale silty clay loam
Z Brookston silty clay loam
F Brookston silt loam
/ Toronto silt loam
- Crosby silt loam
= Celina silt loam
· Reesville silt loam

FURTHER READING

M. F. Baumgardner, S. J. Kristof, et al
Effects of Organic Matter on the Multispectral Properties of Soils
Proceedings of the Indiana Academy of Science for 1969, Volume 79, 1970
LARS Information Note 030570. 1970

S. J. Kristof
Preliminary Multispectral Studies of Soils
Journal of Soil and Water Conservation 26:1 (1971) pp15-18
LARS Information Note 043070. 1970

A. L. Zachary, J. E. Cipra, et al
Application of Multispectral Remote Sensing to Soil Survey Research in Indiana
LARS Information Note 110972. 1972

J. E. Cipra
Mapping Soil Associations Using ERTS MSS Data
Proceedings of the Conference on Machine Processing of Remotely Sensed Data, W. Lafayette, Indiana. 1973
LARS Information Note 101773, 1973

Prepared by
The Laboratory for Applications of Remote Sensing
Purdue University, West Lafayette, Indiana 47907

S. M. Davis, General Editor

LARS-Purdue

SAMPLE CLASSIFICATION

Sample Classification

A *sample* is a collection of data points, perhaps from a remote sensing data set. In *sample classification*, a collection of data points, all assumed to be members of the same class, are classified as a group, i.e., simultaneously and into the same class. The reader may be more familiar with the operation of point classification in which, by contrast, data points are always classified one at a time (Figure 1).

In sample classification, we compute the "distance" from the data points comprising the sample to the training samples (representative data points) for the classes of interest and assign all of the points in the sample to the nearest class. The "distances" which must be computed involve the statistical distributions of the data in the unknown sample and the training samples. They are considerably more complicated than simple point-to-point distances. The details, beyond the scope of this article, may be found in the suggested Further Reading (see the back cover).

Why use sample classification for analyzing remote sensing data? The answer to this question can be derived from the observation that the group of data points (the sample) contains more information than any one of the data points. As with the training samples, both the location of the points and how much they tend to differ from each other provide information about which class they belong to. Another reason for using sample classification is that it may be more economical computationally to classify samples than to classify the data points individually. This depends to a large extent on the size of the samples.

To be useful in practice it is necessary that the computer be able to automatically select the samples to be classified. Algorithms have been developed which can accomplish this quite effectively for agricultural remote sensing data, in which case the samples are usually agricultural fields -- hence the term "per-field classification" is sometimes used. Figure 2 shows an example in which the field boundaries have been located and drawn by the computer.

Figure 3 shows a comparison of classification accuracies achieved by point classification and sample classification for the same set of data. These results are typical. They illustrate the improved classification accuracy which can often be achieved by using sample classification.

Prepared by Philip H. Swain

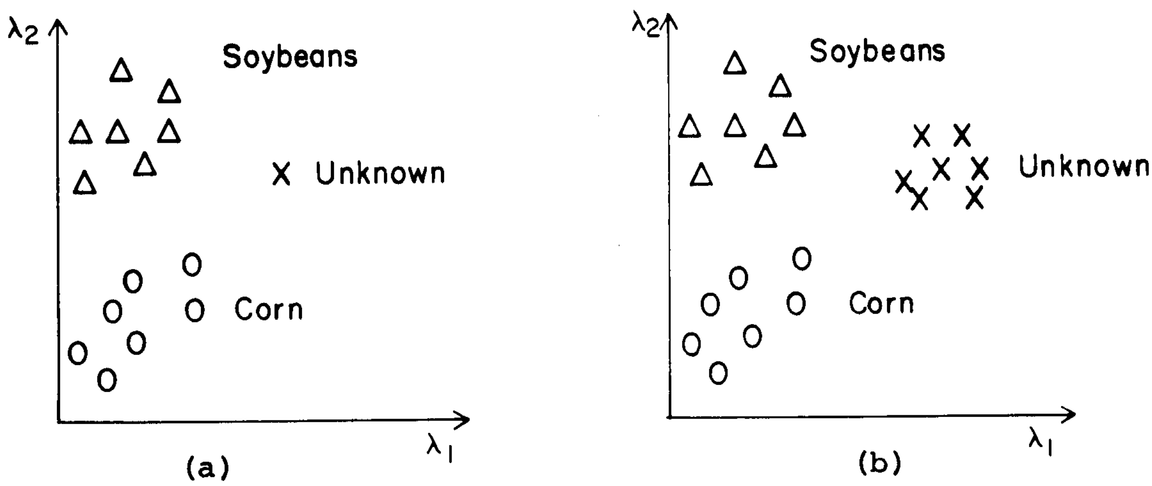


Figure 1. Point classification (a) vs. sample classification (b).

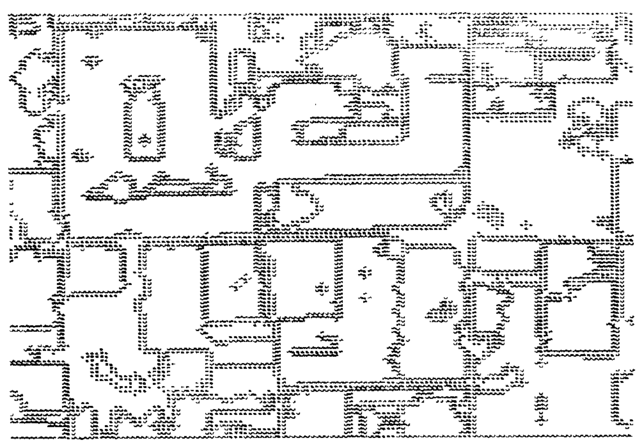


Figure 2. Computer-drawn boundaries

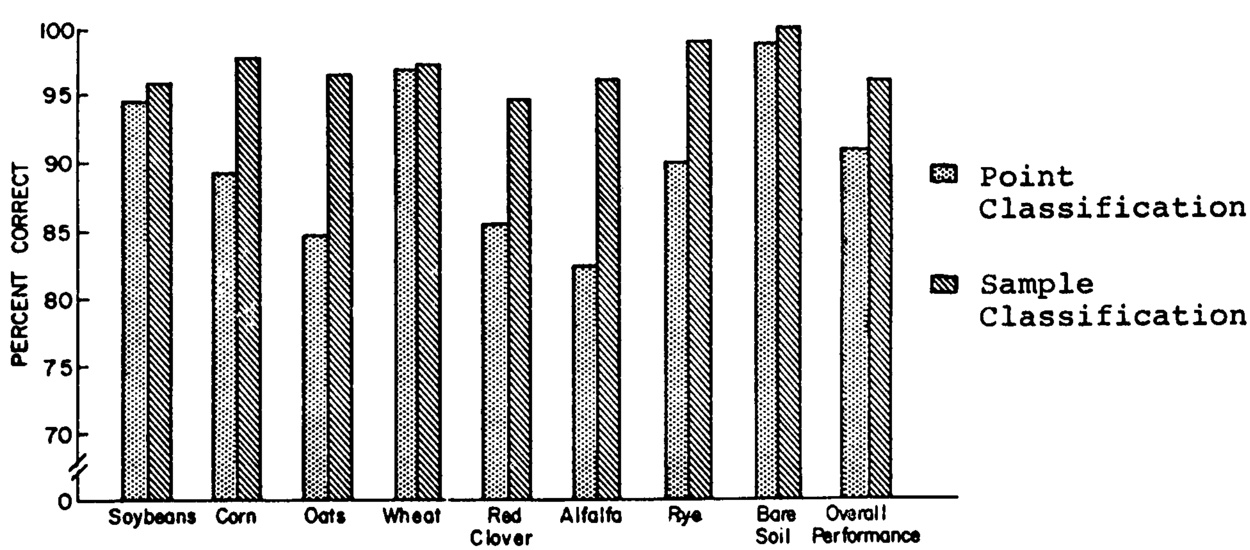


Figure 3. Comparison of point classification and sample classification results.

FURTHER READING

R. L. Kettig and D. A. Landgrebe
Automatic Boundary Finding and Sample Classification
LARS Information Note 041773. 1973

P. H. Swain
Pattern Recognition: A Basis for Remote Sensing Data Analysis
LARS Information Note 111572. 1972

Also see a related title in this series:
FOCUS: Pattern Recognition

Prepared by
The Laboratory for Applications of Remote Sensing
Purdue University, West Lafayette, Indiana 47907

S. M. Davis, General Editor

Research reported here was supported in part by NASA Contract NAS-9-14016.

75-2

LARS-Purdue

Earth Resources Data Processing System

Earth Resources Data Processing System

The Laboratory for Applications of Remote Sensing at Purdue University (Purdue/LARS) has developed an Earth Resources Data Processing System which is being used by a dispersed community of remote sensing scientists (see map).

The facility consists of the LARSYS software system, a multispectral data bank and a general purpose computer. LARSYS is a fully-documented, multi-image data analysis software system designed to provide for advanced research, development, and applications of remote sensing concepts and systems. The multispectral data bank, a collection of data acquired above the earth's surface via aircraft and satellite scanners recording radiation levels in selected portions of the electromagnetic spectrum, is available to all users of the Earth Resources Data Processing System and serves as its primary data base. The implementation of LARSYS on a general purpose computer with time sharing and remote terminal capabilities increases the system's value to the large group of users.

The resulting Earth Resources Data Processing System provides: 1) full user access, at the user's location, to both the data and the processing capability; 2) centralization and sharing of the expensive hardware or computer equipment at considerable cost advantage; 3) centralization of programming or software maintenance, with additional cost advantage and updating flexibility; 4) ease of training users; and 5) the opportunity of sharing results through standard data formats, terminology and simplicity of communication.

Prepared by B. J. Pratt

PURDUE/LARS Computer Center

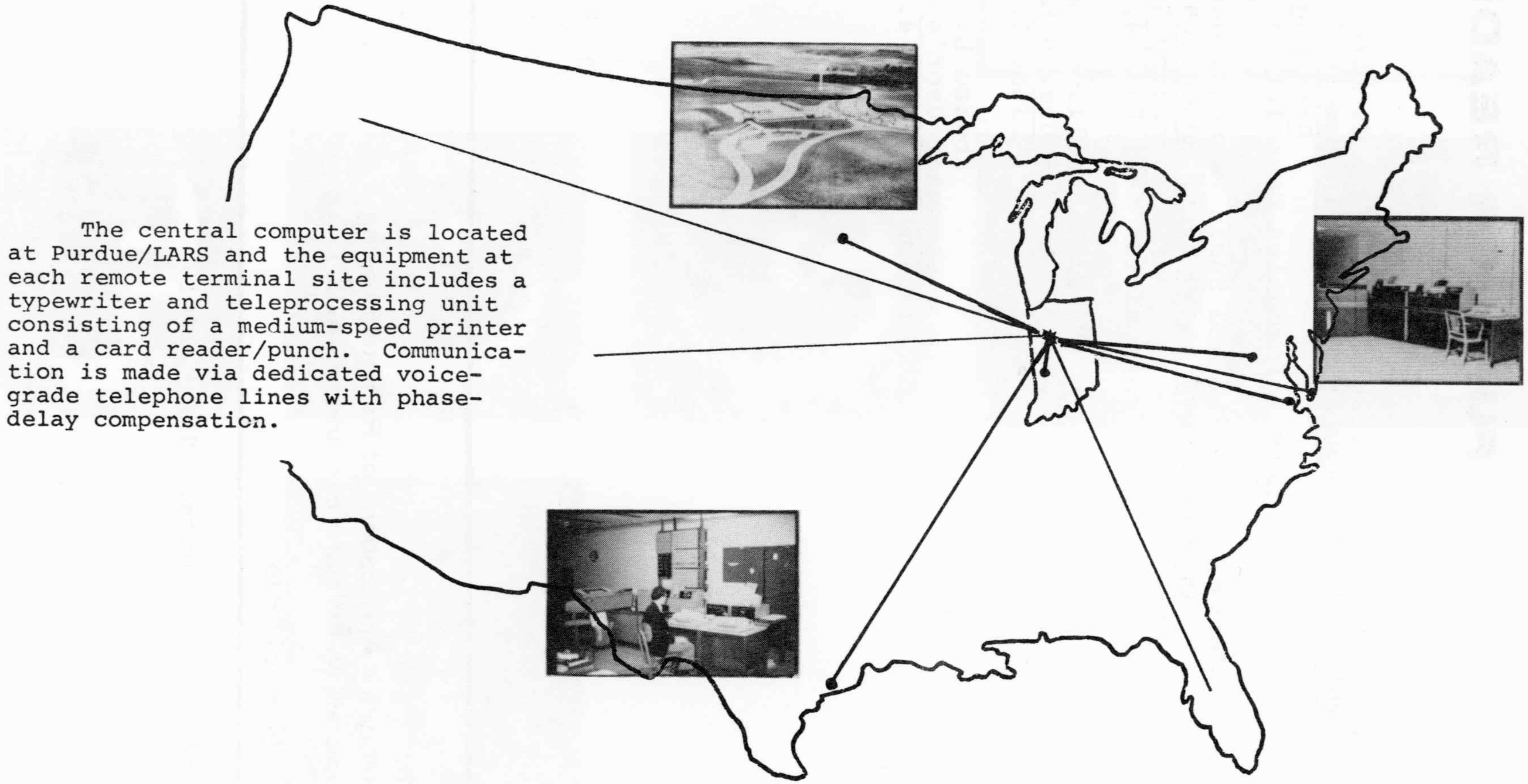


Figure 1. Earth Resources Data Processing Network

FURTHER READING

P. H. Swain, T. L. Phillips and J. C. Lindenlaub
The Role of Computer Networks in Remote Sensing Data Analysis
LARS Information Note 101373, 1973

Terry L. Phillips and Susan K. Schwingendorf
On the Access to An Earth Resources Data Processing System
LARS Information Note 031274, 1974

T. L. Phillips, Editor
LARSYS User's Manual
June 1, 1973

Howard L. Grams
Computer User's Guide
LARS Information Note 011074, 1974

Prepared by
The Laboratory for Applications of Remote Sensing
Purdue University, West Lafayette, Indiana 47907

S. M. Davis, General Editor

Prepared under NASA Contract NAS 9-14016

LARS-Purdue

REMOTE SENSING

REMOTE SENSING

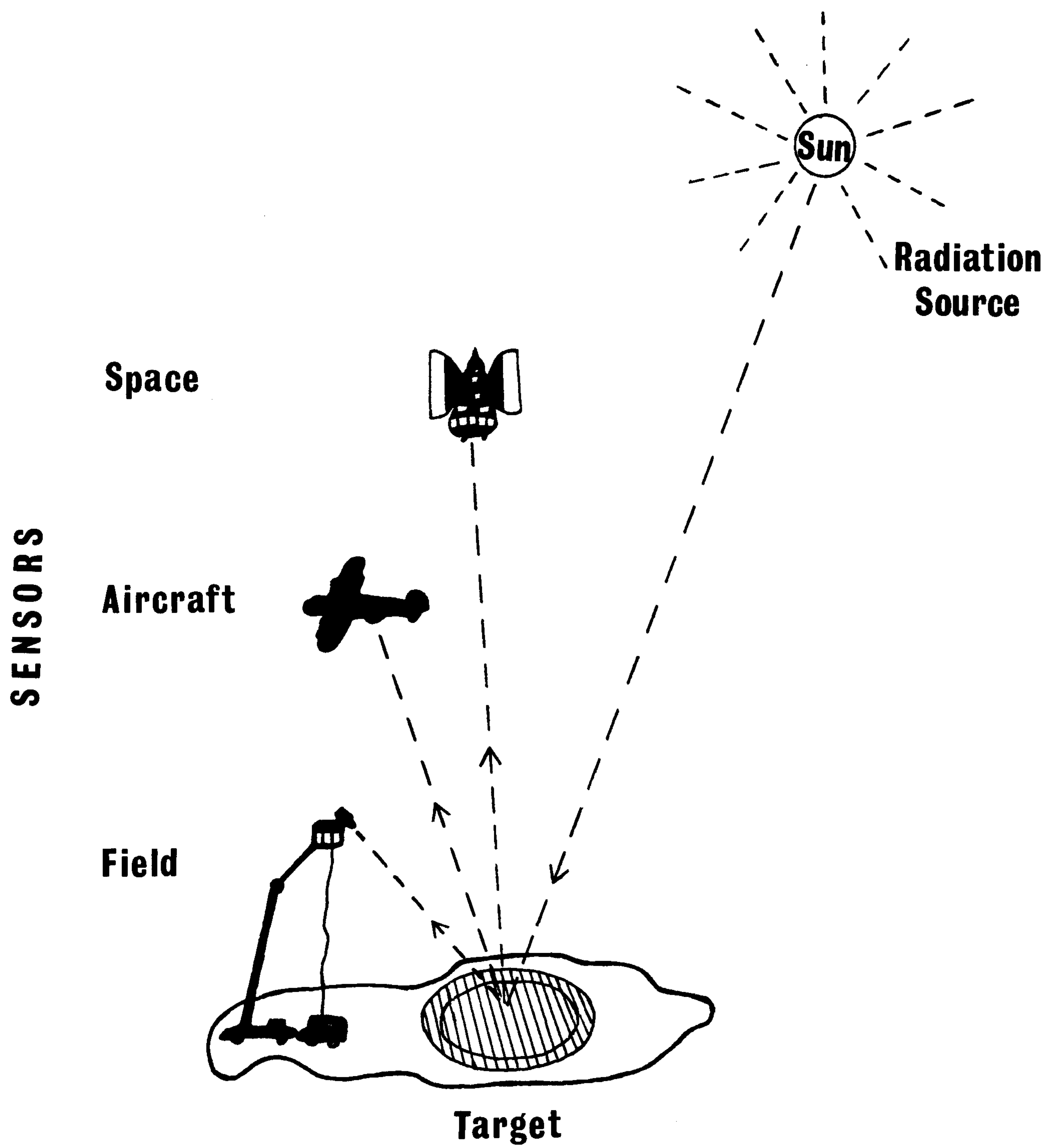
> Remote sensing is the science of acquiring information about distant objects from measurements made without coming into contact with the objects.

This is a technical definition of remote sensing. Let's look at some familiar examples of remote sensing instruments, such as your eye. You can see the moon, but certainly there is no way you can touch the moon -- unless you are an astronaut. A camera is another example. It can "acquire information" about objects, people, and landscape scenes without actually touching them. In fact cameras are widely used in remote sensing.

The figure shows three types of remote sensing data collection systems. The sensor, which may be a camera or other energy-measuring instrument, is aimed at a target or scene on earth. The sensor measures and records the energy reflected or emitted from objects on earth. Different objects radiate different kinds and amounts of energy -- in our camera analogy, different colors. The different colors, sizes, locations and changes over time which characterize the objects can be recorded by a remote sensing system. As in the diagram, the sun is often the primary source of the energy. Some remote sensing systems, such as laser and radar systems, use energy sources other than the sun. These two types of systems are often referred to as active systems. Returning to our camera analogy, when you take a picture outside during the day, the sun is the energy source and the camera is a passive sensor, i.e., using an external energy source. However, if you want to take a picture at night, you must use a flashbulb or other energy source in conjunction with the camera. The camera then provides its own light source and is an active remote sensing system.

The applications of this new technology are very diverse and continue to grow rapidly. Agricultural applications include identification and mapping of crop species; the value of this information is substantial in today's world with its increasing demand for food. Remote sensing can also be used to distinguish the types of trees in a forest and identify areas of trees that are diseased. Land-use maps, helpful in urban planning, can be produced from remote sensing data. Remote sensing has also been used for detecting pollution, studying environmental problems, exploring for mineral resources and assessing rapidly the damage of natural disasters.

Prepared by James D. Russell



Radiation from the sun is reflected or emitted by the target or scene on the earth and then detected by remote sensing instruments. These instruments may be in field-based trucks, on aircraft or aboard satellites.

FURTHER READING

R. B. MacDonald
A Look Ahead
LARS Information Note 100570. 1970

J. E. Estes and L. W. Senger
Remote Sensing:
Techniques for Environmental Analysis
Hamilton Publishing Company
Santa Barbara, California. 1974

J. Lindenlaub and J. Russell
An Introduction to
Quantitative Remote Sensing
LARS Information Note 110474. 1974

D. C. Parker and M. F. Wolff
"Remote Sensing" in
The Surveillant Science:
Remote Sensing of the Environment
Houghton Mifflin Company,
Boston. 1973

Prepared by
The Laboratory for Applications of Remote Sensing
Purdue University, West Lafayette, Indiana 47907

S. M. Davis, General Editor

Prepared under NASA Contract NAS 9-14016 75-4

LARS-Purdue

LANDSAT: An Earth Resources Data Collection System

LANDSAT: An Earth Resources Data Collection System

In July 1972, the National Aeronautics and Space Administration launched the first Earth Resources Technology Satellite, originally called ERTS-1, to collect information about the surface of the earth from hundreds of miles above it. In February 1975, a second satellite in the series was launched to continue this data-collection task. At about the same time, the satellites were renamed LANDSAT.

To collect data over as much of the earth as possible, the LANDSAT satellites follow a polar orbit at an altitude of 920 km (570 miles). Circling the globe every 103 minutes (14 times a day), each satellite has an 18-day cycle, which means all portions of the earth are covered every 18 days. Thus, changes occurring on the earth can be monitored on 18-day intervals. The orbit was designed to allow all data to be collected at approximately the same local time each day in every location.

The figure shows the configuration of the satellites; they are about 3 meters (10 feet) tall with a 2.6 meter (8.5 foot) solar panel span. The satellites weigh about 900 kg (one ton). The remote sensors on LANDSAT include a multispectral scanner (MSS) and a return beam vidicon (RBV) system. The scanner gathers spectral reflectance data about the earth's surface in four spectral bands, two in the visible portion of the spectrum and two in the near infrared. The return beam vidicon system consists of three television cameras which view the ground and collect data in three spectral bands, two in the visible range and one in the near infrared.

As each satellite passes over the earth, it collects continuous data from an area 185 kilometers (115 miles) wide. For ease of handling, the MSS data is divided into frames with dimensions of 185 by 185 km, which corresponds to the frame size of the RBV data. It takes just 25 seconds to collect the data in one frame. Each satellite is capable of collecting data 825 million sq km (320 million square miles) each week.

Another type of data is collected by LANDSAT. In the United States, some 150 unmanned data collection stations monitor local environmental conditions such as temperature, humidity, snow depth, soil moisture content, stream flow, water level of lakes and streams, ocean salinity and atmospheric pollution. Information from these earth-based sensing stations is relayed from the ground to the satellite where it is received through the data collection antenna.

The data collected by the satellites is transmitted to one of the ground receiving sites. After some processing by NASA, it is then made available to users through the data distribution centers.

LANDSAT data are being applied to many resource management problems, including agricultural crop surveys, land use mapping, geological studies of structures and rock types, mineral exploration, determining soil type and moisture content, assessing water resources including surface water distribution, surveying coastal and marine resources, collecting water pollution data, evaluating forest and range resources, and detecting air pollution.

Prepared by James D. Russell

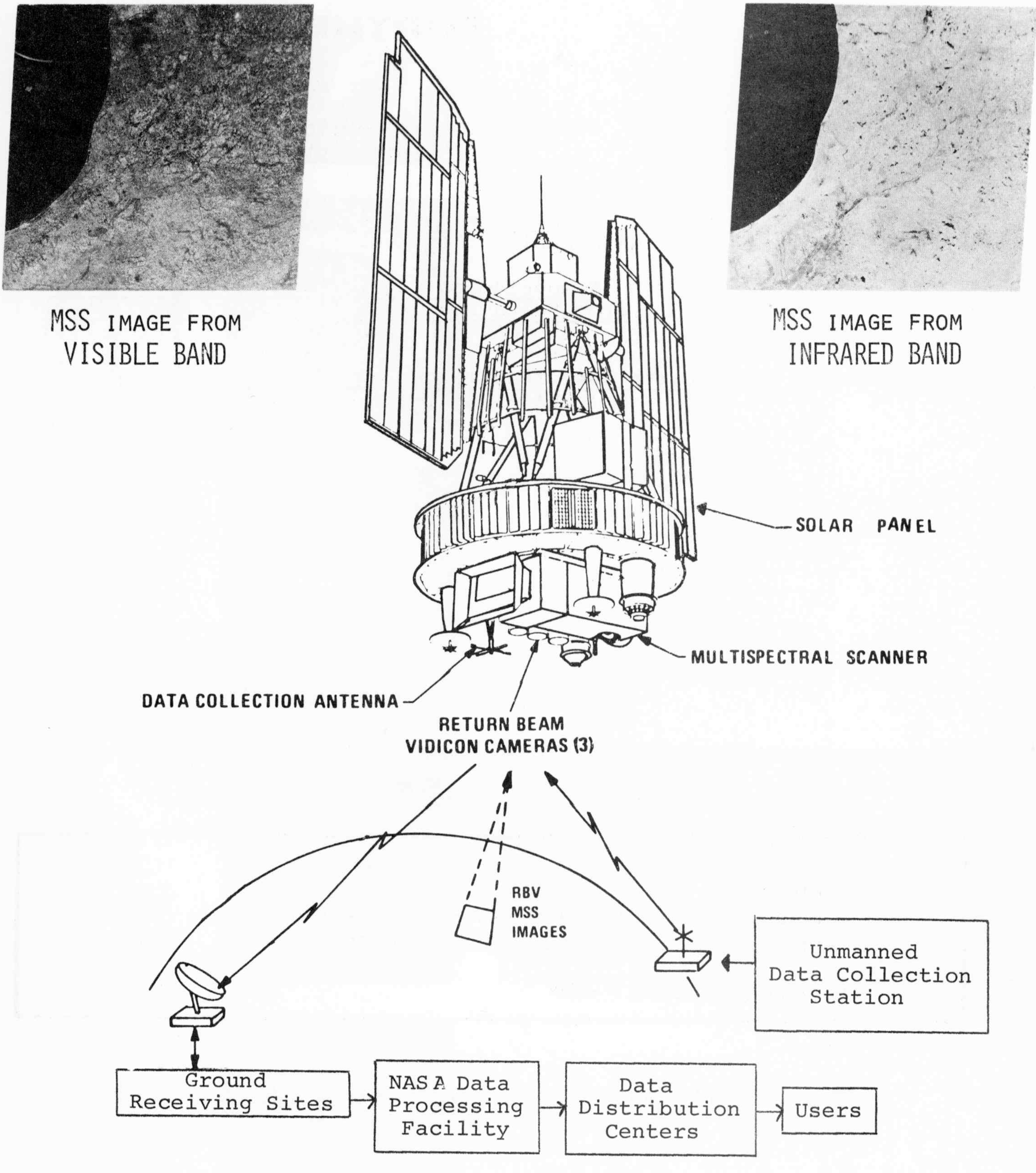

MSS IMAGE FROM
VISIBLE BAND
MSS IMAGE FROM
INFRARED BAND
SOLAR PANEL
MULTISPECTRAL SCANNER
DATA COLLECTION ANTENNA
RETURN BEAM
VIDICON CAMERAS (3)
RBV
MSS
IMAGES
Unmanned
Data Collection
Station
Ground
Receiving Sites
NASA Data
Processing
Facility
Data
Distribution
Centers
Users

Figure 1

FURTHER READING

James C. Fletcher
"ERTS-1: Toward Global Monitoring"
Astronautics and Aeronautics
September 1973

Earth Resources Technology Satellite-1
NASA Publication X-650-73-10, September 1972

Symposium on Significant Results Obtained from Earth Resources Technology Satellite-1
NASA Publication SP-327, March 1973

Third Earth Resources Technology Satellite-1 Symposium
NASA Publication SP-351, December 1973

Prepared by
The Laboratory for Applications of Remote Sensing
Purdue University, West Lafayette, Indiana 47907

S. M. Davis, General Editor

Prepared under NASA Contract NAS 9-14016

LARS-Purdue

Role of Images in Numerical Data Analysis

Role of Images in Numerical Data Analysis

Remote sensing data is often collected in numerical rather than image form; for instance, measurements of ground radiation may be recorded on computer tape instead of photographic film. Numerical data is essential for many quantitative analysis methods but, during the analysis, the data analyst may wish to create images from the numerical data and thus have the measurements represented in a form that can be visualized. In numerical data analysis, the image may not be an essential part of the analysis process--as it is for photointerpretation--but it can often provide a convenient way for the analyst to assess data quality and monitor the analysis procedure.

Typically, three kinds of images may be produced during the analysis sequence: 1) the reconstructed image, derived from the unaltered data; 2) the enhanced image, an improvement of the reconstructed image or a representation of data which has been improved in some way; and 3) the classification image, representing the results of analyzing the data. These images may be produced in several forms: as computer printouts with alphanumeric symbols; as black-and-white or color images on a television-like screen; or as photographic images.

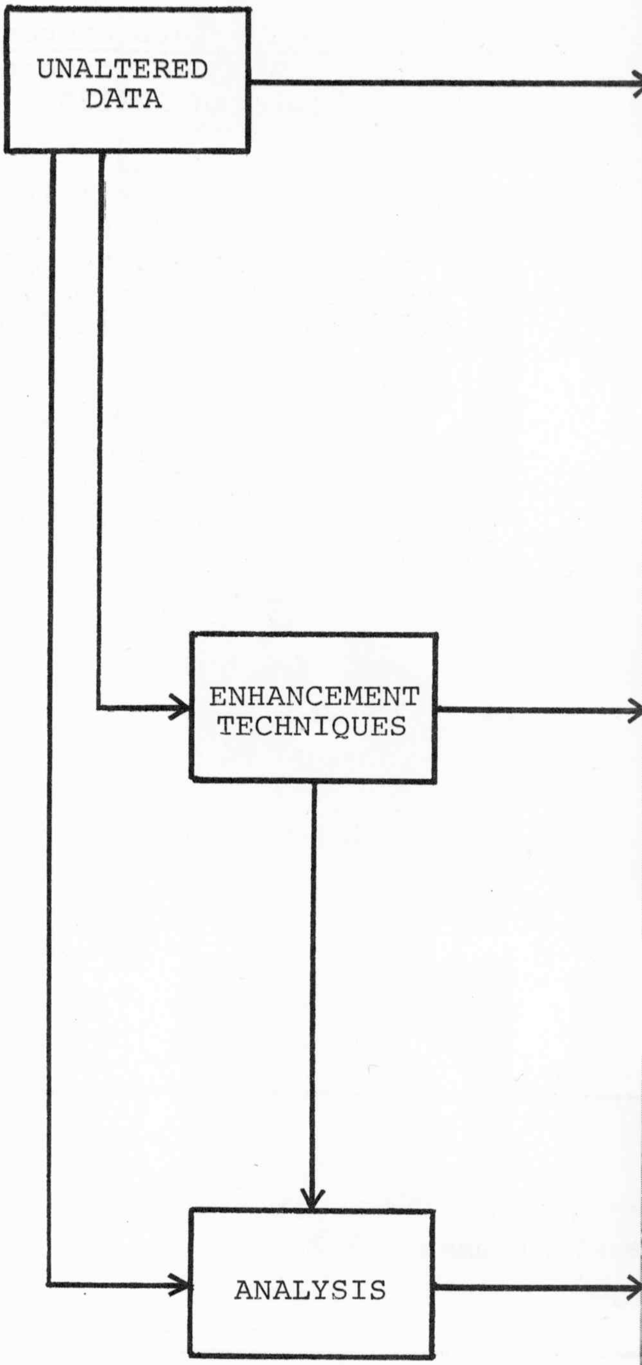
The reconstructed image (Figure 1) represents the radiation from the original ground scene; the process used to produce it is simply a reassembling process. Imagine that a picture of the ground has been cut into narrow strips and the strips have been spliced, end-to-end, into one long continuous strip. This is roughly analogous to the form in which the numerical data is stored on magnetic tape. It would be impossible to tell by inspecting the long strip what the original scene looked like, yet the image is still there--all of the information is retained. Furthermore, it is a fairly routine matter to reassemble the original image by electronic means. The process of reassembling these strips is analogous to reconstructing the image.

The enhanced image represents data that has been "improved" in some way. Figure 2 represents satellite data which has been corrected for geometric distortions inherent in LANDSAT data. Other numerical enhancement techniques include correcting for sun-angle effects and improving the contrast in the data. When data is enhanced photographically, it is sometimes displayed as a "synthetic" color image, which may emphasize selected ground features. To create a "synthetic" color image of a particular scene, a single frame of color film is exposed to three black-and-white images representing the data in different spectral bands, with a different color filter used for each exposure.

The third type of image is the classification image. If an analyst had classified data according to land use (i.e., urban, agricultural, forest, etc.) an image representing his results might display each class as a different symbol, a different color, or as shown in Figure 3, a different gray level.

The representation of numerical data in an image format is a useful tool for the data analyst. It provides him with a means of visually monitoring the analysis and presenting his results in an easily interpreted format.

Prepared by Leslie Wilson



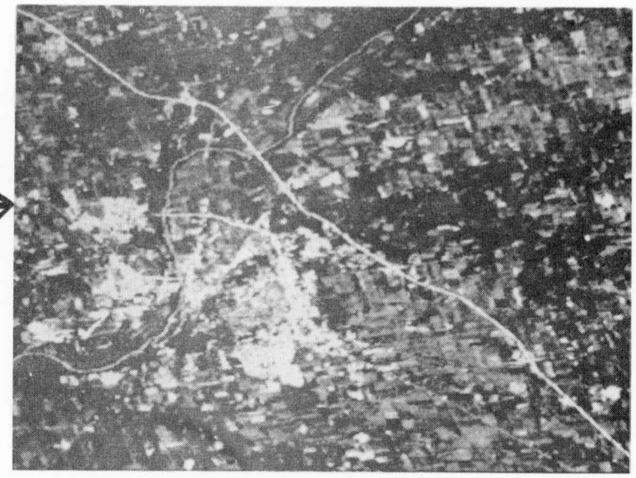


FIGURE 1
Reconstructed Image

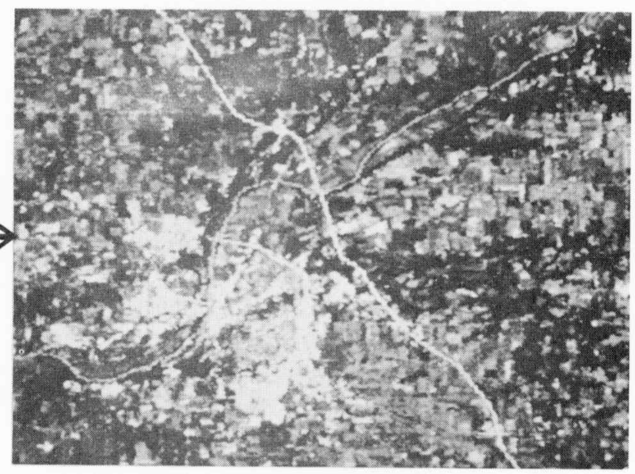


FIGURE 2
Enhanced Image

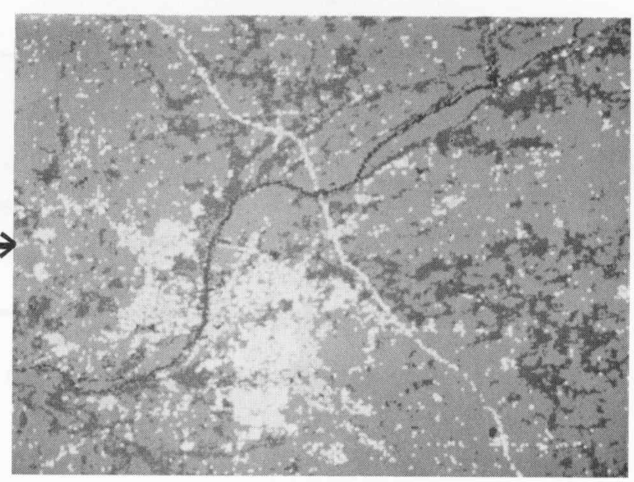


FIGURE 3
Classification Image

FURTHER READING

Image Data Processing
DICOMED Corporation
Bulletin 12G125. 1974

D. A. Landgrebe
F. C. Billingsley
J. D. Nichols
Machine Processing Methods for Earth Observational Data
LARS Information Note 100773. 1973

P. H. Swain & Staff
Data Processing I: Advancements in Machine Analysis of Multispectral Data
LARS Information Note 012472. 1972

Prepared by
The Laboratory for Applications of Remote Sensing
Purdue University, West Lafayette, Indiana 47907

S. M. Davis, General Editor

Prepared under NASA Contract 9-14016

LARS-Purdue

Crop Species Identification

Crop Species Identification

Since each vegetative species reflects, transmits, and absorbs the sun's energy in characteristic ways, crop species identification is possible by remote sensing. For example, corn and soybean leaves of comparable moisture content reflect the incident solar energy distinctly enough to be differentiated spectrally (note the lower curves on Figure 1).

Color infrared photography has been widely used for crop species identification because of its sensitivity to energy in both the visible and near infrared regions of the spectrum; significant reflectance differences in these wavelength regions can frequently be used to distinguish between crop species. Crop species identification may be achieved with still greater accuracy by using data from multispectral scanner systems capable of providing more measurements over a wider spectral range.

If reflectance data are available from several dates during the growing season, some crops which are difficult to discriminate at any one time may be more readily identified. For example, in the fall a field of newly seeded winter wheat might be spectrally indistinguishable from bare soil; in May it might be indistinguishable from alfalfa. But if data are available from both dates, the fields of winter wheat can be identified since there is no other field type which is characteristically bare soil in late fall and green in May.

For any crop, the measured spectral reflectance is affected by many natural and cultural variables, such as moisture availability, planting and fertilization practices, climate, and soil type. Figure 1 shows the effect of leaf moisture content on the spectral reflectance of corn. Research in crop species identification is now being directed toward understanding how to compensate for these variables over large geographic areas.

Figure 2 is an example of crop species classification in a three-county region in northern Illinois. The goal of the analysis was to estimate the percentage of the area planted in corn and in soybeans. The data used was collected by the LANDSAT multispectral scanner during August 1972. The crop area percentages resulting from the analysis were consistent with those gathered in conventional surveys conducted by the United States Department of Agriculture.

In the United States and other developed countries, crop surveys have been conducted for many years and have become essential to wise management of agricultural resources. Traditionally these surveys have been conducted using subjective and often time-consuming sampling methods such as personal interviews, mailed questionnaires, and on-the-ground observations. Crop species identification by remote sensing offers an alternative to traditional survey methods and has the potential for greater accuracy, cost-effectiveness and timeliness.

Prepared by Shirley M. Davis

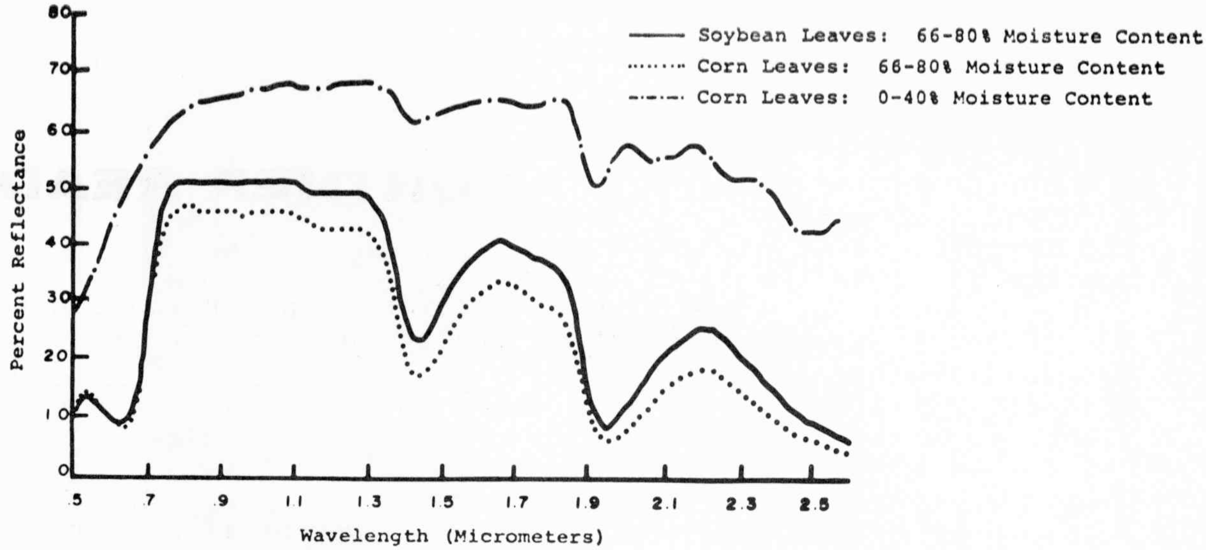


Figure 1. Reflectance curves for corn and soybean leaves

Figure 2. Computer classification map of corn, soybeans and "other." (Corn: black; soybeans: gray; "other" white.)

Comparison of USDA acreage estimates with estimates derived from computer analysis of LANDSAT data (Dekalb, Ogle, and Lee Counties, Illinois).

	USDA	LANDSAT
	(Percent of Total Area)	
Corn	40.2	39.6
Soybeans	18.0	17.8
"Other"	41.8	42.6

FURTHER READING

Marvin E. Bauer and Jan E. Cipra
Identification of Agricultural Crops by Computer Processing of ERTS MSS Data
LARS Information Note 030173. 1973

National Research Council
Remote Sensing with Special Reference to Agriculture and Forestry
National Academy of Sciences, Washington, D. C., 1970

Marvin E. Bauer
Role of Remote Sensing in Determining the Distribution and Yield of Crops
Advances in Agronomy
Academic Press, New York. 1975

Prepared by
The Laboratory for Applications of Remote Sensing
Purdue University, West Lafayette, Indiana 47907

S. M. Davis, General Editor

Prepared under NASA Contract 9-14016

FOCUS

LARS-Purdue

WHAT IS LARSYS?

What is LARSYS?

To many people in the remote sensing community, LARSYS is a software system -- an integrated set of computer programs -- for analyzing remote sensing data. But in fact, LARSYS is much more than that. LARSYS is an entire approach to the conversion of remote sensing data into information useful for monitoring and inventorying earth resources. Any adequate description of LARSYS would have to include the terms *multispectral, quantitative, pattern recognition,* and *computer-assisted.*

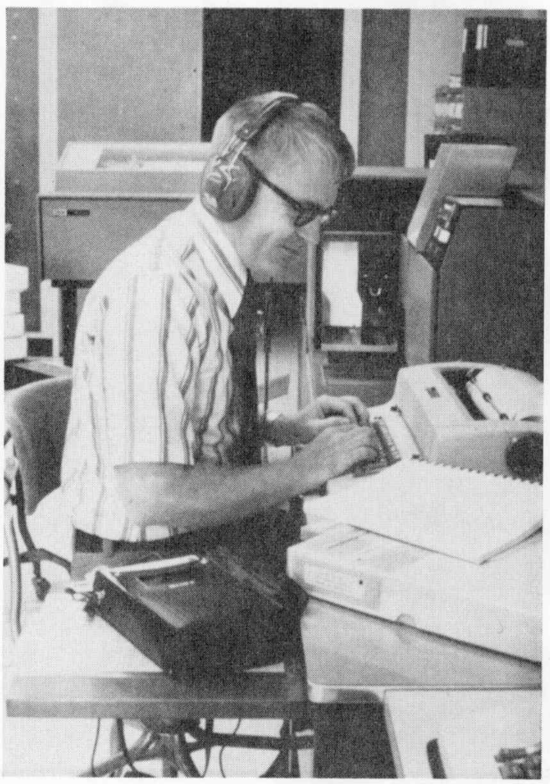
The LARSYS concept began to evolve in the mid-1960's. A group of scientists noted that aerial surveillance data from multispectral scanners could be used to discriminate among a wide range of earth cover types. Although it was still fairly early in the Space Age, they recognized the potential for using multispectral scanners aboard earth-orbiting satellites to gather earth resources data. They also recognized that the volume and rate of acquisition of data collected by such systems would be staggering -- as would the job of analyzing it! Furthermore, to produce the most useful results, the analysis process would have to be quantitative, operating on numerical data and producing numerical descriptions of the area surveyed. Clearly, this was a job requiring the data handling and computational abilities of computers.

Thus, in 1966 the Laboratory for Applications of Remote Sensing (LARS) was organized at Purdue University with the goal of applying modern computer technology to the quantitative analysis of multispectral earth resources data. Two significant factors recognized early in this effort were (1) that an emerging data analysis technique known as "pattern recognition" represented a powerful methodology for accomodating the multivariate nature of the data, and (2) that for the foreseeable future, man was an indispensable part of the overall analysis process, which would therefore be better described as "computer-assisted" rather than "automatic."

LARSYS, then, is the approach which has evolved at LARS -- and continues to evolve -- from these basic ideas. It includes a software system (Figure 1) comprising a versatile package of data handling and analysis programs; a hardware system on which the software is implemented to provide the necessary interface between analyst and data; and an easily accessed library of multispectral earth resources data. Just as important, however, LARSYS includes comprehensive documentation of the data processing algorithms and their implementation as well as an educational package (Figure 2) through which the user can learn to apply this tool effectively. Finally, LARSYS includes the philosophy which continues to guide its evolution: optimal synthesis of man and computer, using the complementary capabilities of each, to produce rapidly the quantitative and accurate analysis results (Figure 3) needed in a wide range of earth resources applications.

Prepared by Philip H. Swain

Figure 1. Analysis processors of the LARSYS software system.



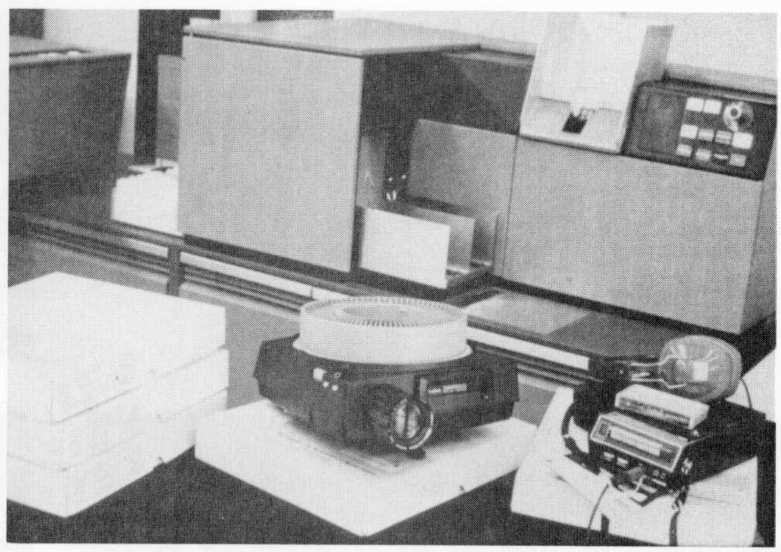


Figure 2. The multimedia LARSYS Educational Package.

Land Use	Number of Data Pts.	Number of Acres	Number of Hectares	% of Study Area
Cmrce/Indstry[1]	25766	28343	11479	8.2
Older Housing[1]	56528	62181	25183	18.0
Newer Housing	28540	31394	12714	9.1
Wooded	52346	57581	23320	16.6
Agric/Grassy[1]	150982	166080	67262	48.0
Water	499	549	222	0.2
TOTAL	314661	346127	140181	100.0

[1] Adjustments made in accordance with test classification accuracy

Figure 3. Quantitative results produced by LARSYS.

FURTHER READING

T. Phillips and S. Schwingendorf
On the Access to an Earth Resources Data Processing System
LARS Information Note 031274. 1974

LARSYS User's Manual (Volume 1)
T. L. Phillips, ed. 1973

Prepared by
The Laboratory for Applications of Remote Sensing
Purdue University, West Lafayette, Indiana 47907

S. M. Davis, General Editor

Prepared under NASA Contract NAS 9-14016

LARS-Purdue

LANDSAT Multispectral Scanner Data

LANDSAT Multispectral Scanner Data

Since July 1972, the multispectral scanners aboard the LANDSAT satellites have collected vast quantities of high-quality data about the surface of the earth. Reflected energy from the earth is measured in four wavelength bands, two in the visible portion of the spectrum (.5-.6μm and .6-.7μm) and two in the near-infrared (.7-.8μm and .8-1.1μm). Thus the data from LANDSAT describes individual areas on the ground of .5 hectares (1.1 acres) by means of four relative radiance values. The assigned values range from 0 to 127 discrete radiance levels for the lower three bands and from 0 to 63 for the .8-1.1μm band.

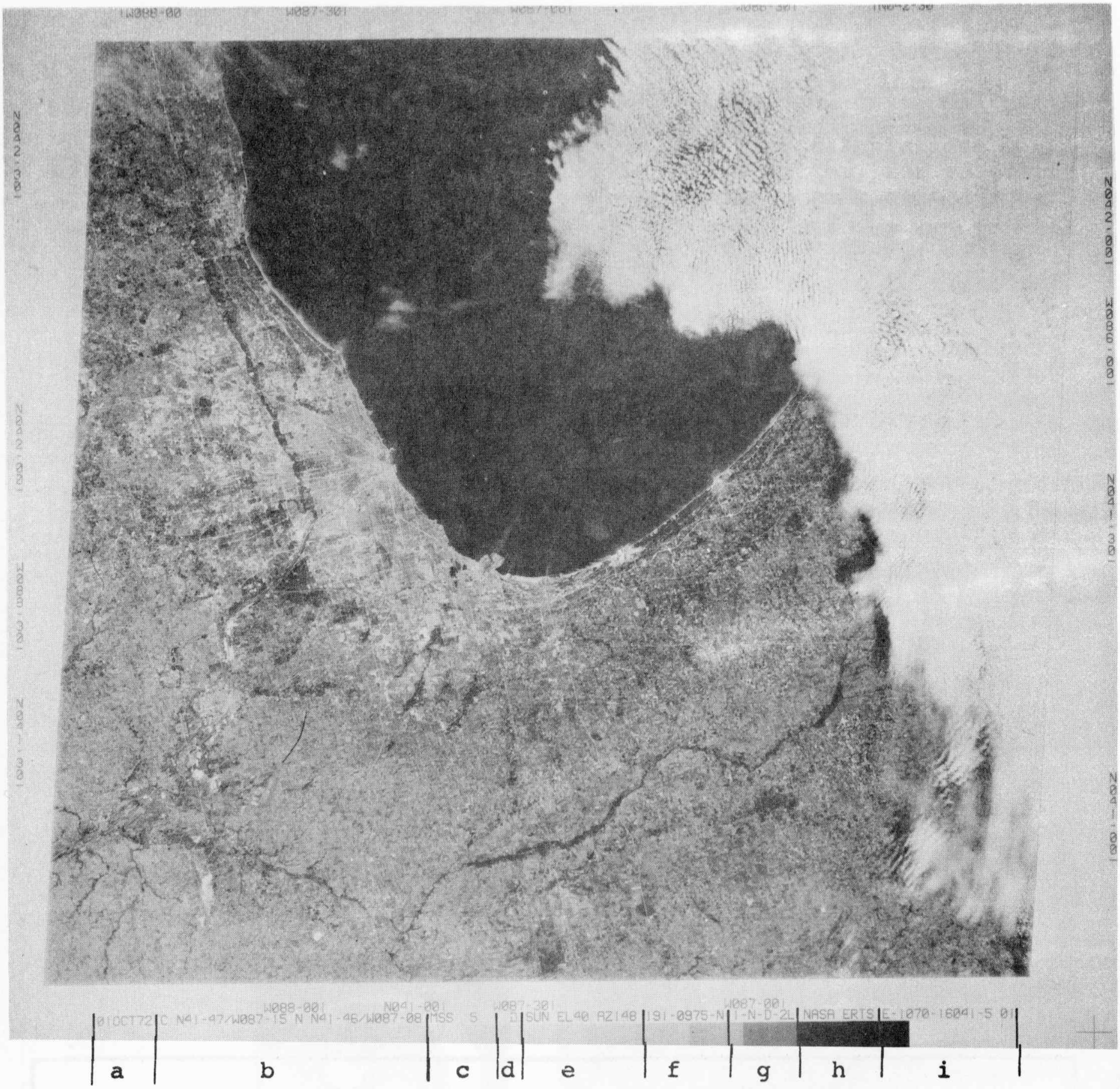
Before LANDSAT multispectral scanner data is delivered to users for analysis, it is corrected at Goddard Space Flight Center for distortions caused by spacecraft instabilities and sensor variabilities. For convenience in handling, the data is also divided into frames, each representing an approximately square ground scene 185 km (115 mi) on a side. Users may order the data either on computer-compatible tape or as black-and-white or simulated color infrared imagery. Prints as well as positive and negative transparencies may be obtained.

Figure 1 is a black-and-white positive image created from numerical data in the .6-.7μm wavelength band, identified as LANDSAT channel 5. The annotations below the image, the longitude and latitude designations around the edges, and the 15-step gray-level strip provide information that is helpful in the identification and interpretation of the image. The rotation of the imagery from a true north-south alignment is caused by the orbital path of the satellite; the skew in the data, evidenced by the non-rectangular shape of the image, is the result of the rotation of the earth beneath the satellite.

Computer-compatible tapes containing LANDSAT multispectral scanner data are especially well-suited for performing analyses based on numerical techniques and for creating digitally enhanced and enlarged images. Data in this numerical format can also be geometrically adapted, allowing it to be matched to aerial photographs, terrain maps, or other data sets describing the same area.

The LANDSAT multispectral scanner is providing high-quality repetitive data from the earth in the visible and near-infrared portions of the spectrum. The synoptic view from the scanner provides a new perspective for viewing the earth, and the variety of data formats available fosters the extraction of useful information through a range of analysis approaches.

Prepared by Shirley M. Davis



a. Day, month, year
b. Latitude and longitude of image and of satellite
c. MSS spectral band code (4=.5-.6μm; 5=.6-.7μm; 6=.7-.8μm; 7=.8-1.1μm)
d. Direct or recorded transmission
e. Sun-angle information
f. Spacecraft heading, orbit number and ground receiving station
g. Encoded information on image size, orbit and data format
h. Agency and project
i. Frame identification number

Figure 1. A LANDSAT frame showing annotations, longitude and latitude designations, and 15-step gray scale.

FURTHER READING

Paul E. Anuta
Geometric Correction of ERTS-1 Digital Multispectral Scanner Data
LARS Information Note 103073. 1973

NASA
ERTS Data User's Handbook. 1972

NASA
Symposium on Significant Results Obtained from Earth Resources Technology Satellite-1
3 vol. 1973

NASA
Third Earth Resources Technology Satellite-1 Symposium
3 vol. 1974

Prepared by
The Laboratory for Applications of Remote Sensing
Purdue University, West Lafayette, Indiana 47907

S. M. Davis, General Editor

Prepared under NASA Contract NAS 9-14016

LARS - Purdue

CLUSTERING

Clustering

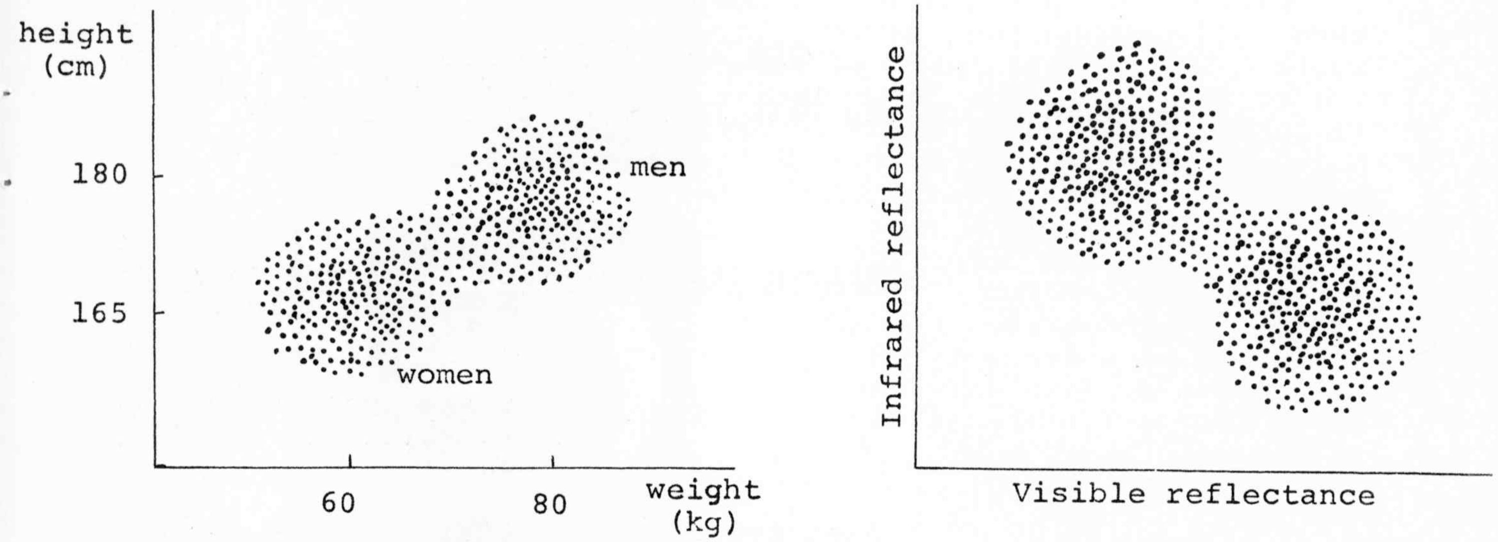
Clustering is a computer-aided data analysis method which seeks to determine the "natural structure" in a set of data. Figure 1 illustrates "natural structure": the tendency of the data to form groupings or "clusters." In remote sensing applications, clustering is commonly used in two ways. The first is in decomposing complex data sets into simpler subsets. The second is in unsupervised classification.

To illustrate the first use, Figure 2a shows a set of data having a distribution with two modes (maximal points). Such a situation might arise, for instance, if the data were drawn from a forested area consisting of two different species of trees. Many remote sensing data analysis algorithms require that each data set have a unimodal distribution (such as the normal or Gaussian distribution). Clustering may be used to separate the data into two subsets, each having a distribution with a single mode (Figure 2b).

Unsupervised classification is a method for categorizing data based on classes determined from the natural structure of the data. (This is in contrast to supervised classification in which the classes are determined from the known identity of a representative sample of data.) For example, referring again to Figure 1, clustering could be used to determine that two "natural classes" exist in the data; the mean or cluster center for each class would then be determined and every new set of measurements would be assigned to the natural class having the nearest cluster center. For this type of analysis to be useful, there must be a meaningful correspondence between the natural classes established by clustering and a set of "informational classes," categories which are of interest to the person who intends to use the analysis results. (In remote sensing, natural classes determined by clustering multispectral data are often called "spectral classes" to distinguish them from "informational classes.")

A large number of clustering algorithms have been investigated which differ largely in how they characterize the natural structure of the data. The most appropriate characterization and hence the choice of algorithm often depends on the specific application involved. The reader interested in examples may consult the material listed as Further Reading.

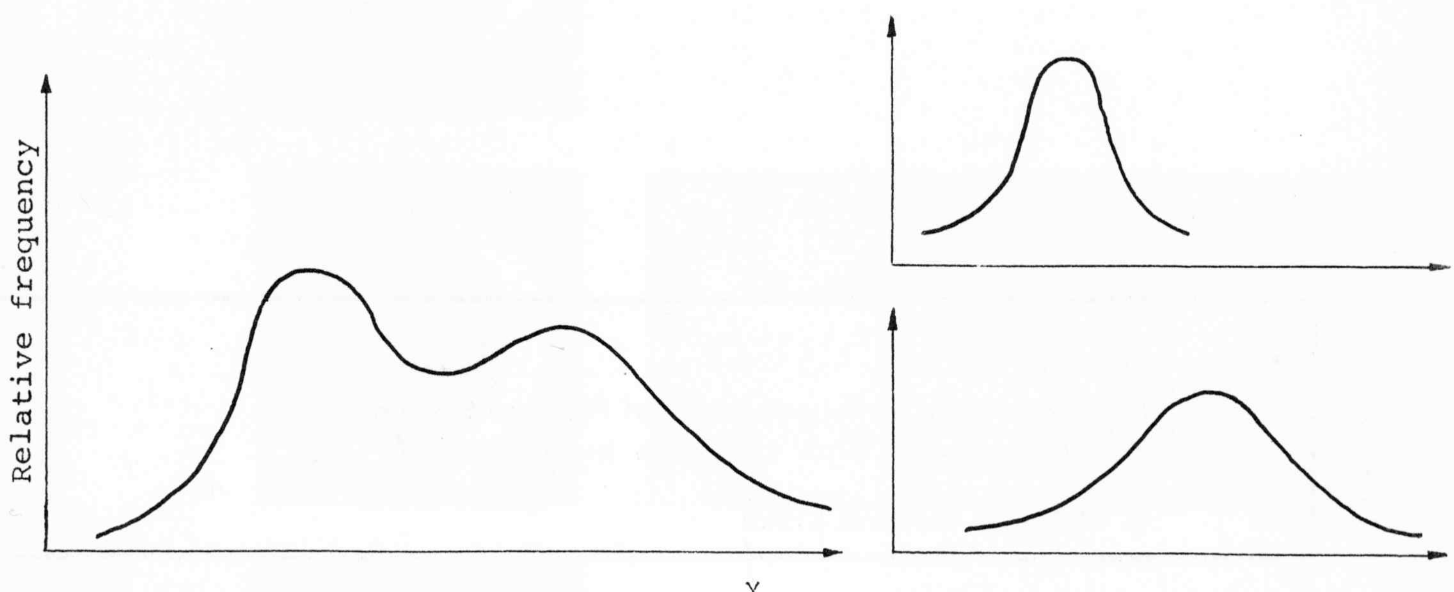
Prepared by Philip H. Swain



(a) A distribution of adult heights and weights

(b) Multimodal data from wheat fields (hypothetical illustration)

Figure 1. Clusters: natural structure in data



(a) A bimodal distribution

(b) Unimodal components

Figure 2. Clustering can be used to separate complex data into simpler components.

FURTHER READING

G. H. Ball
Data Analysis in the Social Sciences:
What About the Details?
Proceedings of the Fall Joint Computer Conference, AFIPS
December 1965

R. O. Duda and P. E. Hart
Pattern Classification and Scene Analysis
John Wiley, 1973

LARSYS User's Manual (Volume 1)
T. L. Phillips, ed. 1973

Also see a related title in this series:
FOCUS: Pattern Recognition

Prepared by
The Laboratory for Applications of Remote Sensing
Purdue University, West Lafayette, Indiana 47907

S. M. Davis, General Editor

Prepared under NASA Contract NAS 9-14016

LARS-Purdue

FOCUS

HOW THE EARTH REFLECTS

How the Earth Reflects

Identifying features on the earth's surface through remote sensing depends in large measure on the varying ways surface materials reflect the sun's energy. It is these variations in reflectance that both photographic sensors and multispectral scanners record.

The amount of energy reflected by a material is a function of three factors: how much of the sun's energy reaches it, how much is absorbed by it, and how much is transmitted through it. This relationship can be expressed as:

$$R_\lambda = I_\lambda - (A_\lambda + T_\lambda)$$

that is, the reflectance (R) at a specific wavelength (λ) is equal to the incident energy at that wavelength (I_λ) minus the sum of the energy abosrbed (A_λ) and transmitted (T_λ) at that wavelength.

Figure 1 shows typical reflectance patterns for three familiar earth surface materials. For each material, the reflectance varies with wavelength. Figure 2 illustrates this variation; here a darker tone on the image represents a lower reflectance, and a lighter tone, a higher reflectance.

Looking first at vegetation we notice relatively low reflectance in the visible wavelengths (Figures 2a and 2b), where the effects of the pigmentation in the leaf determine the shape of the curve. For example, chlorophyll absorbs energy in the blue and red wavelengths, but reflects it in the green band (.50-.55μm), making it appear green to our eyes. This higher reflectance can be seen in both the rise of the curve in Figure 1 and the relatively lighter tones in Figure 2b. The typically high near-infrared reflectance of healthy vegetation is evidenced by the brighter tones in Figures 2c and 2d, and the reduced reflectance in the middle infrared by the darker tones in Figure 2e. Near 1.4μm and 1.9μm two major water absorption bands occur, so called because water absorbs greater amounts of energy at those wavelengths. Water is present in the leaves of healthly vegetation, and the reflectance curve reveals the decreased reflectance at those wavelengths.

Soils reflect very differently depending on their color, moisture, surface condition, and the amounts of organic matter and iron oxide present. General characteristics to note are that soils tend to reflect more energy than vegetation in the visible wavelengths (Figures 2a and 2b) and in the middle infrared (Figure 2e). Moist soils generally have a lower reflectance throughout the spectrum than dry soils and exhibit the effects of the water absorption bands.

A significant reflectance characteristic of water is its distinct decrease in reflectance in moving from the visible to the near-infrared image. Both clear water and turbid water behave in this way. In the visible wavelengths, river water generally reflects more energy than clear lake water because of its turbidity. Variations in reflectance can be used to determine water depth and condition.

Although basic reflectance characteristics make possible the spectral identification of specific cover materials, these generalized curves vary in many ways and for many reasons. For example, a moist corn leaf reflects differently than a dry one; a more mature field of soybeans reflects differently than a less mature one; vegetation under stress reflects differently than healthy vegetation; a crop on good soil may appear different from the same crop on poor soil. In addition, these spectral characteristics are not static, but vary with time.

Understanding the physical and biological reasons for variations in reflectance is essential to effective analysis of multispectral data.

Prepared by Shirley M. Davis

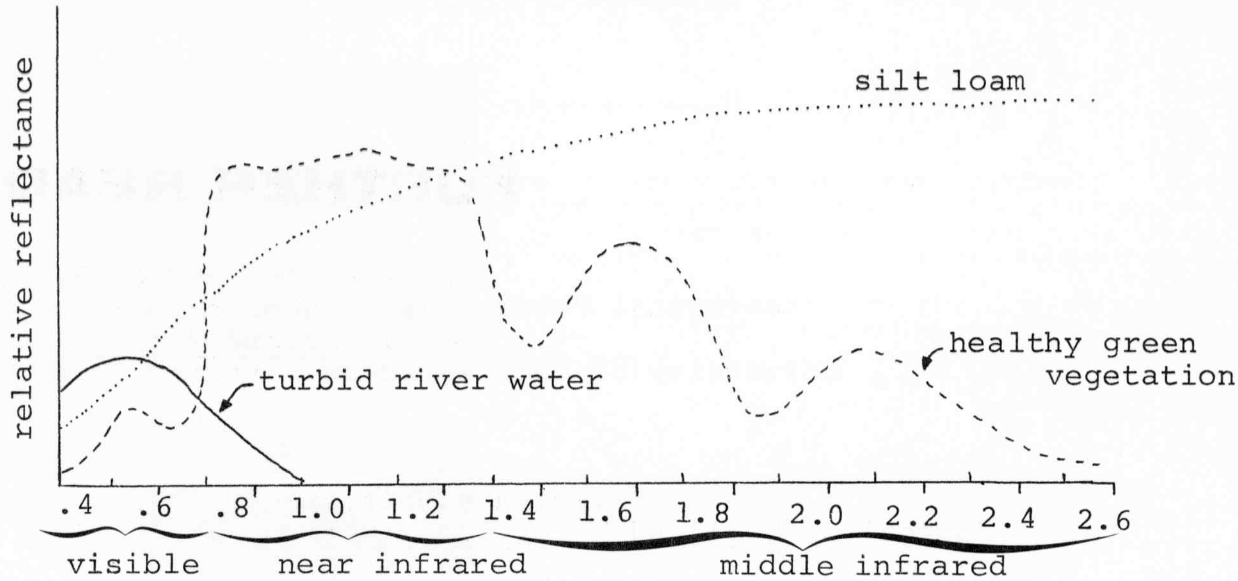


Figure 1. Typical spectral reflectance curves for three earth surface materials.

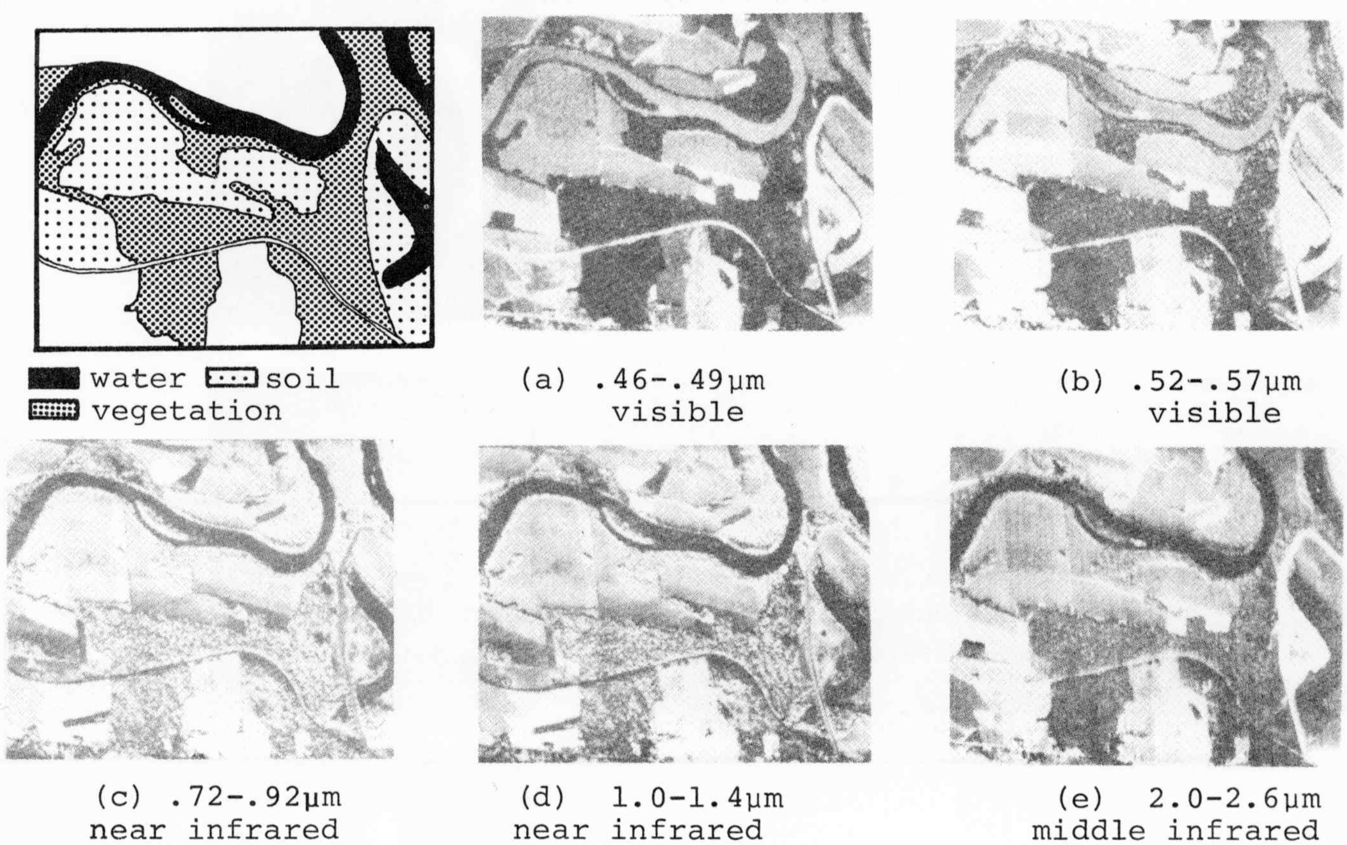


Figure 2. Images created from multispectral scanner data.

FURTHER READING

R. M. Hoffer and C. J. Johannsen
Ecological Potentials in Spectral Signal Analysis
in _Remote Sensing in Ecology_
University of Georgia Press, Athens, Georgia. 1969

S. J. Kristof
Preliminary Multispectral Studies of Soils
Journal of Soil and Water Conservation 26(1):15-18. 1971

D. M. Gates, H. J. Keegan, et al.
Spectral Properties of Plants
Applied Optics 1(4):11-20. 1965

J. P. Scherz, D. R. Graff, and W. C. Boyle
Photographic Characteristics of Water Pollution
Photogrammetric Engineering 35(1):38-43. 1969

Prepared by
The Laboratory for Applications of Remote Sensing
Purdue University, West Lafayette, Indiana 47907

S. M. Davis, General Editor

Prepared Under NASA Contract NAS 9-14016

LARS - Purdue

MULTISPECTRAL - MULTITEMPORAL CONCEPT

Multispectral-Multitemporal Concept

Many remote sensing data collection systems, such as the LANDSAT satellites, are designed to record information in several spectral bands. In the illustration shown, information for each ground resolution element is recorded from four bands: two visible bands, .5-.6 micrometers (green/yellow) and .6-.7 micrometers (red), and two near infrared bands, .7-.8 micrometers and .8-1.1 micrometers. The scanning action of the sensor system is designed to record a set of spectral measurements for adjacent ground resolution elements. We refer to the set of numbers which represents the data for each resolution element as a *data vector*--in this case, a *multispectral data vector*.

By combining data from two or more different passes of the sensor system over the same area on the ground, a single set can be created (commonly recorded on a single magnetic tape) which combines multispectral data from these different times to form a *multispectral-multitemporal data vector* for each ground resolution element. This is illustrated in Figure 1, which shows October LANDSAT data merged with May data. Associated with each resolution element is an eight-component multispectral-multitemporal data vector, identified by a row and column number.

The ability to derive from the data both spectral and temporal information about a scene allows the use of variations in both the spectral and time dimensions for identification of different types of ground cover. Figure 2 shows a situation where both multispectral and multitemporal data are useful for distinguishing different types of ground covers. In the fall, before newly planted wheat emerges from the ground, winter wheat fields have the spectral characteristics of bare soil. At this same time pasture has spectral characteristics similar to those of green vegetation; harvested row crops, such as corn or soybeans, have spectral characteristics similar to dried vegetation. In early spring, winter wheat fields look green as do pastures, but newly planted soybeans and corn still behave spectrally like bare soil. A comparison of the columns in Figure 2 illustrates how data from different times might be used to distinguish winter wheat from pasture and other agricultural crops.

In summary, one of the advantages of recording remote sensing data in numerical form is the convenience of merging data from different times to create a multispectral-multitemporal data set so that both the spectral and temporal information may be used to aid in the analysis and classification of different ground cover types.

Prepared by John C. Lindenlaub

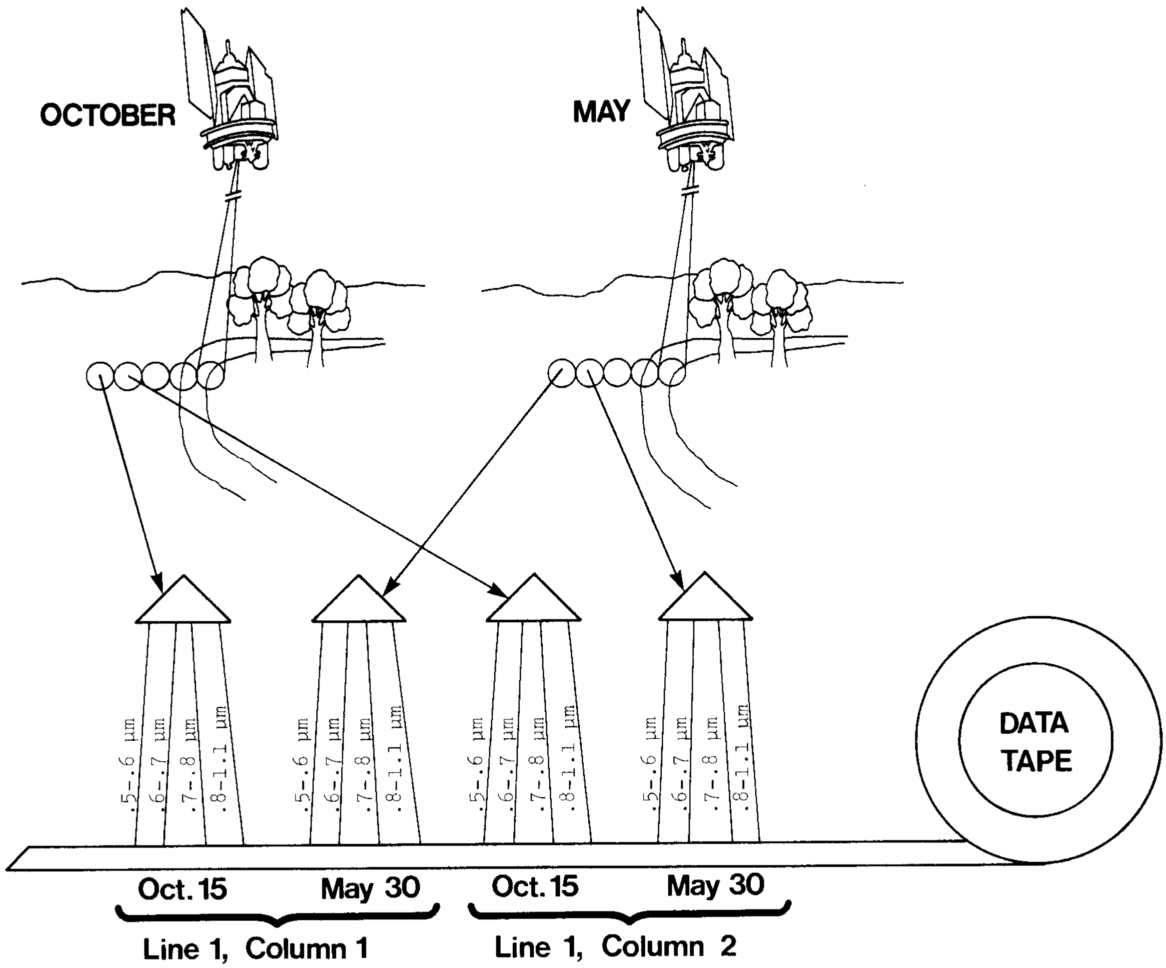


Figure 1. Merging LANDSAT data collected over the same scene at two different times to form a multispectral-multitemporal data set.

	Cover		
Season	Winter Wheat	Pasture	Row Crops
Fall	bare soil	green	dry stubble
Spring	green	green	bare soil

Figure 2. An example of distinctive temporal variations.

FURTHER READING

D. Steiner
"Time Dimension for Crop Surveys from Space"
Photogrammetric Engineering,
Vol. 36, pp. 187-194, 1970.

P. E. Anuta
"Spatial Registration of Multispectral and Multitemporal Digital Imagery Using Fast Fourier Transform Techniques"
IEEE Transactions on Geoscience Electronics,
Vol. GE-8, pp. 353-368, 1970.

R. L. Lillestrand
"Techniques for Change Detection"
IEEE Transactions on Computers,
Vol. C-21, No. 7, 1972.

P. E. Anuta and M. E. Bauer
An Analysis of Temporal Data for Crop Species Classification and Urban Change Detection
LARS Information Note 110873. 1973.

Prepared by
The Laboratory for Applications of Remote Sensing
Purdue University,West Lafayette, Indiana 47907

S. M. Davis, General Editor

Prepared under NASA Contract NAS9-14970

LARS-Purdue

LARSYS Version 3.1

LARSYS Version 3.1

LARSYS Version 3.1 is a fully documented set of computer programs designed for installation on a general purpose computer to provide data analysis capabilities for remote sensing research. It was developed after nearly a decade of research into remote sensing data analysis at the Laboratory for Applications of Remote Sensing (LARS).

The total LARSYS concept, of which Version 3.1 is a part, includes a software system, a hardware system, a library of multispectral earth resources data, comprehensive documentation, and an educational package to train users. LARSYS Version 3.1 contains only those programs which have been refined and well-documented; others, such as the image registration and geometric correction programs which are much less developed and not fully documented, are not available for general distribution. As LARSYS continues to evolve through further research in remote sensing and pattern recognition, it is likely that Version 3.1 will be supplanted by a newer version of LARSYS, just as LARSYSAA, LARSYS Version 2 and Version 3.0 have been replaced.

Although LARSYS Version 3.1 is easier to use than earlier versions and contains improved data analysis capabilities, the basic analysis approach remains unchanged. First, the analyst locates on a multispectral image storage tape those data vectors which he believes to be representative of classes of interest. These classes may be spectral classes or they may be identifiable as information classes, e.g. certain crops, cover types, coastal features, forest types or geologic features. These selected data vectors are used to characterize each class statistically, and then they and the remaining data vectors in the data set are classified, according to their spectral similarity, into the classes of interest.

The eighteen processing functions included in LARSYS Version 3.1 are interrelated as shown on the accompanying figure. They can be grouped into six categories according to the type of function they perform:

1. Utility functions - to extract or manipulate data from multispectral storage tapes: a) print identification information, b) duplicate data runs, c) transfer data from one medium to another.

2. Data evaluation functions - to evaluate individual channels of data: a) graph functions to display the range of magnitudes of the line data and the column data, b) histograms to show the distribution of spectral values, and c) graphs of histogram results.

3. Data display functions - to aid in selecting training fields and test fields: a) printouts of single channels of data in image form, b) displays of data on a gray-level image display device.

4. Statistical calculation functions - to aid in analyzing a multi-

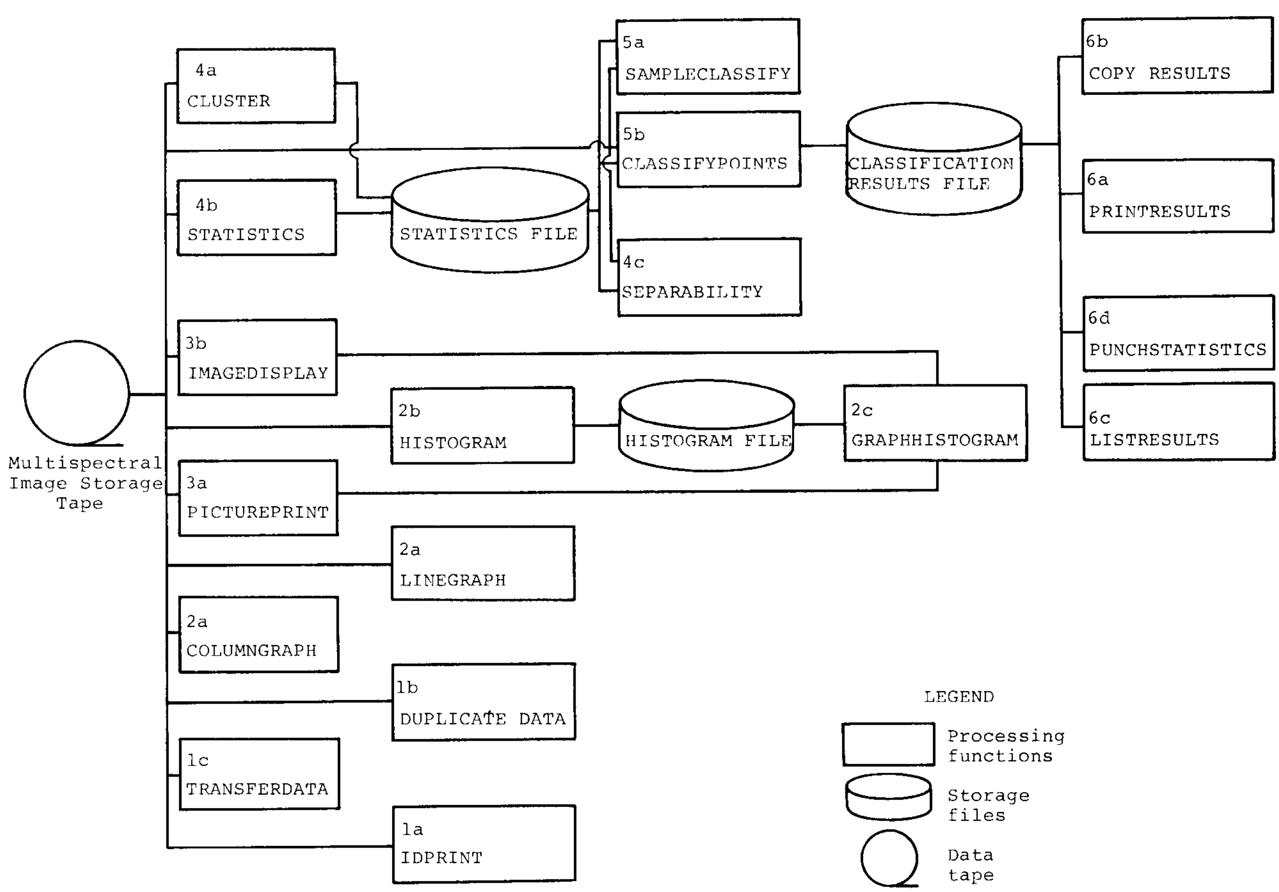
spectral data set: a) cluster processor for unsupervised classification of data points, b) statistics calculations for training fields, c) separability information, for selecting the channels and classes that will yield the best classifications.

5. Classification functions - to perform a supervised classification using the statistics file as input on: a) sample basis using group statistics, or b) a point-by-point basis based on maximum likelihood.

6. Output functions - to aid in analysis and handling of results from the classification outputs produced are: a) printed classification map and performance tables, b) copy of results on tapes, c) printed information identifying and describing the classification results, and d) a statistics file on cards.

For information about purchasing LARSYS Version 3.1, contact LARS System Services at Purdue University or COSMIC at the University of Georgia, Athens, Georgia.

Prepared by C. Royal Sand



LARSYS Multi-image Data Analysis System

FURTHER READING

LARSYS Version 3 User's Manual, T. L. Phillips (editor)
LARS, Purdue University, West Lafayette, Indiana. 1973

P. H. Swain, T. L. Phillips and J. C. Lindenlaub
"The Role of Computer Networks on Remote Sensing Data Analysis"
Proceedings of the Conference on Machine Processing of Remotely Sensed Data
Purdue University, October, 1973
IEEE Catalog No. 73 CHO 834-2GE

Also see another title in the FOCUS series:
What is LARSYS?

Prepared by
The Laboratory for Applications of Remote Sensing
Purdue University, West Lafayette, Indiana 47907

S. M. Davis, General Editor

Prepared under NASA Contract NA59-14970 77-13

LARS - Purdue

REGIONAL LAND USE INVENTORIES

Regional Land Use Inventories

Recently there has been a marked growth in concern about the proper use of the earth's shrinking resources, and extensive effort has gone into endeavors such as water quality improvement, land reclamation, controlling urban growth, and the preservation of agricultural lands. Current land use inventories are often an essential part of these environmental stewardship efforts, particularly when they encompass large geographic areas.

Remote sensing provides a rapid and effective way to obtain regional land use information. For example, a land use inventory of the United States portion of the Great Lakes Basin was completed in 1975 to identify probable areas of pollution contribution, as part of an effort to improve the water quality of the Great Lakes. LANDSAT multispectral scanner data was used to identify the level I and level II land use categories shown in the Table I over the entire area of 34,000,000 hectares (85,000,000 acres). The synoptic view afforded by LANDSAT was well-suited to the regional scope of the survey, and the satellite's repetitive coverage of the area provided a choice of data collection dates enabling analysts to choose data from those times of the year when spectral differences between classes were good and the data was predominantly cloud-free.

The analysis approach used in this study was a sampling method appropriate for surveys of large areas. In this case 25% of the data points evenly distributed throughout the county were sufficient to give information of the desired detail. More costly aerial photography, used for reference data covered 4% of the total study area in several two and one-half mile wide flightlines. Evaluation of the analysis was done by comparing field observations with classification maps and by comparing the acreage figures obtained with acreage figures reported in U.S. Department of Agriculture surveys.

Because of the many ways land use information can be used, it is important that the results of surveys can be presented in various formats. In some applications, tabular results in varying degrees of detail and different aggregations may be needed, and in others black-and-white or full-color maps may be required. Figure 1 and Table 2 show two typical presentations of land use information for Winnebago County, Wisconsin, one of the 191 counties analyzed in the Great Lakes study. Figure 1 identifies locations of level 1 categories by tones of gray; Table 2 gives information about the area of categories similar to level II categories.

Compiling land use inventories through remote sensing is complicated by the fact that there is not a direct correspondence between land use categories, ground cover materials, and spectrally distinct classes; two or more different uses may be made of lands with identical cover materials, and different cover materials may not always be spectrally distinct. These difficulties can be minimized if the data selected for analysis is collected at a time of year when class

LEVEL I	LEVEL II
Urban	Residential Commercial/Industrial
Agricultural	Row crops Close grown crops Pasture/grassland
Forest	Forest
No Major Use	Water Wetland

Table 1. Land use classes used in this study, similar to USGS Circular 671.

differences are the greatest or if data from more than one date is used in the analysis. Increased accuracy may also be achieved through effective use of appropriate reference data.

In the past, large-area land use inventories have required considerable manpower, time and expense, and were often out of date by the time they were prepared and published. Now computer-aided analysis of satellite-obtained multispectral scanner data provides another tool to the land use specialist in preparing timely land use surveys for a variety of uses.

Prepared by
Shirley Davis

KEY:

White - Urban/Commercial/Industrial

Light Gray - Agriculture

Dark Gray - Forest

Black - No major use

Figure 1. Classification Map of level I land uses, Winnebago County, Wis.

Winnebago County, Wis.	Acres Level I	Acres Level II	Hectares Level I	Hectares Level II	Percent Level I	Percent Level II
Urban-Commercial-Industrial	26930		10900		7.3	
Residential		26930		10900		7.3
Commercial		-		-		-
Agriculture	203360		82330		55.0	
Row crop		134200		54330		36.3
Close grown crop		23200		9390		6.3
Pasture		45960		18600		12.4
Forest	56310		22790		15.2	
No Major Use	83330		33730		22.5	
Water		83330		33730		22.5
Wetland		-		-		-
TOTALS	369930	369930	149760	149760	100.0	100.0

Table 2. General level I and more specific level II land use analysis results.

FURTHER READING

R. A. Weismiller and M. F. Baumgardner
Land Use Inventory of the Great Lakes Basin by Computer Analysis of Satellite Data, In Proceedings of the 1974 Earth Environment and Resources Conference, September 1974, Lewis Winner, New York, 10036

J. R. Anderson, E. Harsy, and J. T. Roach
A Land-Use Classification System for Use With Remote Sensor Data, U. S. Geological Survey Circular 671, Washington, D. C. 1972

J. R. Anderson, E. Hardy, J. T. Roach, and R. G. Witmer
A Land-Use and Land-Cover Classification System for Use With Remote Sensor Data, U. S. Geological Survey Professional Paper, 964, Washington, D.C., 1976

Great Lakes Basin Commission
Inventory of Land Use and Land Use Practices in the United States Great Lakes Basins - With Emphasis on Certain Trends and Projections to 1980 and Where Appropriate to 2020, To be Published
Vol. I Great Lakes Basin
Vol. II Lake Superior Basin
Vol. III Lake Michigan Basin
Vol. IV Lake Huron Basin
Vol. V Lake Erie Basin
Vol. VI Lake Ontario Basin

Paul Mausel, Carl Leivo, and Michael Lewellen
Regional Land Use Classification Derived from Computer Processed Satellite Data, Journal of American Institute of Planners, April 1976

Prepared by
The Laboratory for Applications of Remote Sensing
Purdue University,West Lafayette, Indiana 47907

S. M. Davis, General Editor

Prepared under NASA Contract NAS9-14970 77-14

LARS-Purdue

REFORMATTING LANDSAT DATA

Reformatting LANDSAT Data

Digital LANDSAT data are supplied to the user community, through data distribution centers, in a NASA-designed format on computer compatible tapes (CCT's). The format used on these tapes is efficient from the standpoint of data collection and data transmission but not from the standpoint of data processing. Thus, LANDSAT CCT data are reformatted to reduce data processing time during computer aided research and analysis.

A LANDSAT frame covers a square of the earth's surface containing approximately 10,000 square nautical miles. As can be seen in Figure 1, four LANDSAT CCT's are required to complete each data frame. Each LANDSAT CCT contains a 25 x 100 nautical mile strip of data which does not overlap either the previous or successive strips of the data frame. Each strip may be stored on its own tape (CCT 1 through CCT 4, figure 1) or, the strips may be stored on four sections of (one) tape (the "Combined LANDSAT CCT", figure 1). In addition to each frame being divided into four strips, the format of the data within each CCT has special characteristics. As shown in figure 2, a line of data on a CCT consists of the values for two consecutive data points (S1, S2) in one channel followed by values for two consecutive data points (S1, S2) in the second channel, on through the third and fourth channels. This pattern of data points is repeated for the complete line of data.

One widely accepted format created during the LANDSAT reformatting is known as LARSYS format. LARSYS format was designed as a common data format to efficiently input image data to the LARS data processing and analysis programs known in concept as LARSYS.

The LARSYS format reduces processing costs and increases the analyst's access to data. The LARSYS data format is shown in the middle of figure 2. A line of data consists of the data values for all the data points of the first channel followed by the values for all the data points of the second channel, on through the third and fourth channels.

Three major operations are performed during the reformatting process. First, identification information is extracted from the original tape and put on the reformatted tape. Second, a single image is constructed from the four subimages on the four LANDSAT CCT's (figure 1). Third, the data values of the LANDSAT CCT are rearranged to LARSYS data tape format (figure 2). The final LARSYS CCT contains approximately 2340 lines of data. Each line contains approximately 3226 data values per channel. Thus, over seven million data values are recorded on a LARSYS tape. The outputs from the LARS reformatting process are a tape in LARSYS format, a unique location for this tape in the LARS data library, and a printed description of the LANDSAT data contained on the LARSYS computer compatible tape.

In summary, the LANDSAT to LARSYS data reformatting process converts the format of the input LANDSAT CCT to LARSYS format. The process includes forming a single image from four adjoining subset images, extracting the appropriate frame identifier information, and rearranging the lines of data. The basic output of the process includes a magnetic tape containing the full LANDSAT frame which is ready for use with the research and analysis programs of LARSYS.

Prepared by David M. Freeman

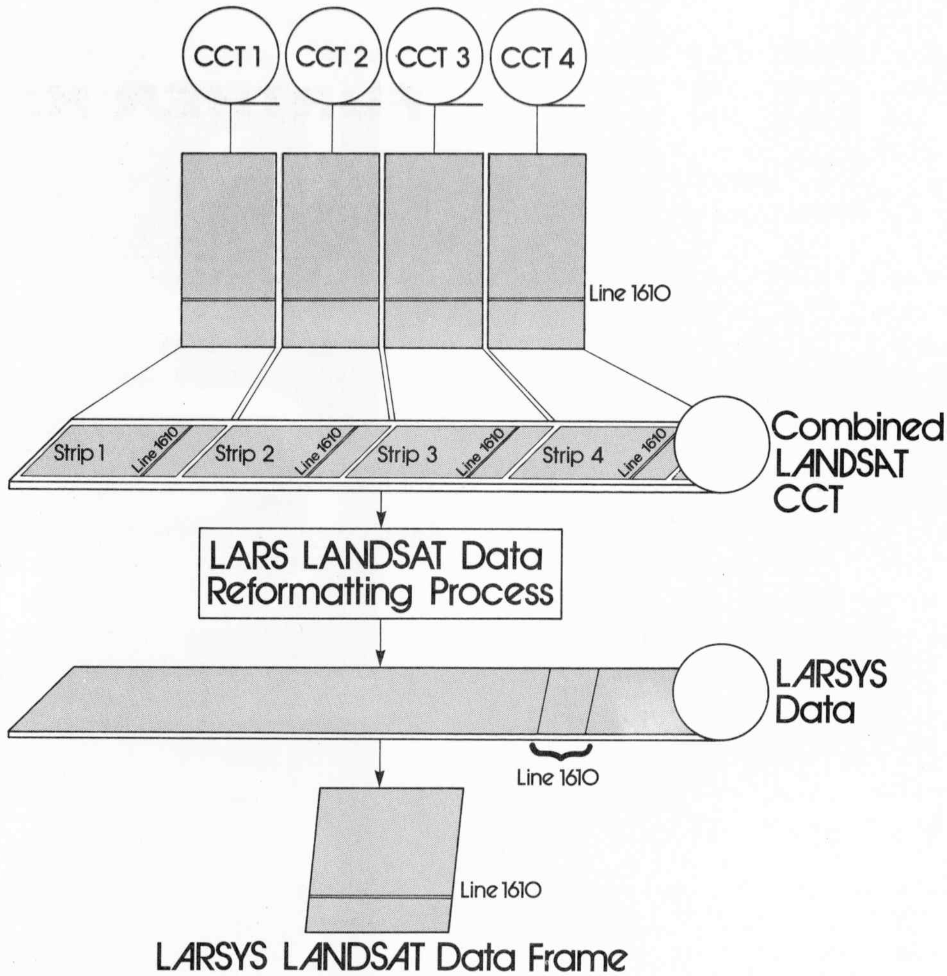


Figure 1

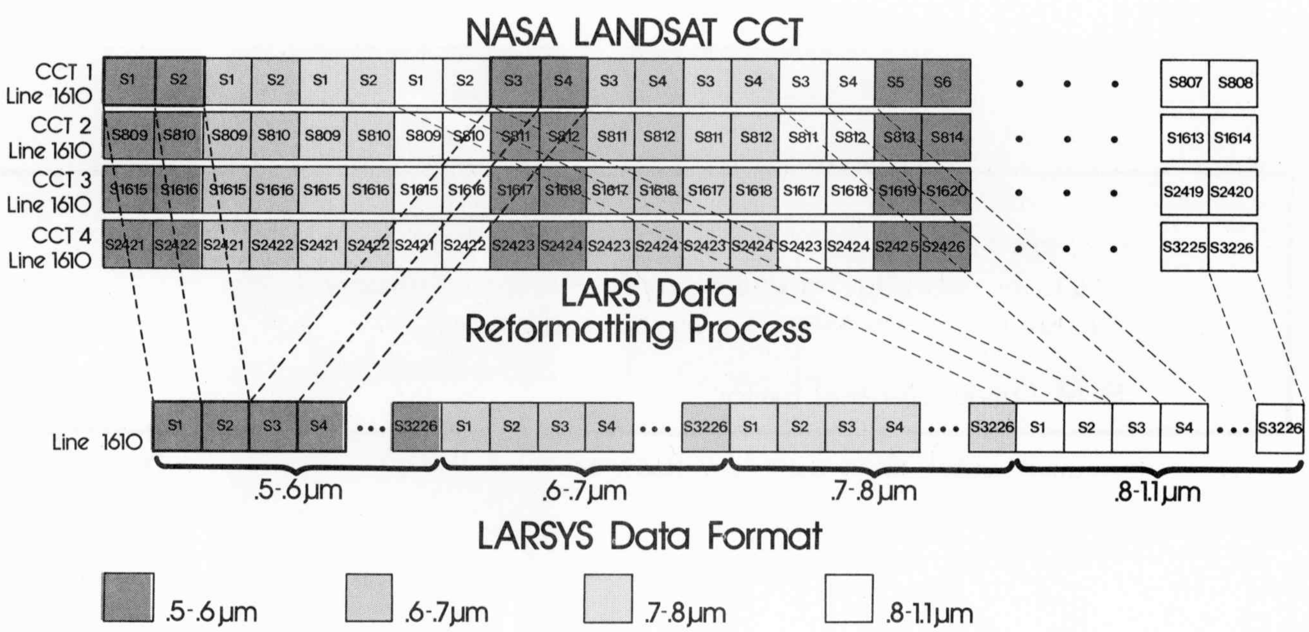


Figure 2

FURTHER READING

LARSYS Users Manual, T. L. Phillips
June 1, 1973

LARSYS Systems Manual, S. K. Hunt
June 1, 1973

LANDSAT Data Users Handbook
NASA Publication, Doc. No. 76SDS4258, Sept., 1976

Earth Resources Data Format Control Book
NASA Publication, TR-543, May, 1973

Prepared by
The Laboratory for Applications of Remote Sensing
Purdue University, West Lafayette, Indiana 47907

S. M. Davis, General Editor

Prepared under NASA Contract NAS9-14970

LARS-Purdue

THE MULTIBAND CONCEPT

The Multiband Concept

The discrimination of ground cover types in multispectral remote sensing data depends largely on the fact that different cover types reflect and emit electromagnetic energy in distinctive ways. Our eyes detect some of these energy differences as different colors.

Suppose you photographed two objects which are identical except for color, using black-and-white film. If one were highly reflective and the other slightly reflective over the range of sensitivity of the film, it would be a simple matter to differentiate one object from the other in the photography by noting the difference in shades. However, if you photographed a dark green object and a dark blue object (both slightly reflective using black-and-white film, the two objects would have a very similar gray-tone appearance in the black-and-white photograph and differentiation may not be possible.

Multiband photography allows a photointerpreter to examine the spectral information from several narrow wavelength bands rather than looking at one broad band. These narrow bands are obtained by using different combinations of photographic films and filters. With conventional black-and-white film the photointerpreter can look at the intensity of the image (varying shades of gray) in different visible wavelength bands. Infrared film allows the photointerpreter to observe wavelengths to which the eye is not sensitive. The sensitivity characteristics of two different types of black-and-white films are shown in Figure 1. Optical filters used in multiband photography are of the three basic types shown in Figure 2. High-pass filters transmit light in the longer wavelengths; low-pass filters transmit in the short wavelengths; and band pass filters transmit a limited range of wavelengths. By combining different films and optical filters as shown in Figure 3 a band pass characteristic can be achieved. A camera system equipped with this film-filter combination will be sensitve to only a narrow band of the spectrum.

With different film and filter combinations, similarly shaped objects with different color or spectral characteristics may be differentiated using two black-and-white photographs, when they could not be differentiated in a single photo. For example, in Figure 4, objects A and B cannot be differentiated on the basis of Image One. However, in Image Two made from film sensitive to a different portion of the spectrum, objects A and B can be differentiated but not objects B and C. As shown in Figure 4, by using both images, each having two gray scale levels (high and low), all four objects can be differentiated. As additional gray levels are used and as different films and filters are combined to be sensitve to different wavelength bands, the number of objects which can be differentiated increases.

The concept of using data from a number of wavelength bands to distinguish different ground cover types has led to the development of multispectral scanner instruments capable of measuring reflected and emitted energy in several bands over a wide spectral range and the use of pattern recognition techniques to analyze the resulting data.

Prepared by James D. Russell

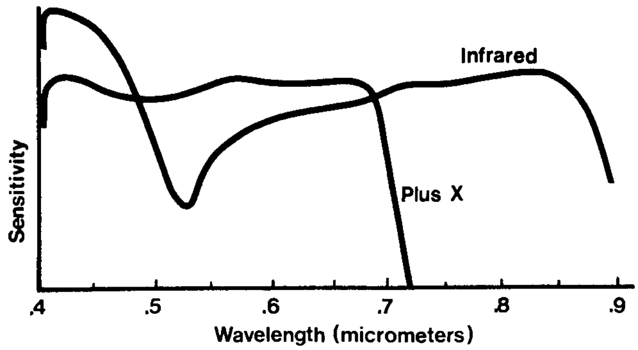


Figure 1. Sensitivity curves of typical black-and-white films.

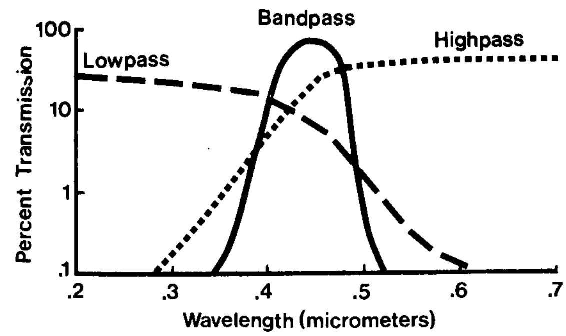


Figure 2. Transmission characteristics of three types of optical filters.

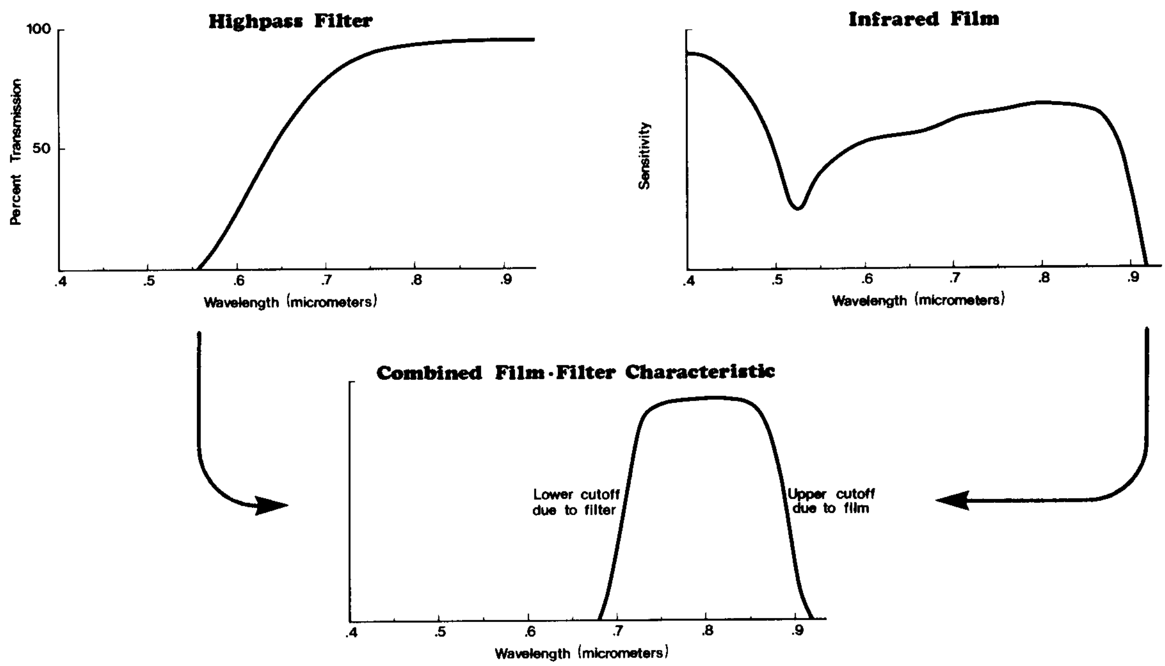


Figure 3. Black-and-white infrared films can be used in conjunction with a highpass optical filter to produce an image resulting from energy reflected in the .7 to .9 µm portion of the spectrum.

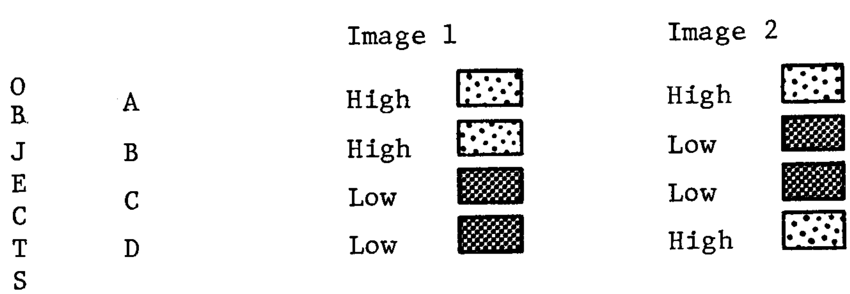


Figure 4. Spectral responses (high and low) of four objects in two different wavelength bands.

FURTHER READING

Manual of Color Aerial Photography
American Society of Photogrammetry
Falls Church, Virginia, 1968

Manual of Remote Sensing
American Society of Photogrammetry
Falls Church, Virginia, 1975

Also see related titles in this series:

FOCUS: The Multispectral Scanner

FOCUS: How the Earth Reflects

FOCUS: Pattern Recognition

Prepared by
The Laboratory for Applications of Remote Sensing
Purdue University, West Lafayette, Indiana 47907

S. M. Davis, General Editor

Prepared under NASA Contract NAS 9-14970

77-16

LARS - Purdue

FOCUS

SNOWCOVER MAPPING

Snowcover Mapping

In many parts of the world, particularly the mountainous regions, snow is the major source of water for home and industrial use, for power production, for irrigation of agricultural lands, and for recreation. Efficient management of the reservoirs storing the water is heavily dependent on accurate and timely forecasts of the rate of water run-off from the melting snow pack. In the past these forecasts have been made through ground-based measurements of snow depth and water content at many individual locations or through low-altitude aerial observations of the areal extent of the snow. Now, satellites capable of obtaining data rapidly and repeatedly in a wide range of wavelength bands and over large geographic areas offer hydrologists a new potential for mapping and monitoring the snow cover.

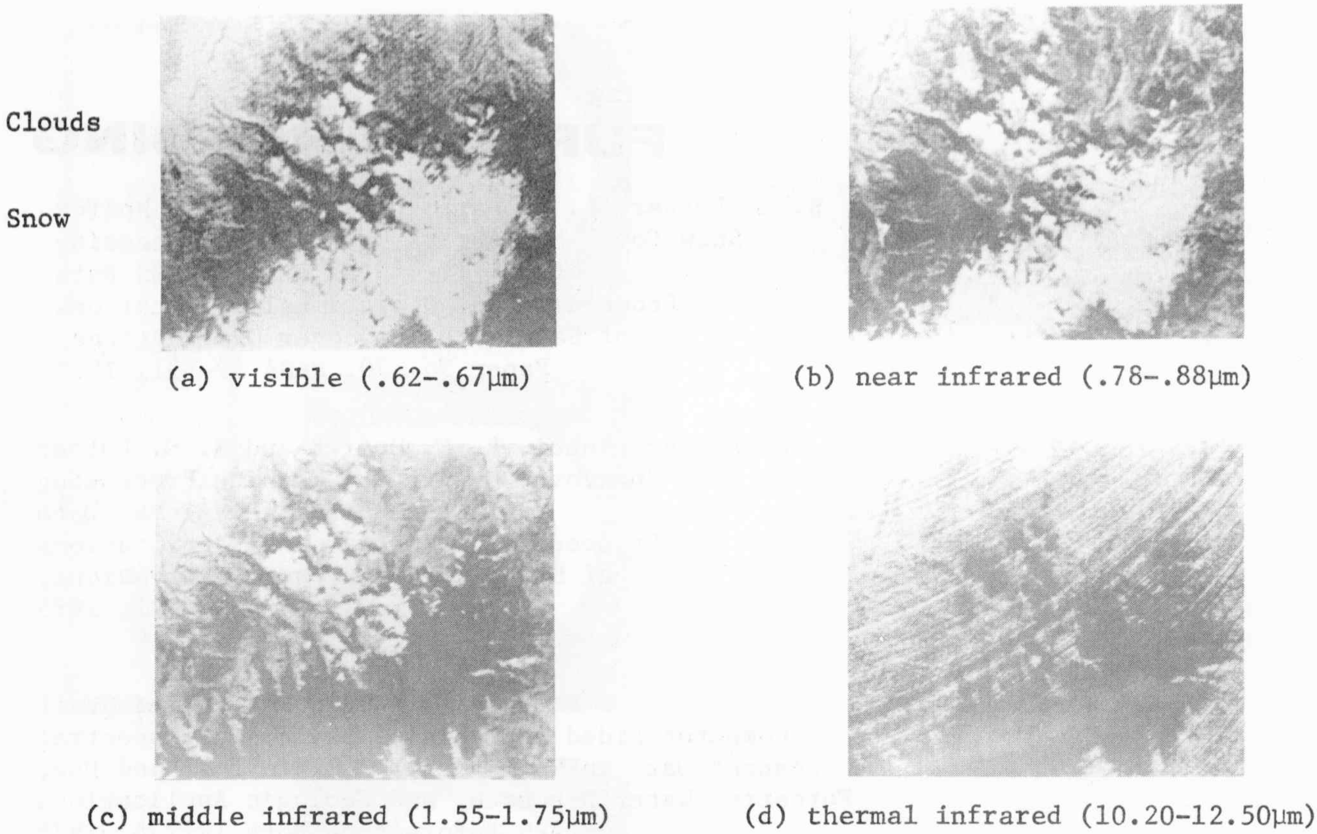
Early work in snowcover mapping from satellite data was thwarted by the spectral similarity between snow and clouds at many wavelengths. It was impossible to differentiate clouds from snow in the visible and near infrared data available from LANDSAT-1. With Skylab multispectral scanner data, it was possible for the first time in 1973 to obtain reflectance measurements from satellite altitudes in the middle infrared wavelengths.

Figure 1 shows the relative response of snow and clouds in the four major regions of the spectrum (visible, near, middle and thermal infrared) and demonstrates the significance of the middle infrared. In both the visible band image (Figure 1a) and the near-infrared image (1b), snow and clouds appear similarly bright; in the thermal infrared image (1d) they both show a low response. Only in the middle infrared image (1c) does the spectral response of clouds differ considerably from that of snow. Clouds have a high reflectance in the middle infrared (creating a light tone on the image) while the reflectance of snow is relatively low (creating a dark tone).

With the wide-area coverage available from satellite altitudes and recent advances in computer-aided analysis techniques, the potential now exists for rapid snowcover mapping of entire regions as well as individual watersheds. Figure 2a shows a portion of the San Juan Mountains for southwestern Colorado (USA) as imaged by Skylab sensors, and gives an intuitive sense of the extent of the snow. Through numerical analysis of such multispectral scanner data, it is possible to calculate the extent of the snow pack in hectares or acres and to identify various spectral classes of snow. The five spectral classes of snow cover shown in Figure 2b represent different conditions of the snow; for example, where the snow pack is melting and will sooner be available for use as water and where it is still frozen. When this type of snowcover information is used in conjunction with elevation information, still more accurate predictions can be obtained; known water equivalency of snow at different elevations can be used in conjunction with the area estimate and condition assessment.

The ability to determine the extent of snow cover, to delineate differences in the condition of the snow and to summarize this in terms of acreage for various elevation zones should prove valuable in predicting water run-off rates from mountain snow packs.

Prepared by Shirley M. Davis



(a) visible (.62-.67μm)   (b) near infrared (.78-.88μm)

(c) middle infrared (1.55-1.75μm)   (d) thermal infrared (10.20-12.50μm)

Figure 1. Skylab multispectral scanner data showing the response of snow and clouds in four different spectral regions. (Hoffer, 1975)

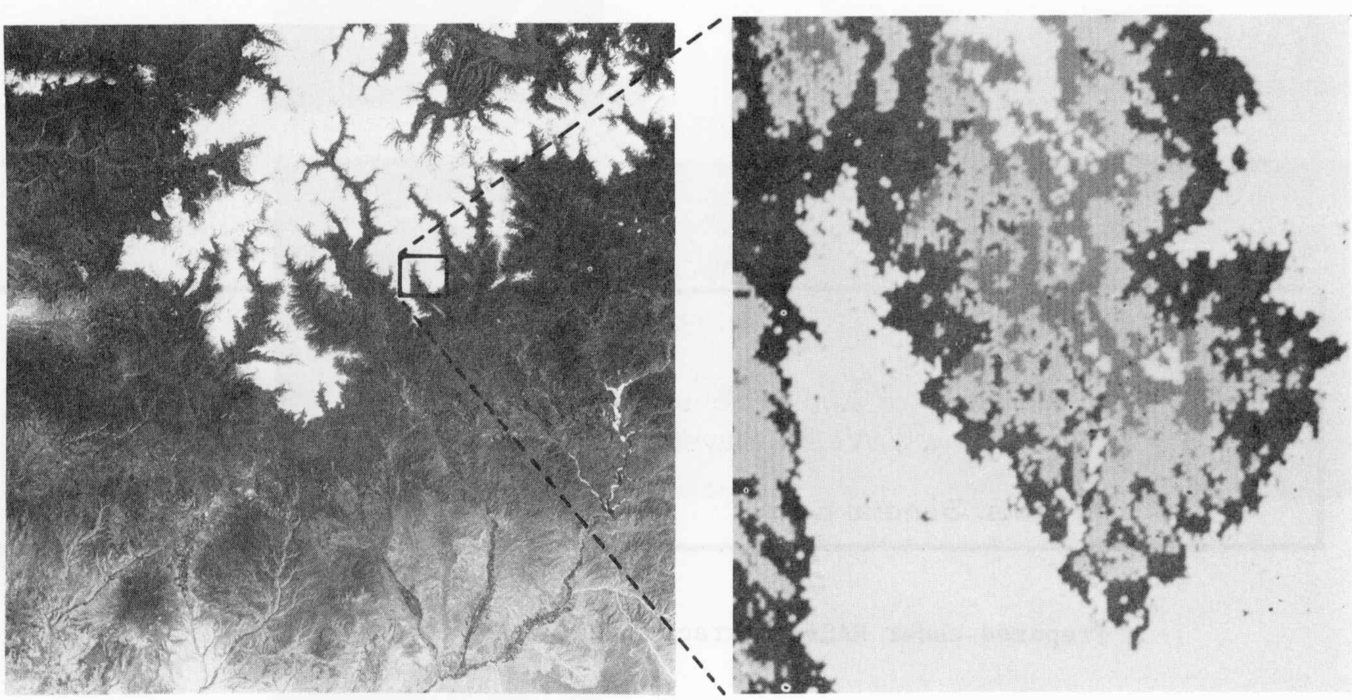


Figure 2. Skylab imagery (left) and detail from computer classification map of a portion of the area showing five different spectral classes of snow (right).

FURTHER READING

S. G. Luther, L. A. Bartolucci, and R. M. Hoffer
Snow Cover Monitoring by Machine Processing of Multitemporal LANDSAT MSS Data
Proceedings of Operational Applications of Satellite Snowcover Observations,
Paper No. 20, NASA SP-391, 1975

L. A. Bartolucci, R. M. Hoffer and S. G. Luther
Snowcover Mapping by Machine Processing of Skylab and LANDSAT MSS Data
Proceedings of Operational Applications of Satellite Snowcover Observations,
Paper No. 21, NASA SP-391, 1975

Roger Hoffer and Staff
Computer-Aided Analysis of Skylab Multispectral Scanner Data in Mountainous Terrain for Land Use, Forestry, Water Resource, and Geologic Applications
LARS Information Note 121275, 1975

Prepared by
The Laboratory for Applications of Remote Sensing
Purdue University, West Lafayette, Indiana 47907

S. M. Davis, General Editor

Prepared under NASA Contract NAS9-14970