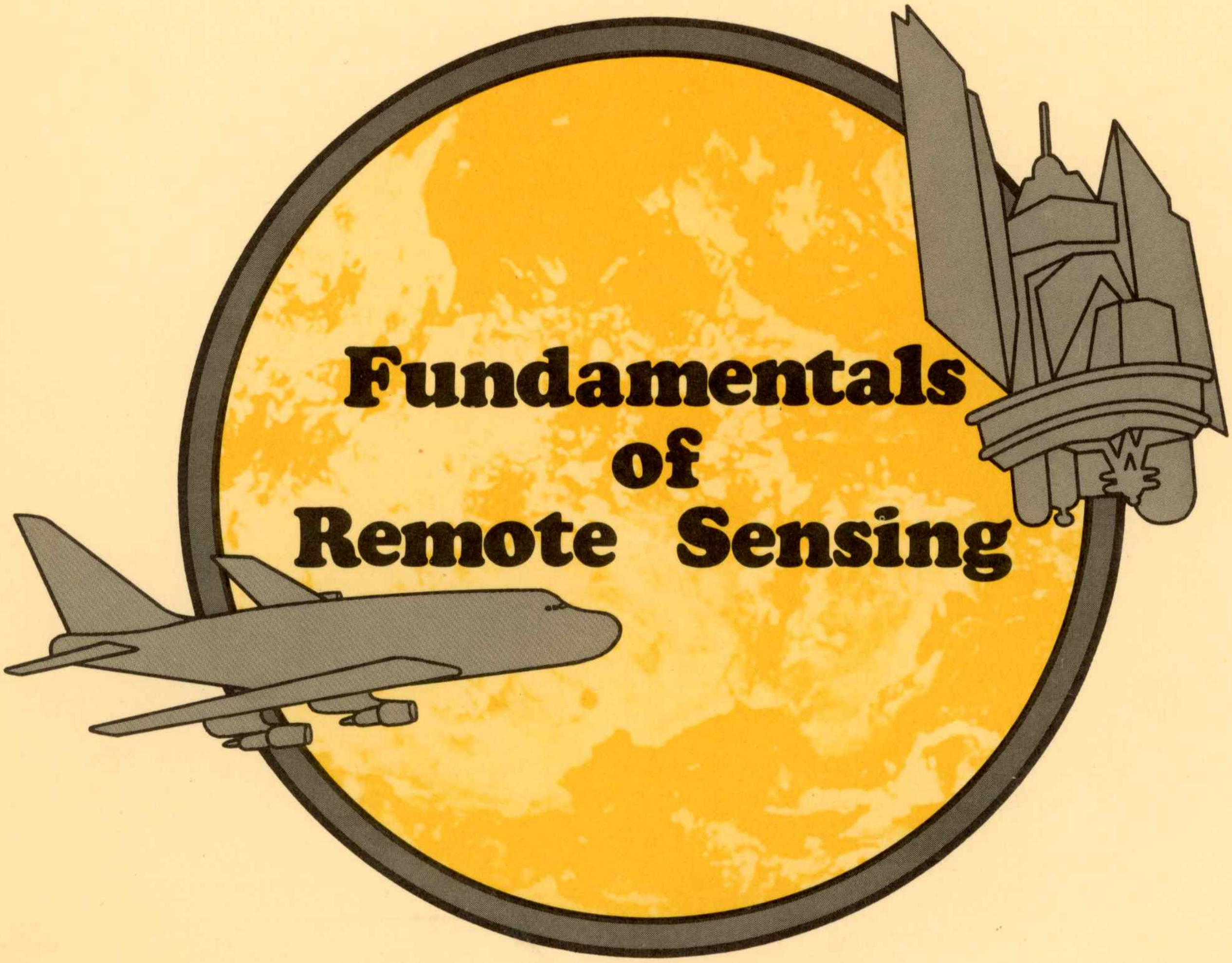
Instructor's Guide

by James D. Russell



Inquiries about the MINICOURSE SERIES may be directed to:

CONTINUING EDUCATION ADMINISTRATION
116 Stewart Center
Purdue University
West Lafayette, Indiana 47907 (USA)

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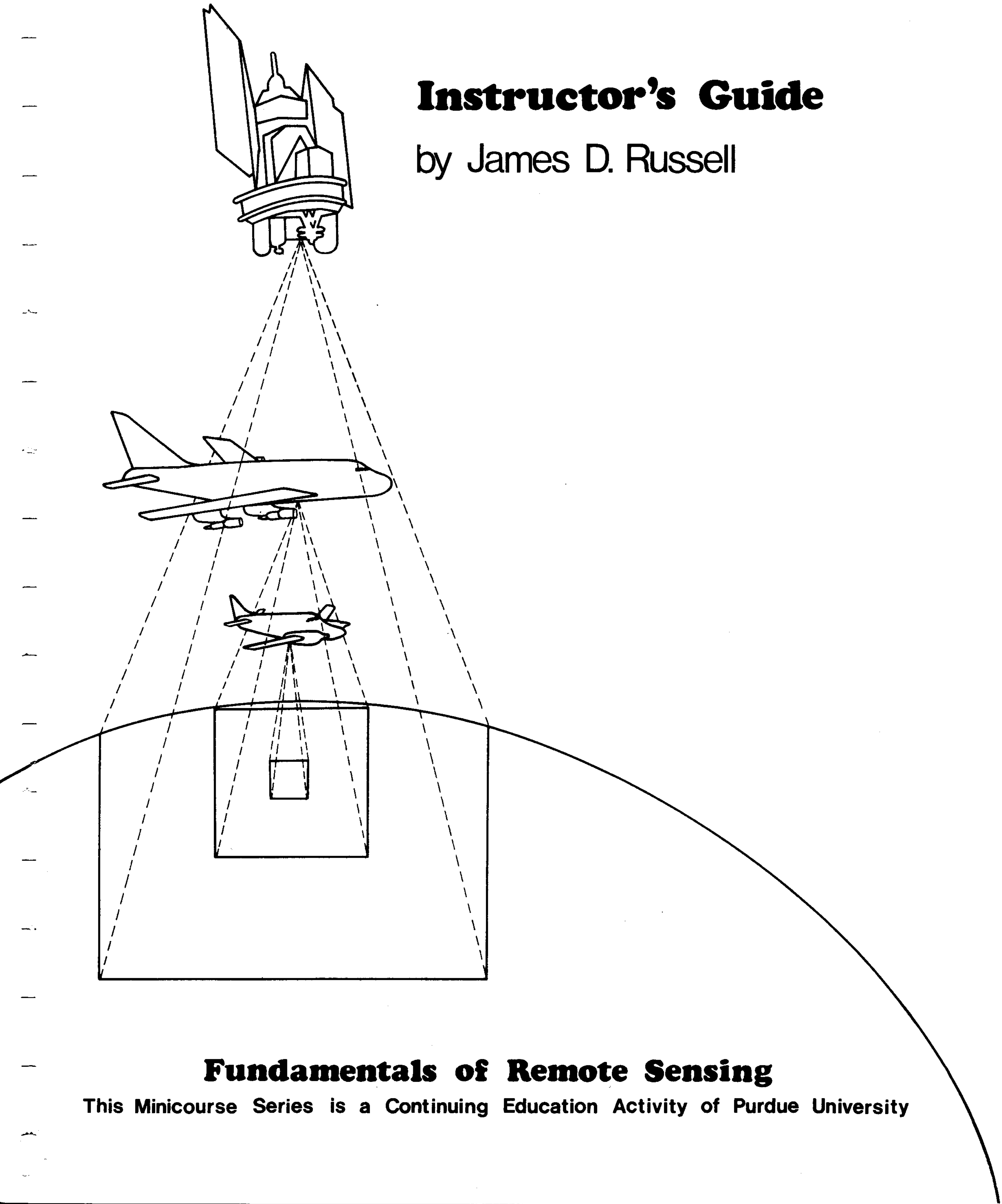
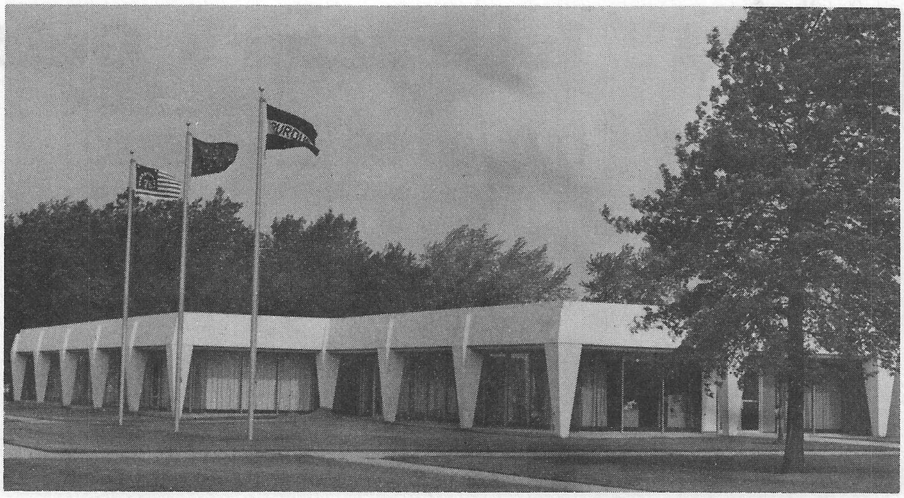


Fundamentals of Remote Sensing

This Minicourse Series is a Continuing Education Activity of Purdue University

THE LABORATORY FOR APPLICATIONS OF REMOTE SENSING



The Laboratory for Applications of Remote Sensing (LARS) is a unit of Purdue University whose function is to bring to bear the University's resources on improving techniques for gathering information on the earth's resources. A multidisciplinary staff of researchers from departments within the Schools of Agriculture, Engineering and Science makes up the LARS team.

Purdue/LARS activities include conducting research, developing technology and training people in the areas of numerically oriented remote sensing systems. Such systems are intended to exploit the tremendous data volume now available from high-flying aircraft and earth-orbiting satellite instruments.

The research objectives of the LARS programs include the development of pattern recognition techniques and application of these techniques to important earth resources problems.

The Laboratory is organized into six program areas: Measurements Research, Crop Inventory Systems Research, Data Processing and Analysis Research, Ecosystems Research, Earth Sciences Research and Technology Transfer.

The Technology Transfer program area is responsible for developing and utilizing educational and training materials to aid in the transfer of remote sensing technology from the research arena to the applications arena. Responsibilities of the group include developing specialized educational packages, such as the LARSYS Educational Package and this Minicourse Series, organizing and running intensive short courses and the Visiting Scientist Program.

I. Introduction

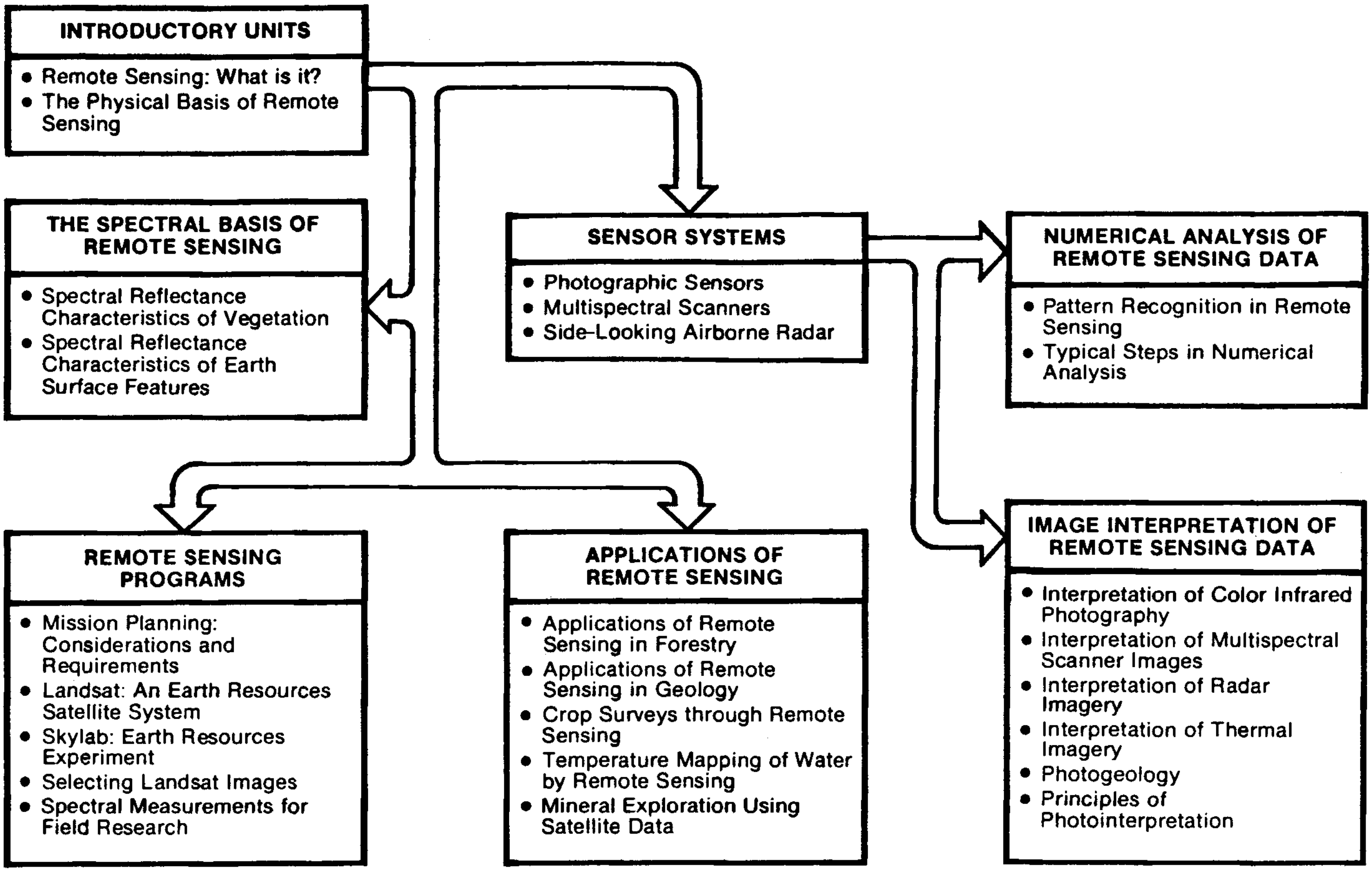
Each of the minicourses in the series includes a set of color slides, an audio tape and a study guide. Each unit is shipped with a set of 25 study guides. Every student must have his own copy of the study guide in order to do the activities and to have a place to take notes. Information about ordering additional study guides is given on page 119.

The content of the series has been modularized so that after completing the two introductory units, the other minicourses may be studied in varying numbers as well as in different logical orders. This flexibility allows the minicourses to be used in a variety of educational situations.

The educational philosophy used in the development of the series is based upon the clear statement of objectives for each minicourse, student activities to reinforce concepts when they are presented, self-evaluation check tests and a study guide containing important diagrams, figures and student notes for easy review. The development of the materials was carried out by a team of subject experts and educational specialists at the Laboratory for Applications of Remote Sensing at Purdue University.

The minicourses are self-contained instructional packages dealing with basic concepts. The package has "instant replay" capability, so the student can go back and listen to a difficult or unclear portion of the minicourse again. The student himself controls the rate and intensity of his study. Since the minicourses are portable, the learner can use them in a classroom, in a learning center or at home (wherever there is a cassette tape player and slide projector).

Each minicourse is enclosed in a box large enough to hold a carousel slide tray and a supply of study guides. The boxes are well-marked for easy access and storage on library shelves.



ORGANIZATION OF THE MINICOURSE SERIES

ORGANIZATION OF THE SERIES

The organization of the minicourse series is shown on the opposite page. It is highly recommended that all students begin with the two introductory units, Remote Sensing: What is it? and The Physical Basis of Remote Sensing, or have met the objectives for these units through other instruction. Following the introductory units, an individual may proceed to any of the minicourses in the following clusters:

The Spectral Basis of Remote Sensing

Sensor Systems

Applications of Remote Sensing

In the cluster on The Spectral Basis of Remote Sensing, Spectral Reflectance Characteristics of Vegetation should precede Spectral Reflectance Characteristics of Earth Surface Features. Both are prerequisites for Spectral Measurements for Field Research.

The Numerical Analysis of Remote Sensing Data cluster has Multispectral Scanners as a prerequisite, and it recommended that the student complete Pattern Recognition in Remote Sensing before doing Typical Steps in Numerical Analysis.

Interpretation of Color Infrared Photography and Principles of Photointerpretation all have Photographic Sensors as a prerequisite minicourse. Interpretation of Multispectral Scanner Images and Interpretation of Thermal Imagery have the Multispectral Scanners minicourse as a prerequisite, where Side-Looking Airborne Radar is a prerequisite to Interpretation of Radar Imagery.

In addition, Temperature Mapping of Water by Remote Sensing should be preceded by Multispectral Scanners.

POSSIBLE MINICOURSE SEQUENCES

Even though it is possible for many of the minicourses to stand alone, they are interrelated. The full understanding of most relies heavily on the satsifactory completion of others in the series.

An individual who is primarily interested in the applications of remote sensing to geology could study the two introductory units plus Applications of Remote Sensing in Geology and Mineral Exploration Using Satellite Data. However, the student may study others in the series (such as Spectral Reflectance Characteristics of Earth Surface Features and Photographic Sensors) to get a fuller appreciation for how the geologist uses remote sensing. If the student is interested in applications of photography for geologic understanding, the following minicourses could be included in the student's plan of study: Interpretation of Color Infrared Photography, Photogeology and/or Principles of Photo-interpretation. Similar sequences can be developed for those interested in forestry, crops or hydrology.

Persons interested in multispectral scanner techniques could do the first two units, study Multispectral Scanners and then move to eitherr the Interpretation of Multispectral Scanner Images, which is image-oriented, or Pattern Recognition in Remote Sensing and Typical Steps in Numerical Analysis which take a numerical analysis viewpoint. Many students may want to complete all six minicourses in this sequence.

The possible combinations of minicourses are many and the appropriate ones should be determined by the instructor based on the needs of the student or class.

POTENTIAL AUDIENCES

The series has been designed with a broad range of users in mind. The minicourses are aimed at the introductory or fundamental principles level. Persons with some background in elementary life science, physical science and mathematics can understand and work with the basic concepts and ideas underlying remote sensing technology and its applications. The minicourses are appropriate for college courses, continuing education activities (workshops and short courses) and in-service training with commerical and governmental agencies.

During tryout of the materials before publication, the minicourses were used with undergraduate and graduate students as well as for in-service training for professionals. For example, the minicourses were used as the basic content of a sophomore course in forestry. In a graduate-level forestry course, they were prerequisites for more detailed lectures and laboratory exercises. The minicourses were also field-tested in an interdisciplinary course on the engineering aspects of remote sensing. Here, selected minicourses were assigned to students on an individual basis to strengthen student backgrounds. For example, minicourses on the spectral basis of remote sensing were assigned to engineering students whose backgrounds are typically weak in this area. Students from the life sciences were asked to review the minicourse on multispectral scanners. During the tryout period, the minicourses were used in university departments of civil engineering, electrical engineering, aeronautical engineering, forestry and geosciences in addition to continuing education activities and staff training.

The series has been used successfully in many non-traditional learning situations. The minicourses lend themselves very well to the format of short courses and workshops. The minicourse series by itself or in conjunction with other educational materials makes it possible to provide a variety of content and learning experiences for small groups of students when a series of lectures might not be possible or economically feasible. In addition, the wide variety of topics makes it possible to individually tailor the workshop or short course to meet the professional objectives of each participant.

It is anticipated that the minicourse series will prove to be useful in a variety of ways to educational, commerical and governmental organizations. They can be used for in-service training programs with a single individual, small group or large class. The minicourses can also be used at junior and community colleges. Some of the minicourses could be implemented successfully with upper-level high school students in biology, physics and earth science courses.

INSTRUCTOR PREPARATION

Before using any of the minicourses it is strongly recommended that you go through the minicourse in detail and fill in the answers to each of the student activities and self-test items. The answers to all these items are provided on the slides or in the study guide.

To facilitate your preparation, key information for each minicourse is contained in Selction II of this manual (page 11). The key information includes the Summary and Objectives from the study guides, prerequsites for each minicourse, a list of materials needed to complete the minicourses and black-and-white prints of all the slides. For additional reference, a list of books and journals related to remote sensing appears on page 115.

To facilitate quick review at a later time, you might want to note the important concepts and principles for your course under "Additional Instructor's Notes" in Section II. The key points for each minicourse will vary with the course or subject discipline and the audience or students with which they are used.

USE OF EDUCATIONAL OBJECTIVES

Each minicourse includes a set of educational objectives. For the instructor using the minicourses, the objectives give insight into the content and appropriateness of each for his students or trainees. For the student or trainee, objectives describe exactly what he is expected to learn, and they provide him with goals to be reached. Hence, the student's learning activities become goal-oriented.

You, the instructor, may want to develop different objectives for some or all the minicourses. It is suggested that you follow the format of the existing objectives. You should describe exactly what the student is to be able to do after having completed the minicourse. Of course, if you modify the objectives for any of the minicourses, your revised objectives should be given to the students.

EVALUATION OF STUDENT PERFORMANCE

Self-test items are included at the end of each minicourse. They are designed to test each student's mastery of the objectives. If he has difficulty with these self-test items, you should recommend that he go back to those portions of the minicourse which he does not understand.

You will undoubtedly want to evaluate your students in a more formal testing situation. You can use modifications of the self-test items or write new evaluation questions. It is important to remember that the test items should be designed to test the student's mastery of what is stated in the objectives.

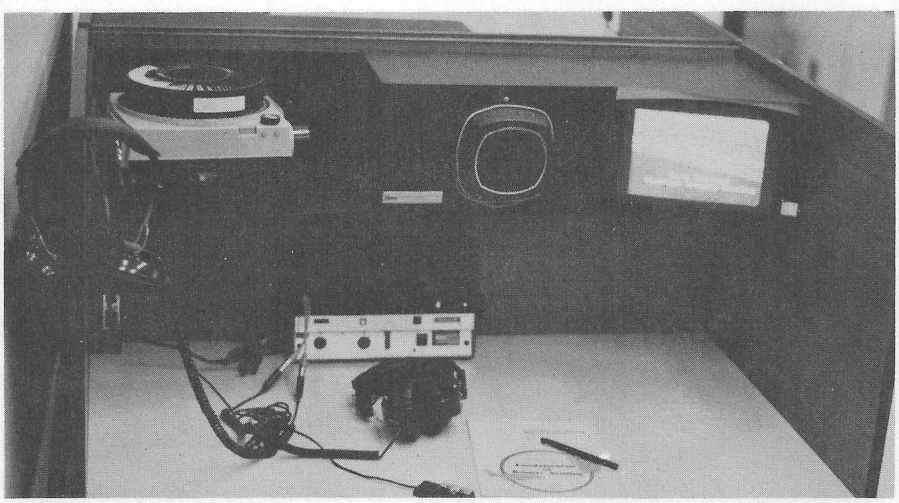
The objectives are also useful in preparing quizzes to allow the students to "test-out" of a particular minicourse. If the student looks over the objectives and content of a minicourse and feels he has already met the objectives, you might give him the opportunity to take a quiz and, if he scores at a satisfactory level, give him credit for the minicourse.

FACILITIES AND EQUIPMENT

The only equipment required to use the minicourses is an audio cassette tape player and a slide projector. For individual or small group use, a piece of white paper or cardboard can be used as a screen for the slides. If several students are going to be using the minicourses in the same area at the same time, headphones will allow each student to concentrate and not be distracted by the other materials being used.

Often self-instructional materials are used in learning carrels. However, carrels are not required. The student can work at a desk or table. In order to cut down visual distrations, the student should be facing a wall. Some instructors have erected portable dividers on tables to allow several students to study individually in the same vicinity and not distract each other.

Some of the minicourses require additional materials. All the materials needed for each minicourse are listed in Section II.



Learning carrel set up for Fundamentals of Remote Sensing minicourse.

ORIENTATION

Regardless how the minicourses are used, it is very important to provide both an introduction and follow-up to them. The purpose of the introduction is to orient the students to the reasons for studying the material and indicate how it will fit into their other studies. The instructor should clearly describe what the students should gain from their study of the materials. The objectives should help with the orientation. New terms should be identified with a brief discussion of their meaning. A rationale as to why the materials in the minicourse are important to the students should also be provided. This is best done by the instructor so he can orient it to the students' specific situation.

IMPLEMENTATION

Even though the intent of the minicourses is individualized instruction, they are not restricted to use by individual students. It is possible to use the minicourses with two or three students as a small group. Depending upon the students, small-group use can have advantages and disadvantages. On the positive side, the students may be able to help each other and immediately discuss new concepts or clarify confusing points. However, sometimes a student in a group is reluctant to interrupt the minicourse when he wants to hear a portion of the tape a second time for fear of being considered "stupid" by his peers. There is also the possibility that one student will participate actively and the other will become a passive observer. You will need to weigh the advantages against the disadvantages and decide upon the best arrangement for you students.

On certain occasions, the minicourses have been used with groups. Except under unusual circumstances, group use negates many of the advantages of materials in this format. Usually there are not enough of the objects such as stereoscopes or straws and maps to allow each student to perform these meaningful learning activities. In addition, the lengths of pauses to complete the activities become a problem. How long should a pause be? Regardless of the time, some students will complete the activity early and will be anxious to move on, while others will be frustrated because they need additional time to fully understand the material. The ideal situation is to have each student in control of the rate of presentation to meet his individual pace, and this can only be accomplished when he can turn off the tape for as long as he needs.

FOLLOW-UP

Equally important with the orientation is the follow-up after the minicourses. There should be an opportunity for the students to discuss the material and ask for additional explanations, if necessary. The instructor should also use this time to present additional applications of the newly mastered material to the course or subject matter under study. During in-service training the follow-up can be used to point out how the content applies to the trainees' job.

SUMMARY

Remote sensing is a rapidly expanding field of research and technology. Therefore, there is a growing need to provide for the continuing education of scientists, engineers and users of this technology. These minicourses have already demonstrated great promise as a tool to meet this need. The possible applications and various uses of these materials are limited only by the imagination of their users -- YOU!

II. Key Information

The following information is provided for each minicourse:

a) Summary
b) Objectives
c) Prerequisites
d) Components of Minicourse
e) Black-and-white prints of the slides

+ Reproduced in this series through agreement with the International Institute for Aerial Survey and Earth Sciences, Enschede, The Netherlands.

* Minicourses released in 1980 are marked with a star; all others were released in 1976.

REMOTE SENSING: WHAT IS IT?

SUMMARY

The term "remote sensing" as it is used in this minicourse series is defined as the science and art of acquiring information about material objects from measurements made at a distance --- measurements made without coming into physical contact with the materials of interest. These measurements are possible because instruments can be designed to measure spectral, spatial and/or temporal variations in field strength. Several remote sensing data collection systems are illustrated and discussed briefly; basic terminology is presented. To complete the remote sensing process the data must be analyzed; such analysis may be carried out using image interpretation techniques, numerical analysis techniques or a combination of the two.

OBJECTIVES

When you have completed this minicourse you should be able to:

1. Define "remote sensing."
2. Identify the two important aspects of remote sensing that are implied by the definition.
3. List three kinds of variations in field strength that make remote sensing possible.
4. Site an example of a remote sensing data collection system based on:
   a) Electromagnetic field variations
   b) Force field variations
   c) Acoustic field variations
5. Given the description of a remote sensing data collection system, classify it as an active or passive system.

TIME: 1 hour

-- PROJECT THE FIRST SLIDE --

-- START THE TAPE --

PREREQUISITES

None

COMPONENTS OF MINICOURSE

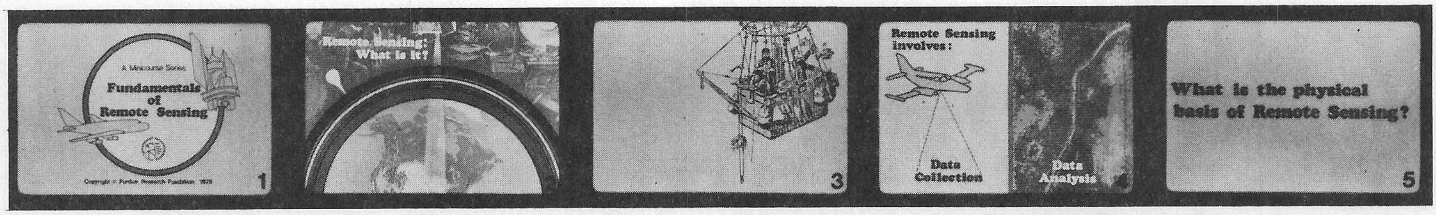
Study Guide for each student

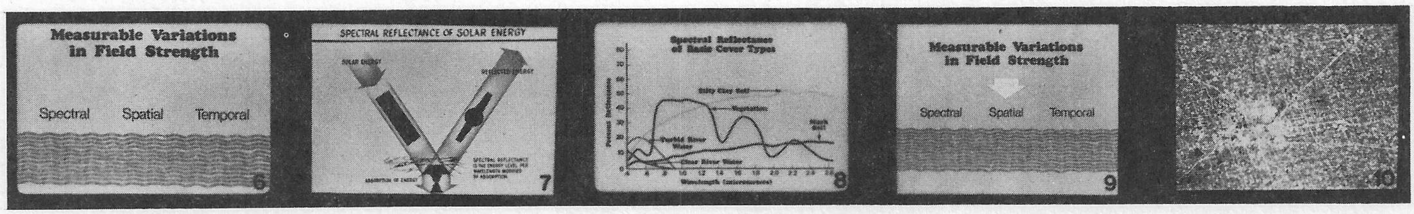
Set of 49 slides

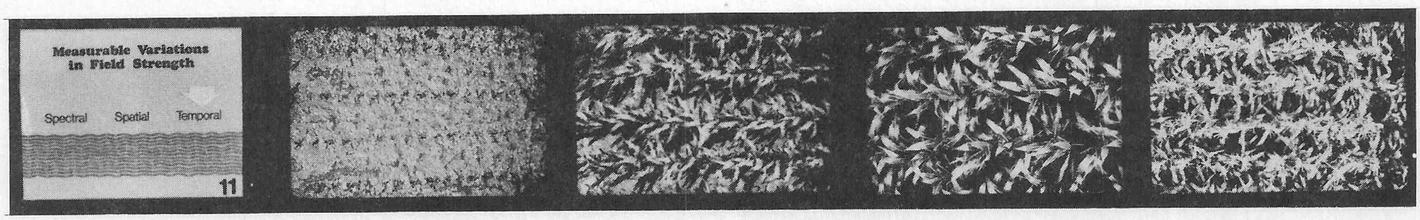
Audio tape

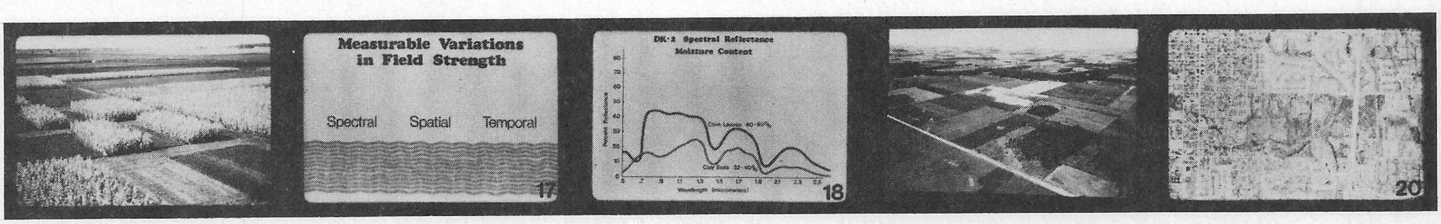
ADDITIONAL INSTRUCTOR'S NOTES

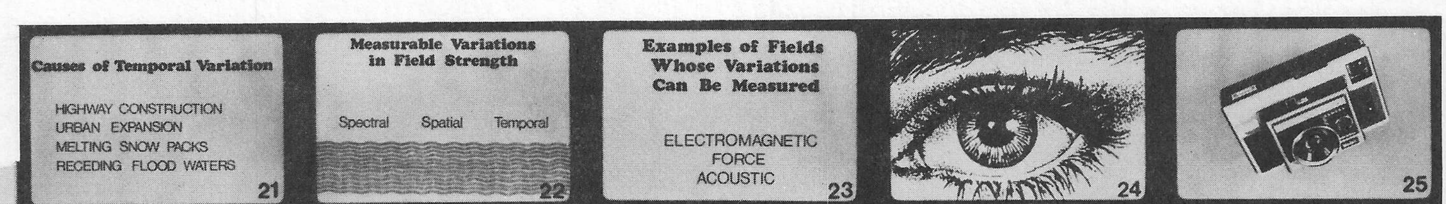
REMOTE SENSING: WHAT IS IT?

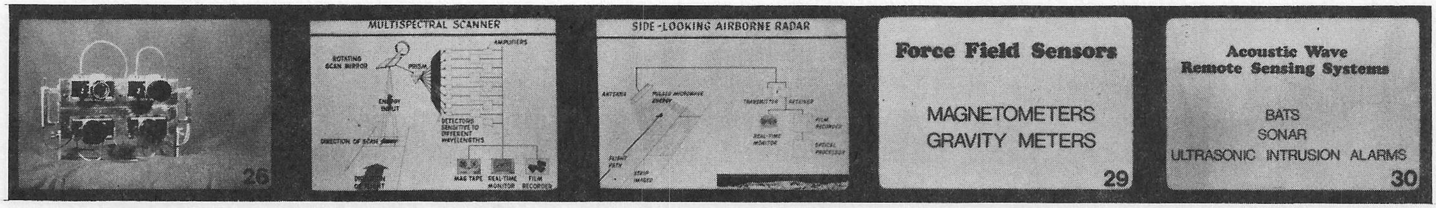


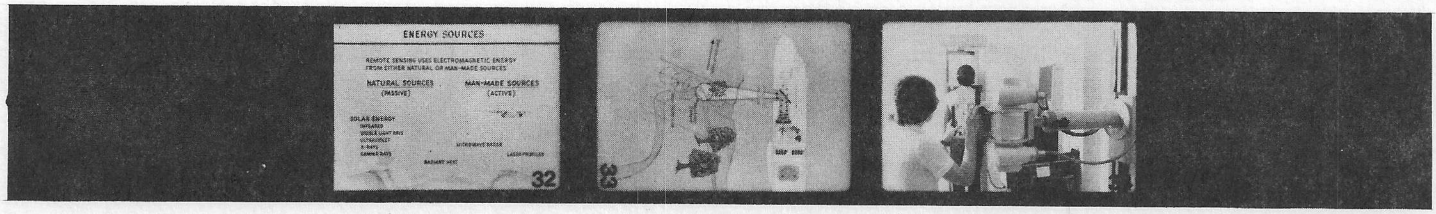


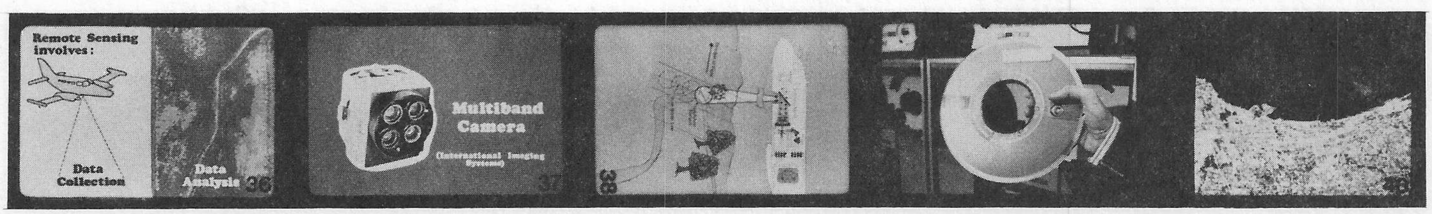




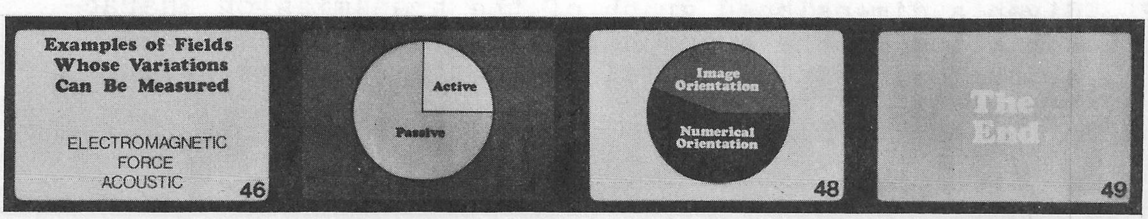



MULTISPECTRAL SCANNER
SIDE-LOOKING AIRBORNE RADAR
Force Field Sensors
MAGNETOMETERS
GRAVITY METERS
29
Acoustic Wave
Remote Sensing Systems
BATS
SONAR
ULTRASONIC INTRUSION ALARMS
30
26


ENERGY SOURCES
NATURAL SOURCES
(PASSIVE)
MAN-MADE SOURCES
(ACTIVE)
32
33


Remote Sensing
involves:
Data
Collection
Data
Analysis
36
Multiband
Camera
37
38


41
43
Remote Sensing
involves:
Data
Collection
Data
Analysis
44
Measurable Variations
in Field Strength
Spectral
Spatial
Temporal
45


Examples of Fields
Whose Variations
Can Be Measured
ELECTROMAGNETIC
FORCE
ACOUSTIC
46
Active
Passive
Image
Orientation
Numerical
Orientation
48
The
End
49

THE PHYSICAL BASIS OF REMOTE SENSING

SUMMARY

The four major components of a remote sensing system - radiation source, target, sensor and transmission path - are used to explain the physical basis of remote sensing. Terms associated with the electromagnetic spectrum are introduced, and the wavelength variations of the solar spectrum, reflectance characteristics of common earth surface cover types and properties of the atmospheric transmission path are presented. The concept of an ideal black body may be used to model both emissive radiation from the earth and solar radiation. These topics are all discussed with reference to a simple pictorial model of a remote sensing system which serves as a point of departure for succeeding minicourses in this series.

OBJECTIVES

When you have completed this minicourse, you should be able to:

1. Name the important components of a remote sensing system.
2. Sketch the important qualitative features of the extraterrestrial solar spectrum. The intensity scale need only indicate relative power; the wavelength scale should be dimensioned in micrometers.
3. Given a wavelength scale which includes the optical portion of the spectrum, identify the wavelength ranges for:

   the optical portion of the spectrum
   the visible band
   the near, middle and far infrared bands
   the ultraviolet band
   the reflective portion of the spectrum
   the emissive portion of the spectrum

4. Identify the spectral ranges within which photographic sensors and multispectral scanners operate.
5. Given the spectrum of a 300°K black body, qualitatively describe how the spectrum would change if the temperature were increased or decreased.
6. Define the term "atmospheric window."
7. Given a dimensioned graph of the transmission characteristics of the atmosphere, identify at least one atmospheric window useful in remote sensing applications.

TIME: 50 minutes

-- PROJECT THE FIRST SLIDE --

-- START THE TAPE --

PREREQUISITES

Before beginning this minicourse, the student should have mastered the objectives for:

Remote Sensing: What is it?

COMPONENTS OF MINICOURSE

Study Guide for each student

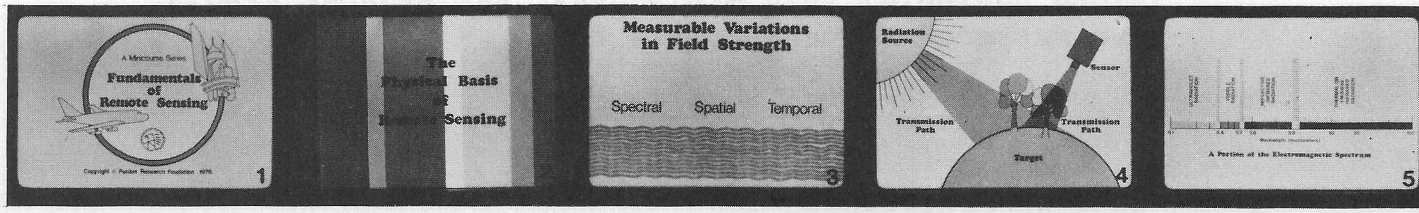
Set of 32 slides. Slides 30, 31 and 32 are actually colored filters to be removed from the slide set and put in an envelope for use by the student in Activity 2.

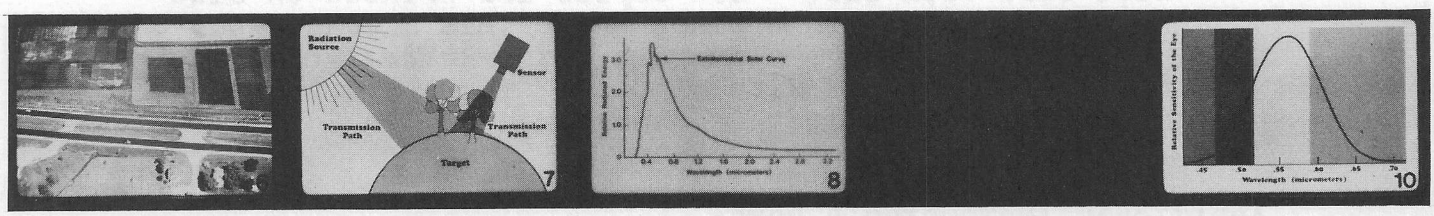
Audio tape

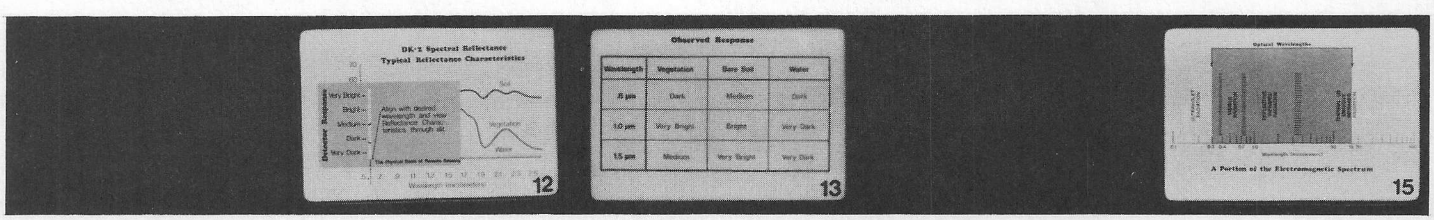
Blue card with slit: Six copies are printed on blue cover stock in Appendix A of this manual. Cut out one and remove slit with razor knife. Put blue card into box with slides. Others are spares if original is lost or damaged.

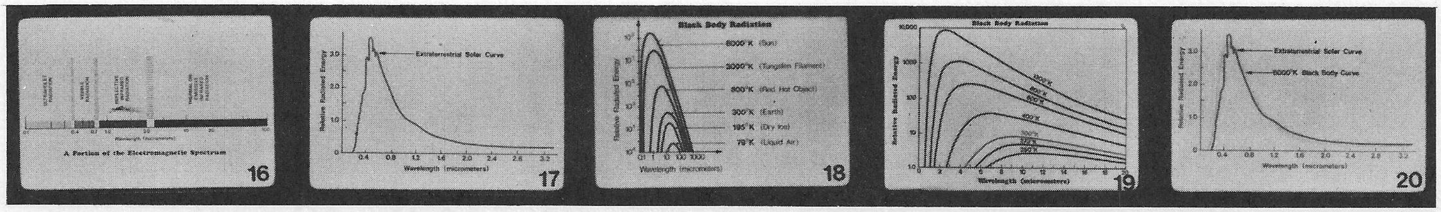
ADDITIONAL INSTRUCTOR'S NOTES

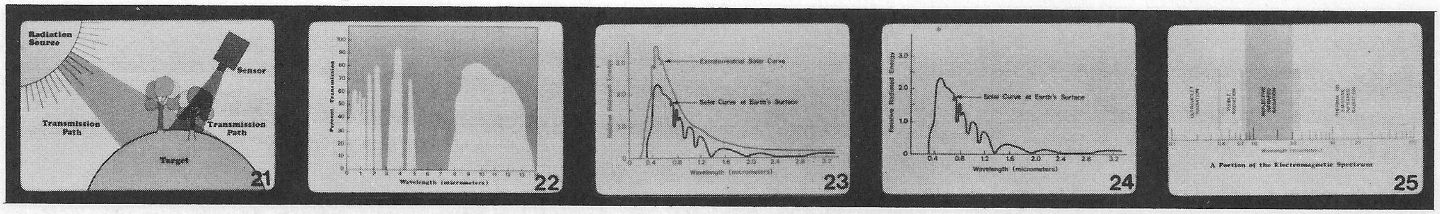
THE PHYSICAL BASIS OF REMOTE SENSING

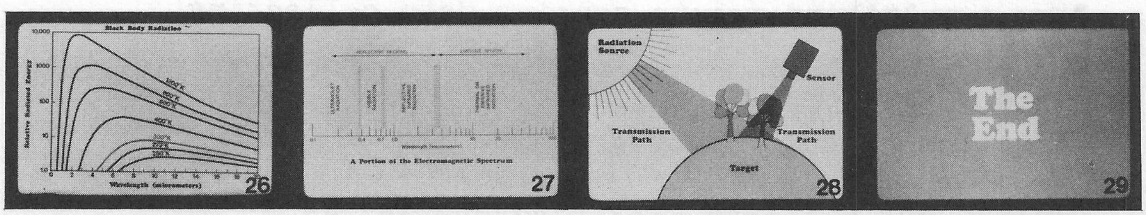







A Portion of the Electromagnetic Spectrum
16
Extraterrestrial Solar Curve
Relative Radiated Energy
Wavelength (micrometers)
17
Black Body Radiation
6000°K (Sun)
3000°K (Tungsten Filament)
800°K (Red Hot Object)
300°K (Earth)
195°K (Dry Ice)
79°K (Liquid Air)
18
Black Body Radiation
Relative Radiated Energy
Wavelength (micrometers)
19
Extraterrestrial Solar Curve
6000°K Black Body Curve
20


Radiation Source
Sensor
Transmission Path
Transmission Path
Target
21
Percent Transmission
Wavelength (micrometers)
22
Extraterrestrial Solar Curve
Solar Curve at Earth's Surface
23
Solar Curve at Earth's Surface
Relative Radiated Energy
Wavelength (micrometers)
24
A Portion of the Electromagnetic Spectrum
25


Black Body Radiation
Relative Radiated Energy
Wavelength (micrometers)
26
A Portion of the Electromagnetic Spectrum
27
Radiation Source
Sensor
Transmission Path
Transmission Path
Target
28
The End
29

PHOTOGRAPHIC SENSORS

SUMMARY

Photographic sensors have been used for remote sensing applications for many years. The capabilities and limitations of this type of data collection system are governed to a large extent by the optical properties of the film and filters used. By properly combining films and filters, photographic methods may be used to produce a set of multiband, or multispectral, images. When combined with knowledge about the reflectance properties of earth surface features, these multiband images yield considerably more information than is available from a single image. The use of color film is one method of combining three spectral bands to form a single image. An understanding of this process is important for proper interpretation of color and color infrared photography.

OBJECTIVES

When you have completed this minicourse, you should be able to:

1. Given the transmission characteristics of an optical filter, identify it as a highpass, lowpass or bandpass filter.

2. Name the two most common types of black-and-white film used in remote sensing systems and identify the spectral bands in which they are sensitive.

3. Name at least two types of color film used in remote sensing and identify the spectral bands in which each emulsion layer is sensitive.

4. Describe how films and filters are combined to form a multiband remote sensing data collecting system.

5. By means of a sketch, describe the physical construction of color photographic film.

6. Explain why a yellow filter should always be used with color infrared film.

TIME: 45 minutes

-- PROJECT THE FIRST SLIDE --

-- START THE TAPE --

PREREQUISITES

Before beginning this minicourse, the student should have mastered the objectives for:

Remote Sensing: What is it?

The Physical Basis of Remote Sensing

COMPONENTS OF MINICOURSE

Study Guide for each student

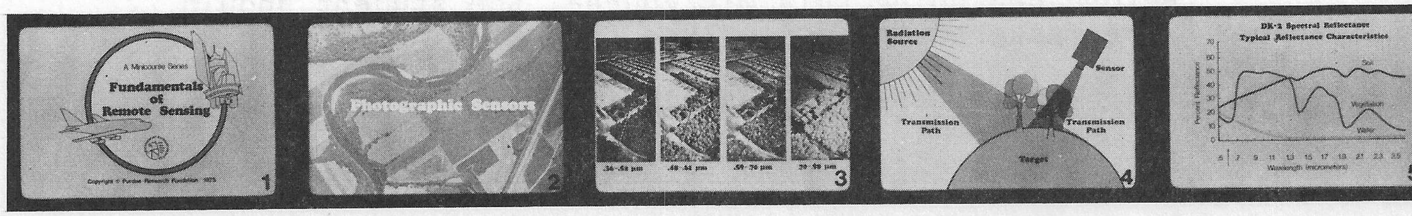
Set of 39 slides

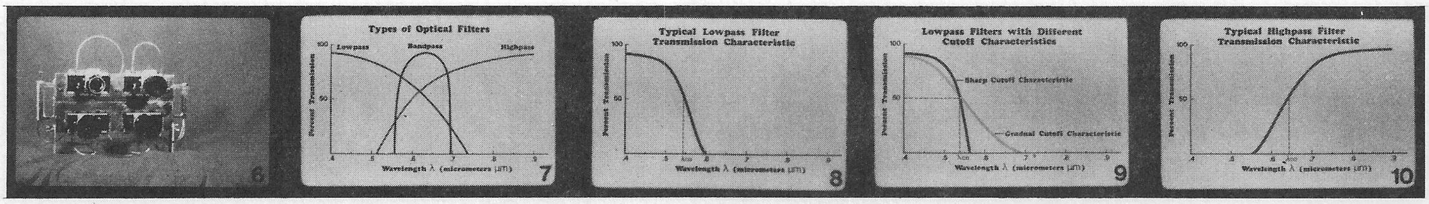
Audio tape

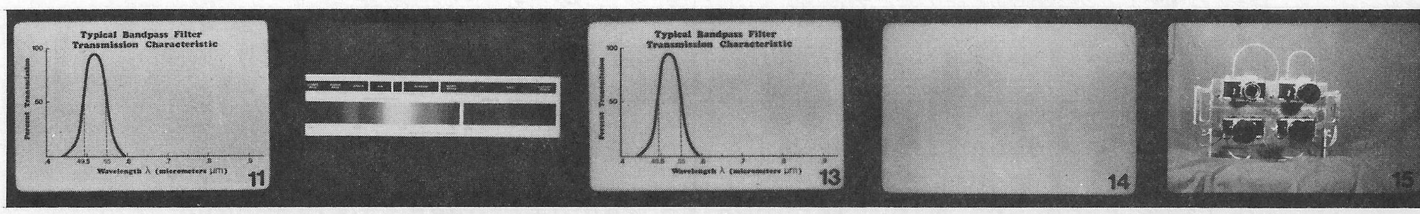
ADDITIONAL INSTRUCTOR'S NOTES

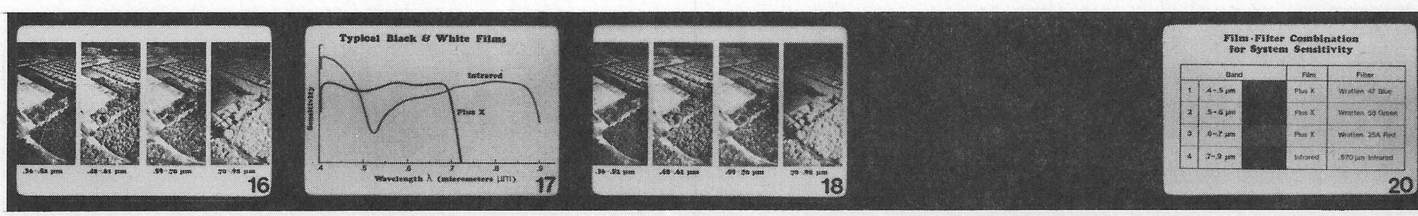
You should be alerted to the fact that perceptive students might catch what appears to be an inconsistency in the upper cutoff wavelength of photographic sensors. An example of multiband photography is illustrated in slides 3, 16, 18 and 24. This slide was adapted with permission from Manual of Color Aerial Photography (American Society of Photogrammetry, 1968). The original source identifies the near infrared band image as extending from .70 to .98μm. There is, of course, some variation in upper cutoff from film type to film type and manufacturer to manufacturer. Elsewhere in the minicourse series .9μm has been used to designate the upper cutoff of color infrared films (see for instance The Physical Basis of Remote Sensing).

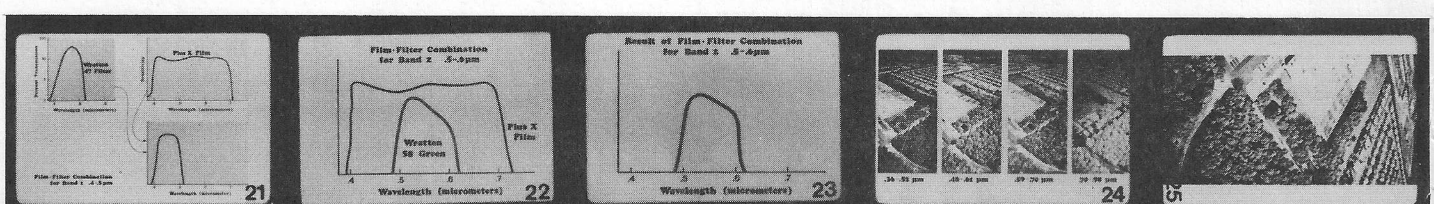
PHOTOGRAPHIC SENSORS

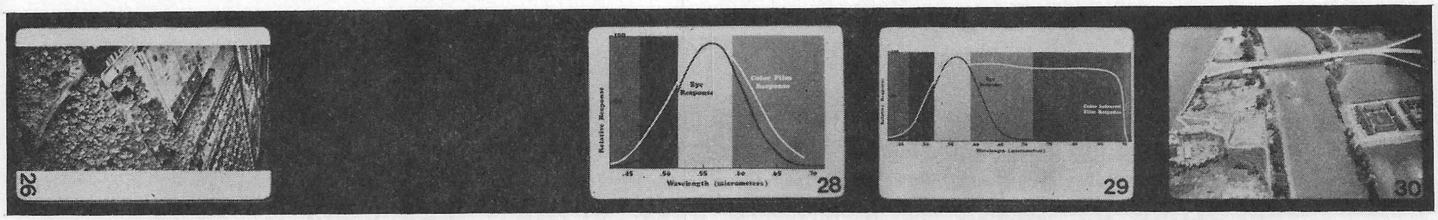


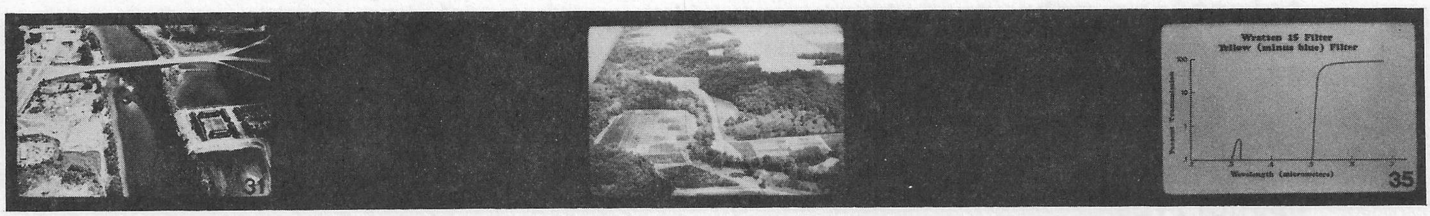


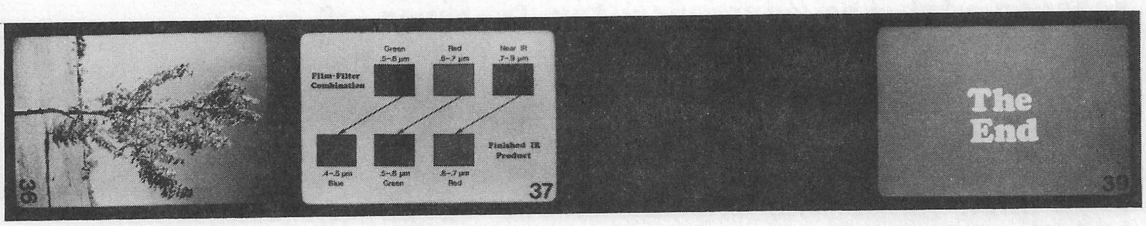







26
Relative Response
Eye Response
Color Film Response
Wavelength (micrometers)
28
29
30


31
Wratten 15 Filter
Yellow (minus blue) Filter
Percent Transmission
Wavelength (micrometers)
35


36
Film-Filter Combination
Green .5–.6 µm
Red .6–.7 µm
Near IR .7–.9 µm
.4–.5 µm Blue
.5–.6 µm Green
.6–.7 µm Red
Finished IR Product
37
The End
39

MULTISPECTRAL SCANNERS

SUMMARY

Multispectral scanners, an important class of remote sensing data gathering instruments, are introduced in this minicourse. The operation of a multispectral scanner is explained by means of a simple simulation. Features of this class of instruments are discussed and in many cases compared to corresponding properties of photographic systems. System parameters are defined and discussed so as to give an understanding of the basis upon which engineers and application scientists make decisions regarding scanner design and mission planning. The parameters of several typical scanners are presented and examples of multispectral scanner imagery are shown.

OBJECTIVES

When you have completed this minicourse, you should be able to:

1. Contrast at least four features of a multispectral scanner with the corresponding features of a multiband photographic system.

2. Describe the operation of a multispectral scanner.

3. Calculate the size of the instantaneous viewing area when given the instantaneous field of view and the altitude of the scanner.

4. Given the data quality equation, describe the effect that changing a system parameter will have upon the quality of scanner data.

TIME: 1 hour

-- PROJECT THE FIRST SLIDE --

-- START THE TAPE --

PREREQUISITES

Before beginning this minicourse, the student should have mastered the objectives for:

Remote Sensing: What is it?

The Physical Basis of Remote Sensing

COMPONENTS OF MINICOURSE

Study Guide for each student

Set of 29 slides

Audio Tape

➡ Two large-diameter (about ¼ inch) drinking straws: one about 3" long and one about 6" long

Card with hole: Four are included in Appendix A on ivory colored cardboard. Cut out one and use a pencil to punch a hole the same size as the straws you are using. Others are spares if original is lost or damaged.

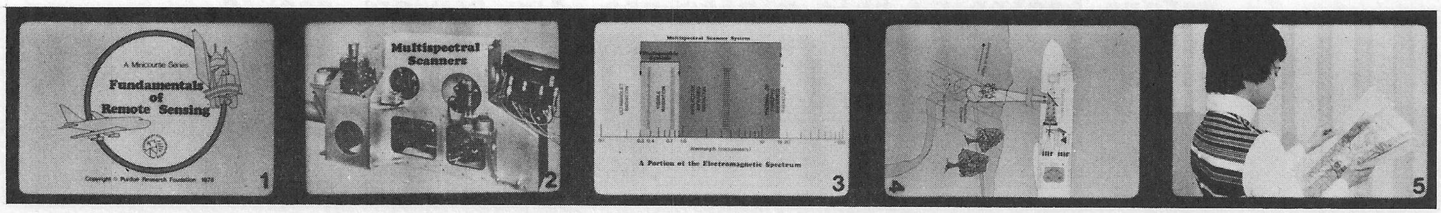
Map of Bloomington, Indiana and Monroe County: One is included with slides. Additional copies can be obtained from:

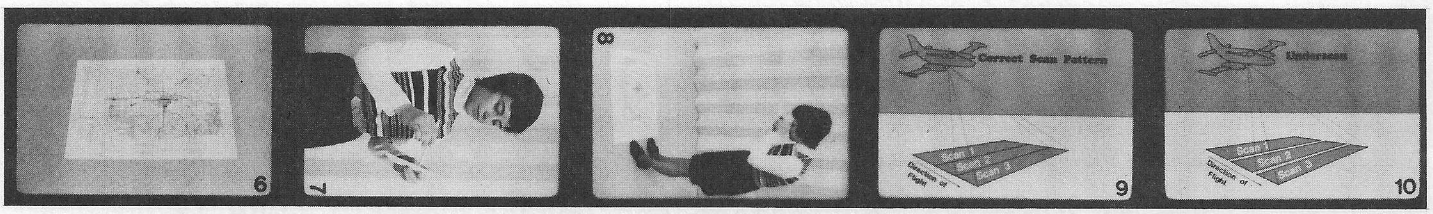
Greater Bloomington Chamber of Commerce
Post Office Box 1302
Bloomington, Indiana 47401

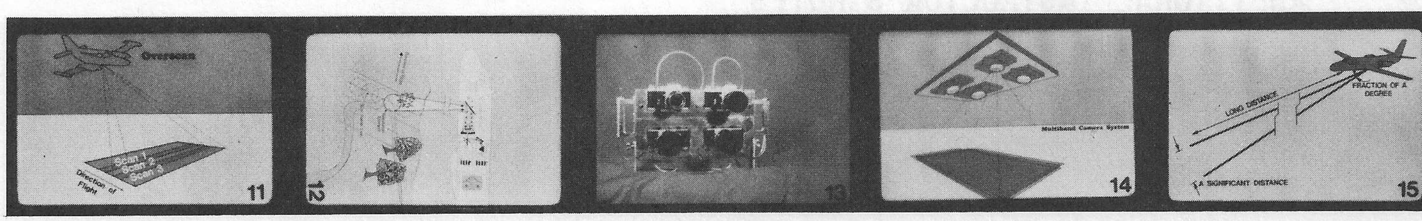
➡ (to be provided by instructor)

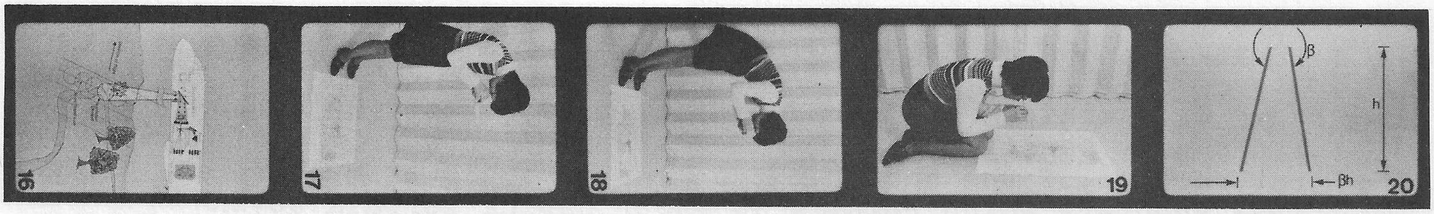
ADDITIONAL INSTRUCTOR'S NOTES

MULTISPECTRAL SCANNERS








16
17
18
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β
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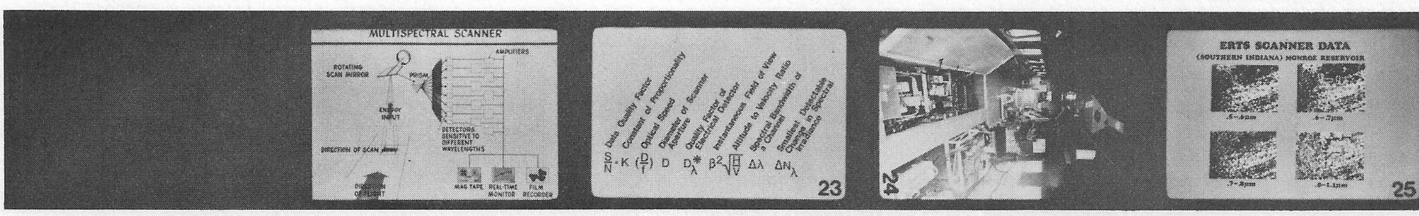
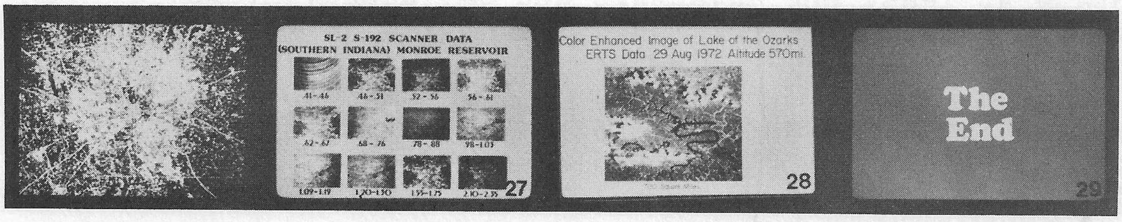

MULTISPECTRAL SCANNER
ROTATING SCAN MIRROR
PRISM
AMPLIFIERS
ENERGY INPUT
DETECTORS SENSITIVE TO DIFFERENT WAVELENGTHS
DIRECTION OF SCAN
MAG TAPE
REAL-TIME MONITOR
FILM RECORDER
Data Quality Factor
Constant of Proportionality
Optical Speed
Diameter of Scanner Aperture
Quality Factor of Electrical Detector
Instantaneous Field of View
Altitude to Velocity Ratio
Spectral Bandwidth of a Channel
Smallest Detectable Change in Spectral Irradiance
23
24
ERTS SCANNER DATA
(SOUTHERN INDIANA) MONROE RESERVOIR
25


SL-2 S-192 SCANNER DATA
(SOUTHERN INDIANA) MONROE RESERVOIR
27
Color Enhanced Image of Lake of the Ozarks
ERTS Data 29 Aug 1972 Altitude 570mi.
28
The End
29

SIDE-LOOKING AIRBORNE RADAR

SUMMARY

This minicourse introduces you to side-looking airborne radar as a sensor system. Radar systems operate in a different portion of the spectrum than photographic or multispectral scanners which results in radar having certain advantages over other sensor systems. The resolution of radar systems is determined by the duration of the radar pulse and the length of the antenna. Improved resolution properties can be achieved by using synthetic aperture antennas. A discussion of the manner in which images are produced from radar signals leads into a brief discussion of typical imagery. Analysis of radar imagery is the subject of another minicourse in this series.

OBJECTIVES

When you have completed this minicourse, you should be able to:

1. List at least three advantages of side-looking airborne radar over other remote sensing systems.

2. Identify the wavelength band in which side-looking airborne radar systems operate.

3. Discuss the implications of radar's "single frequency" operation as compared to the "multiple frequency" operation of multispectral scanner and multiband photography systems.

4. Identify the two factors which enter into the resolution capability of side-looking airborne radar and the system parameters they are proportional to.

5. State at least one advantage and one disadvantage of synthetic aperture radar as compared to real aperture radar.

6. When given a sketch of the system, explain in your own words how a photographic image is produced from radar returns.

7. Describe how polarization effects can be used to extract additional information from radar imagery.

TIME: 1 hour

-- PROJECT THE FIRST SLIDE --

-- START THE TAPE --

PREREQUSITES

Before beginning this minicourse, the student should have mastered the objectives for:

Remote Sensing: What is it?

The Physical Basis of Remote Sensing

COMPONENTS OF MINICOURSE

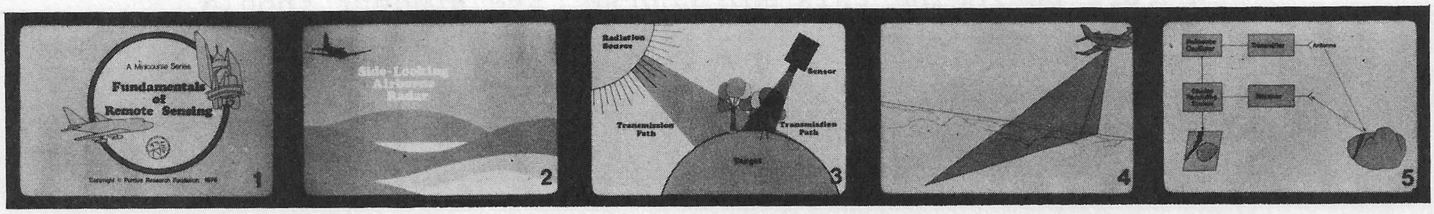
Study Guide for each student

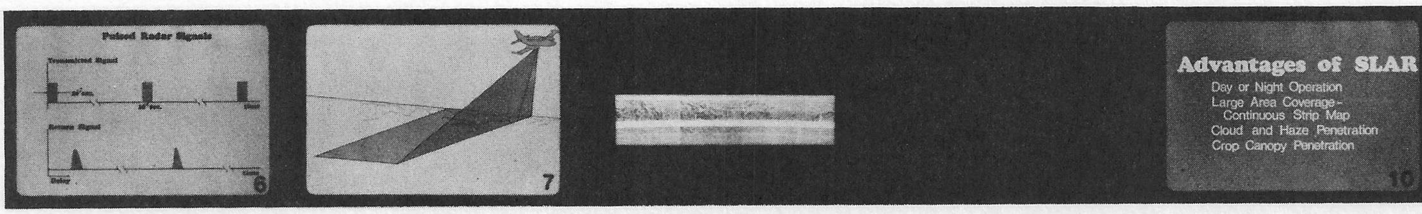
Set of 32 slides

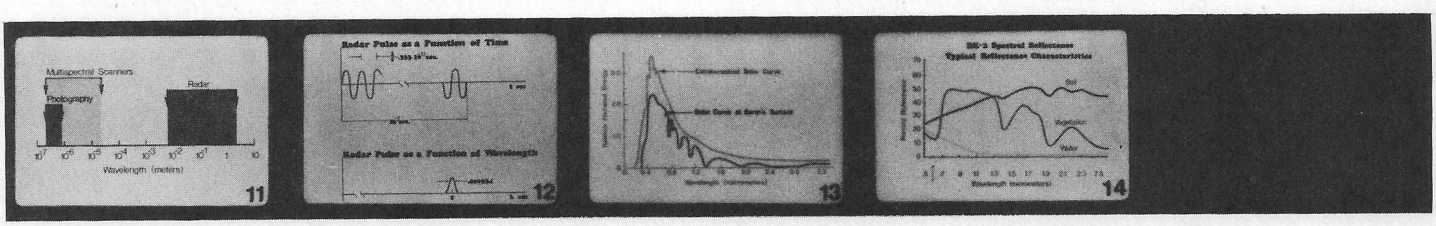
Audio tape

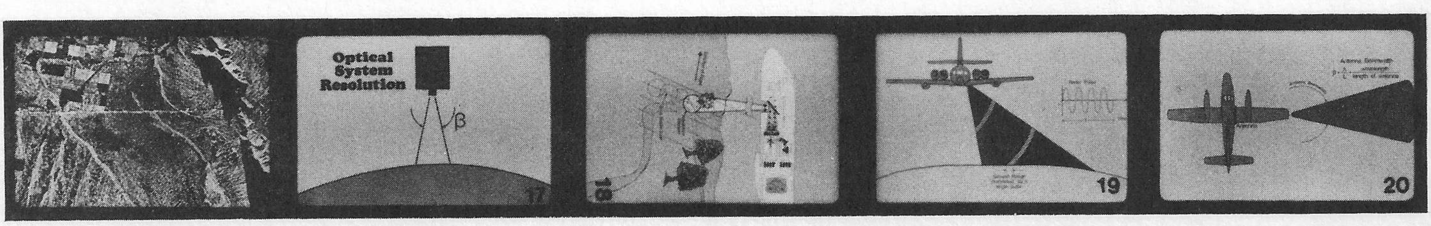
ADDITIONAL INSTRUCTOR'S NOTES

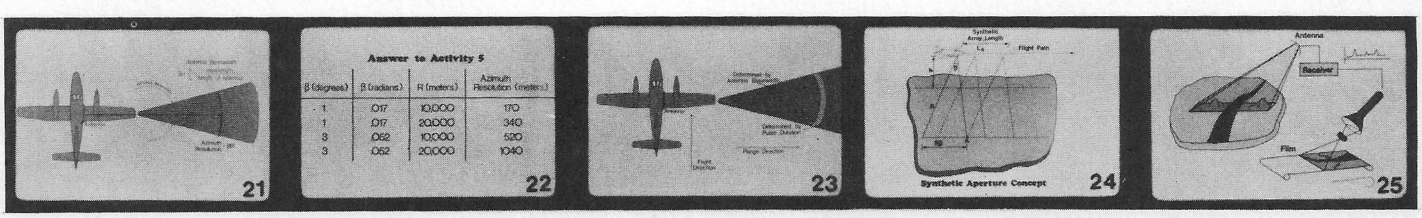
SIDE-LOOKING AIRBORNE RADAR

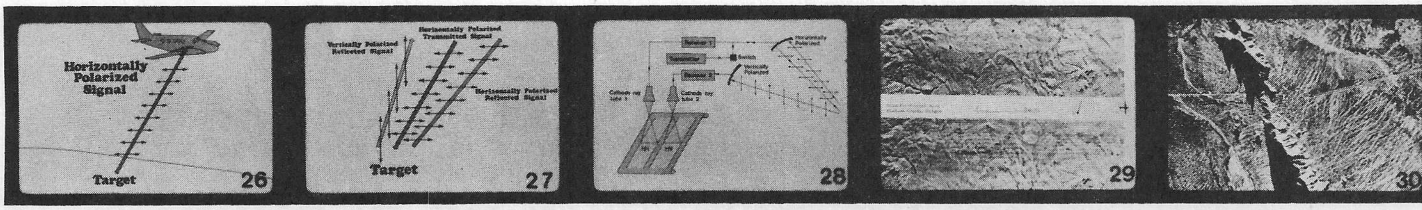


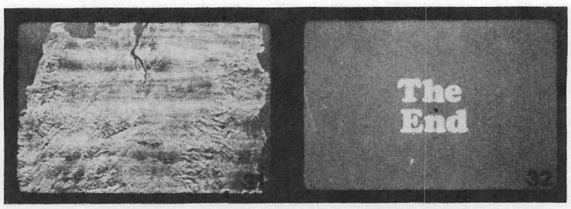









Horizontally Polarized Signal
Target
26
Vertically Polarized Reflected Signal
Horizontally Polarized Transmitted Signal
Horizontally Polarized Reflected Signal
Target
27
28
29
30


31
The End
32

SPECTRAL REFLECTANCE CHARACTERISTICS OF VEGETATION

SUMMARY

This minicourse is the first of two discussing spectral characteristics of earth surface features. In this one we will examine the fundamentals involved in the reflection of energy from vegetation, and we will see that the reflection is controlled by absorption -- particularly by absorption due to the pigments present in the leaf and by the moisture content of the leaf. As we study these fundamentals involved in plant leaf reflectance, we will also take a look at their impact on remote sensor imagery, in order to learn how to interpret remote sensing data more knowledgeably and effectively.

OBJECTIVES

When you have completed this minicourse, you should be able to:

1. Define, in an equation format, the three energy balance factors.

2. Describe the primary energy-matter interaction that occurs when (a) visible, (b) near infrared, and (c) middle infrared energy strikes a leaf.

3. State the approximate wavelength (in μm) where chlorophyll absorption dominates and where the yellow and red leaf pigments absorb strongly.

4. Identify the approximate spectral location of the five primary absorption bands found in green vegetation between 0.4 and 2.6 μm, and describe the cause of absorption at each of these wavelengths.

5. Differentiate between corn and soybeans on a color infrared photo by noting relative near-IR reflectances.

6. State the relationship between moisture content and leaf reflectance in the middle infrared wavelengths.

TIME: 1 hour

-- PROJECT THE FIRST SLIDE --

-- START THE TAPE --

PREREQUISITES

Before beginning this minicourse, the student should have mastered the objectives for:

Remote Sensing: What is it?

The Physical Basis of Remote Sensing

COMPONENTS OF MINICOURSE

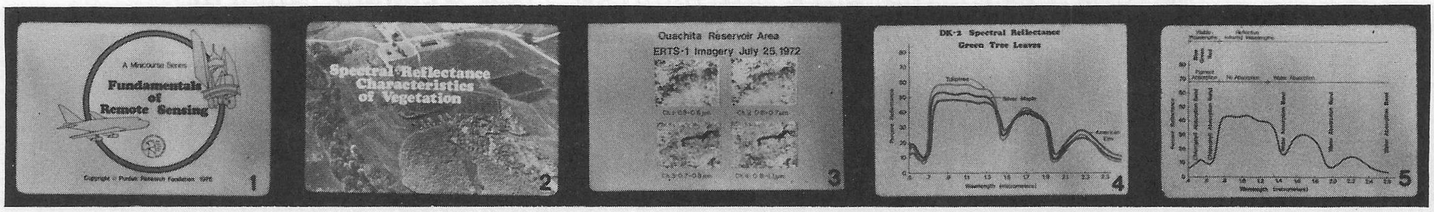
Study Guide for each student

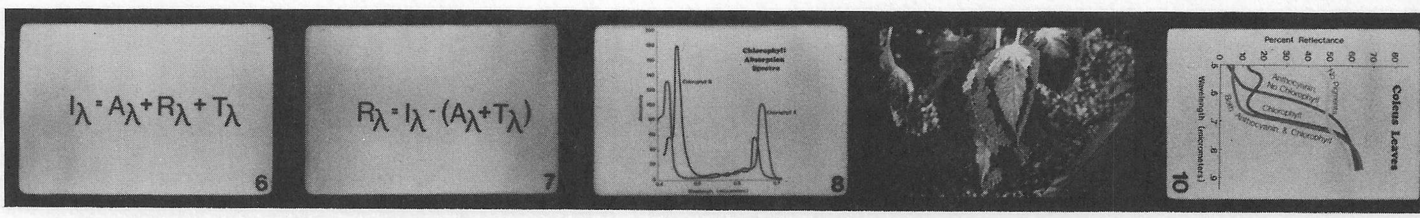
Set of 30 slides

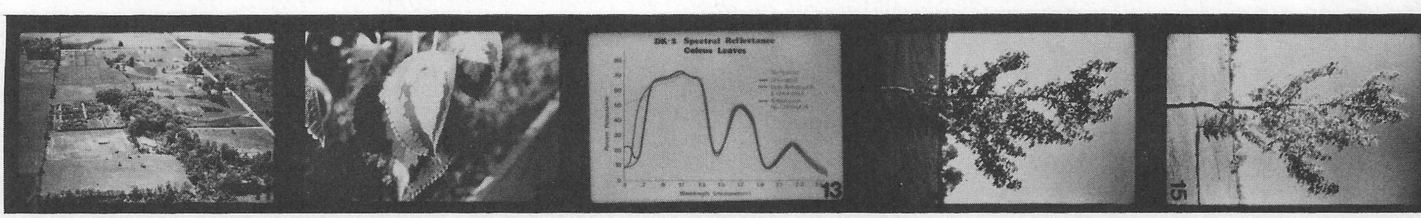
Audio Tape

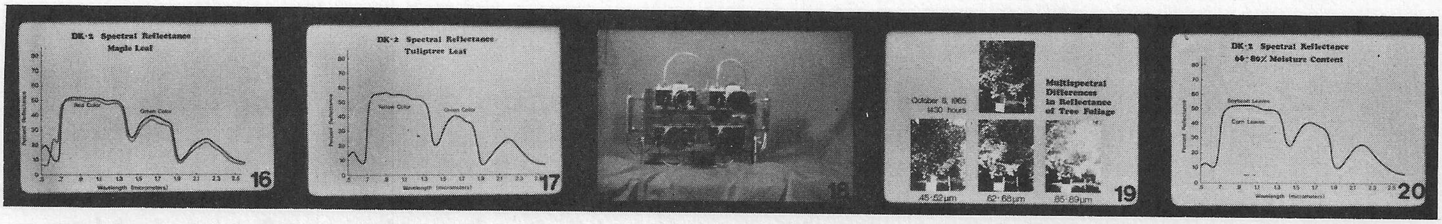
ADDITIONAL INSTRUCTOR'S NOTES

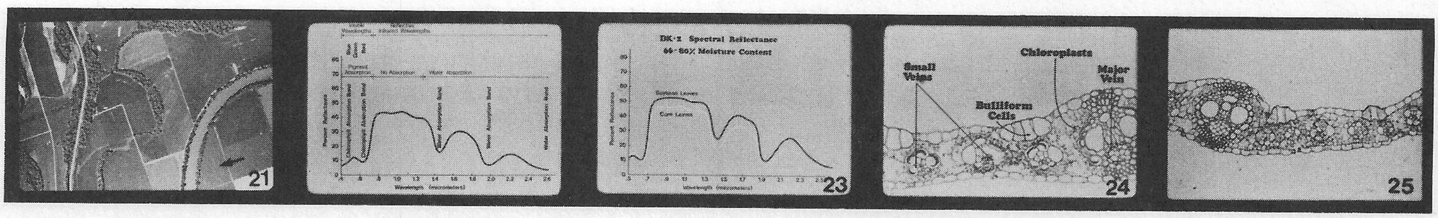
SPECTRAL REFLECTANCE CHARACTERISTICS OF VEGETATION

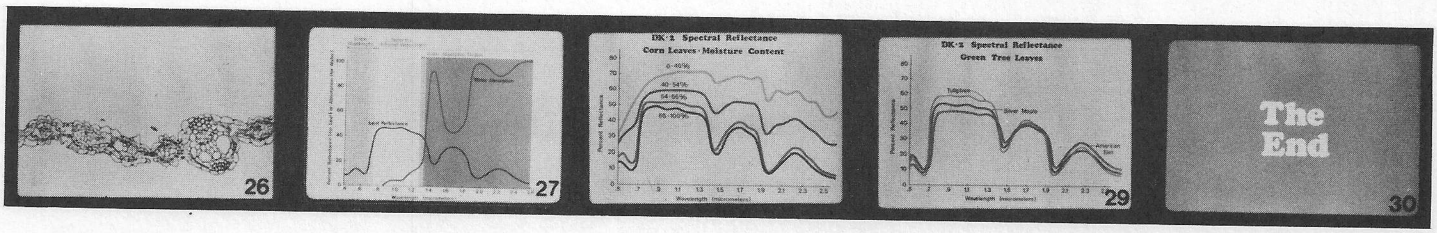







DK-2 Spectral Reflectance
Maple Leaf
Red Color
Green Color
16
DK-2 Spectral Reflectance
Tuliptree Leaf
Yellow Color
Green Color
17
18
Multispectral Differences in Reflectance of Tree Foliage
October 8, 1965
1430 hours
.45-.52μm
.62-.68μm
.85-.89μm
19
DK-2 Spectral Reflectance
66-86% Moisture Content
Soybean Leaves
Corn Leaves
20


21
Visible Wavelengths
Reflective Infrared Wavelengths
Pigment Absorption
No Absorption
Water Absorption
Wavelength (micrometers)
DK-2 Spectral Reflectance
66-86% Moisture Content
Soybean Leaves
Corn Leaves
23
Small Veins
Chloroplasts
Major Vein
Bulliform Cells
24
25


26
Leaf Reflectance
Water Absorption
27
DK-2 Spectral Reflectance
Corn Leaves-Moisture Content
DK-2 Spectral Reflectance
Green Tree Leaves
Tuliptree
Silver Maple
American Elm
29
The End
30

SPECTRAL REFLECTANCE CHARACTERISTICS OF EARTH SURFACE FEATURES

SUMMARY

This minicourse is intended to follow the unit on Spectral Reflectance Characteristics of Vegetation. Together, these two units form the basis for effective interpretation of multispectral scanner data and color IR photograghy. In the first unit, we restricted the discussion to fundamentals of vegetative reflectance, whereas in this unit we examine the factors influencing reflectance from soils and water. Finally, vegetation, soil, and water reflectances are combined and the spectral interrelationships of these basic cover types are compared.

OBJECTIVES

When you have completed this minicourse, you should be able to:

1. List the major factors influencing the amount of reflectance from surface soil -- two are inherent soil characteristics and two are temporary variables.

2. Define the relationship between reflectance and moisture content in soils.

3. Sketch the approximate shape of the reflectance curves for clear and turbid water.

4. Describe the relative spectral response for vegetation, soil, and water in the visible, near infrared, and middle infrared wavelengths.

TIME: 1 hour

-- PROJECT THE FIRST SLIDE --

-- START THE TAPE --

PREREQUISITES

Before beginning this minicourse, the student should have mastered the objectives for:

Remote Sensing: What is it?

The Physical Basis of Remote Sensing

Spectral Reflectance Characteristics of Vegetation

COMPONENTS OF MINICOURSE

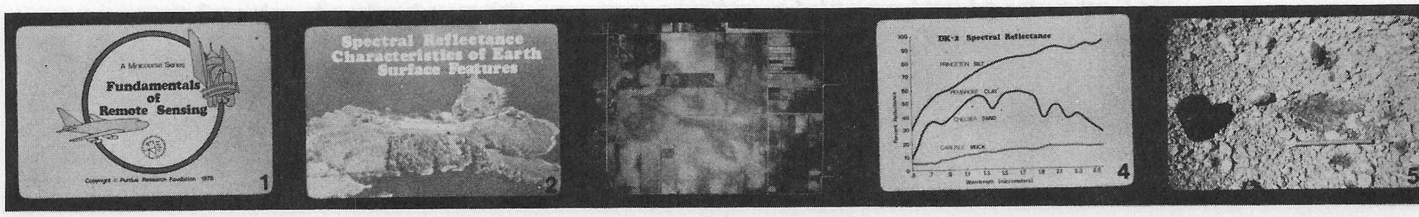
Study Guide for each student

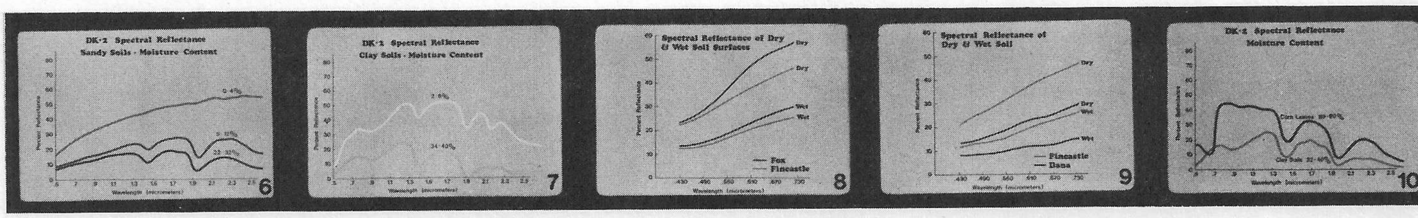
Set of 30 slides

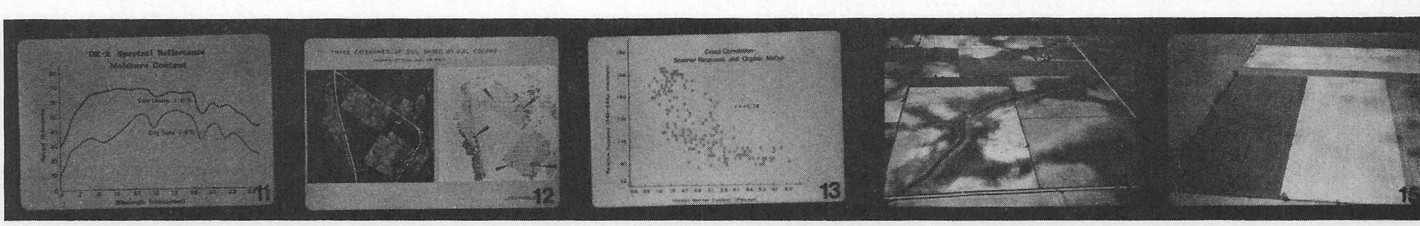
Audio Tape

ADDITIONAL INSTRUCTOR'S NOTES

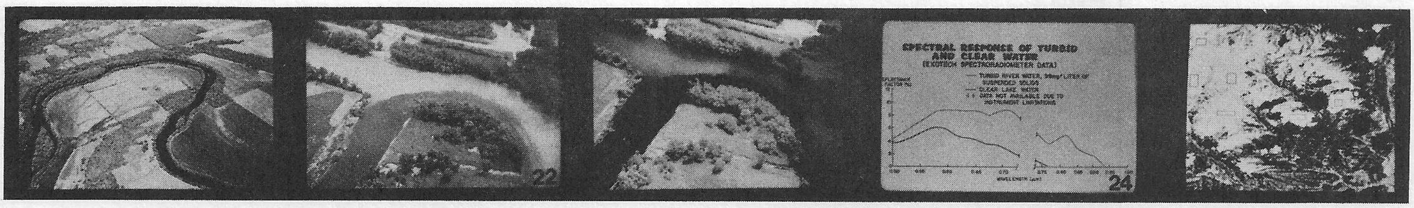
SPECTRAL REFLECTANCE CHARACTERISTICS OF EARTH SURFACE FEATURES

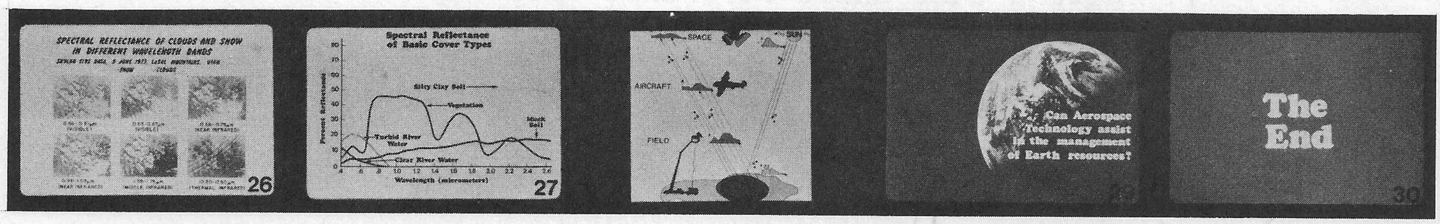







Effect of Soil Crust on Spectral Reflectance
Crider Soil
Crusted
Crust Broken
16
17
Ouachita Reservoir Area
ERTS-1 Imagery July 25,1972
19


22
SPECTRAL RESPONSE OF TURBID AND CLEAR WATER
(EXOTECH SPECTRORADIOMETER DATA)
24


SPECTRAL REFLECTANCE OF CLOUDS AND SNOW IN DIFFERENT WAVELENGTH BANDS
26
Spectral Reflectance of Basic Cover Types
Silty Clay Soil
Vegetation
Turbid River Water
Clear River Water
Muck Soil
Percent Reflectance
Wavelength (micrometers)
27
SPACE
SUN
AIRCRAFT
FIELD
Can Aerospace Technology assist in the management of Earth resources?
The End
30

MISSION PLANNING -- CONSIDERATIONS AND REQUIREMENTS

SUMMARY

Before planning remote sensing missions, the project director first determines what information he needs and then, if remote sensing can help meet those needs, he can decide which data collection systems and analysis methods are most appropriate for the task. Reference data or ancillary data necessary to the analysis can be collected in a number of ways. Such data is especially useful for understanding and limiting the spectral variability that might be encountered in the primary data.

OBJECTIVES

When you have completed this minicourse, you should be able to:

1. Discuss why a user needs to define his information needs.
2. List spectral, spatial, and temporal considerations involved in mission planning.
3. Name three kinds of sensor systems and give an advantage of each.
4. Describe how sensor altitude affects viewing area and the sensor's ability to distinguish objects on the ground.
5. Site circumstances when manual interpretation would be the more effective analysis procedure to use, and when computer classification would be.
6. Describe and give examples of reference data.
7. Cite a case where reference data can aid in the interpretation of remote sensing data.

TIME: 1 hour

-- PROJECT THE FIRST SLIDE --

-- START THE TAPE --

PREREQUISITES

Before beginning this minicourse, the student should have mastered the objectives for:

Remote Sensing: What is it?

The Physical Basis of Remote Sensing

COMPONENTS OF MINICOURSE

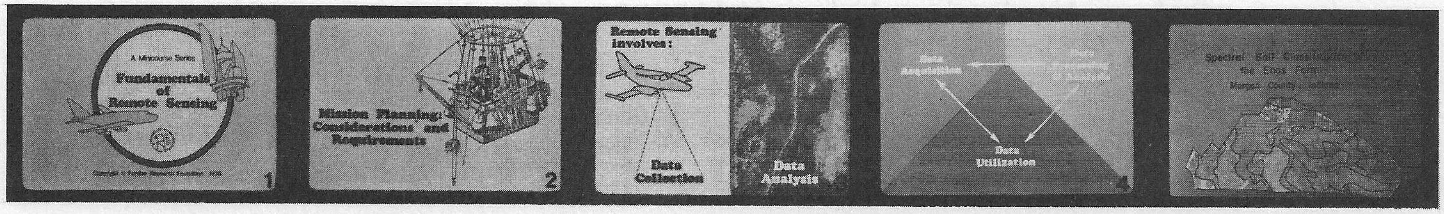
Study Guide for each student

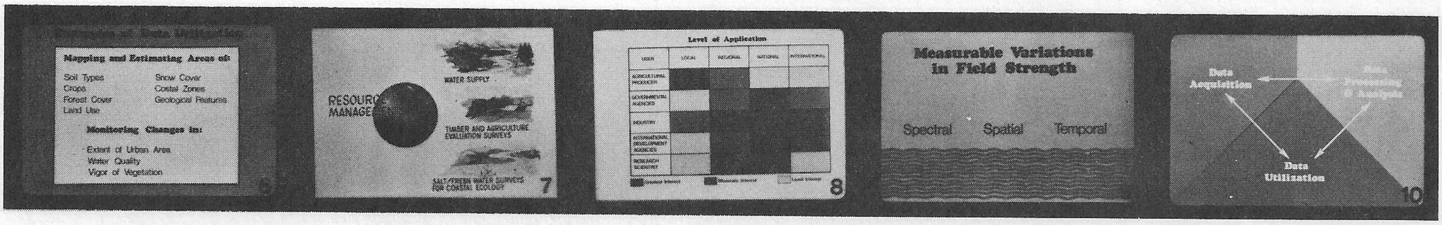
Set of 41 slides

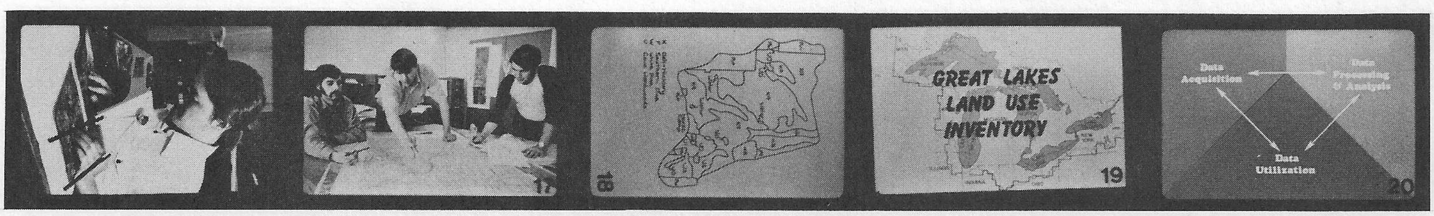
Audio Tape

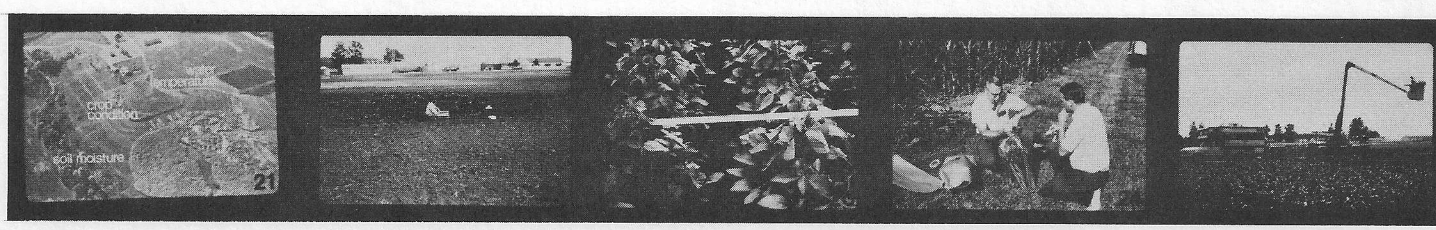
ADDITIONAL INSTRUCTOR'S NOTES

MISSION PLANNING -- CONSIDERATIONS AND REQUIREMENTS

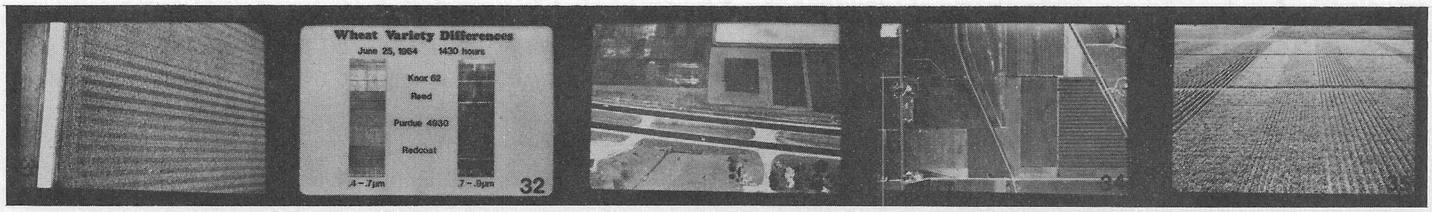


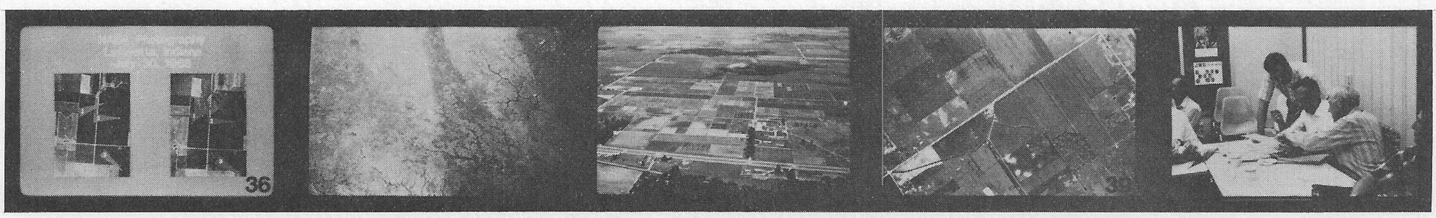


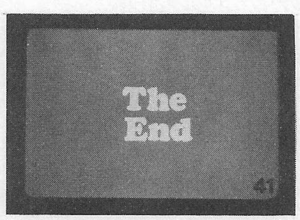





water temperature
crop condition
soil moisture
27
29


Wheat Variety Differences
June 25, 1964 1430 hours
Knox 62
Reed
Purdue 4930
Redcoat
.4–.7μm
.7–.9μm
32
34
35


36
39


The End
41

LANDSAT: AN EARTH RESOURCES SATELLITE SYSTEM

SUMMARY

The first Earth Resources Technology Satellite was launched in 1972 with the expectation that the data it collected would be useful in acquiring needed information about the resources of the Earth. Both LANDSAT-1 (formerly ERTS-1) and LANDSAT-2 have collected large quantities of high-quality multispectral data which have been applied to a variety of resources-related tasks--for example, surveying crops and forests, mapping land use patterns, and monitoring water and air quality. This minicourse discusses the characteristics of the sensors aboard the satellites, the orbits they follow, and the data they collect. Some of the types of information that have been derived from LANDSAT data are also presented.

OBJECTIVES

When you have completed this minicourse, you should be able to:

1. Describe the two spectral sensors on board LANDSAT and the range of sensitivity of each.
2. List four characteristics of the orbital path of LANDSAT.
3. Describe what is meant by the term "LANDSAT frame," including its approximate size.
4. Describe the LANDSAT data flow from the sensors (including ground-based collectors) to the users.
5. List five specific kinds of information that have been extracted from LANDSAT data.

TIME: 1 hour

-- PROJECT THE FIRST SLIDE --

-- START THE TAPE --

PREREQUISITES

Before beginning this minicourse, the student should have mastered the objectives for:

Remote Sensing: What is it?

The Physical Basis of Remote Sensing

COMPONENTS OF MINICOURSE

Study Guide for each student

Set of 27 slides

Audio Tape

Single LANDSAT Coverage Map: One included with slides. Extra copies available from:

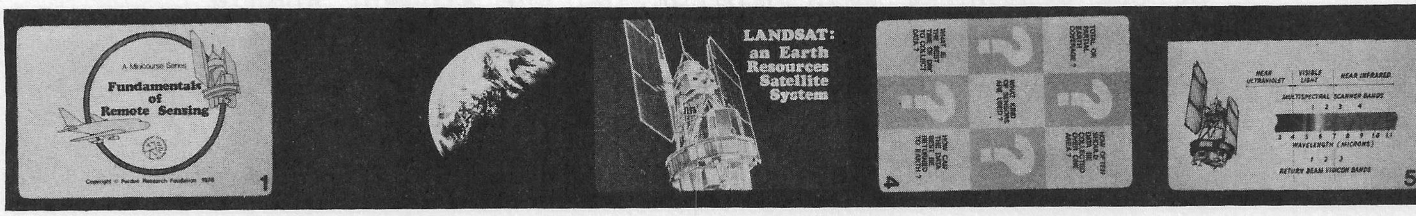
User's Services Unit
EROS Data Center
Sioux Falls, South Dakota 57198

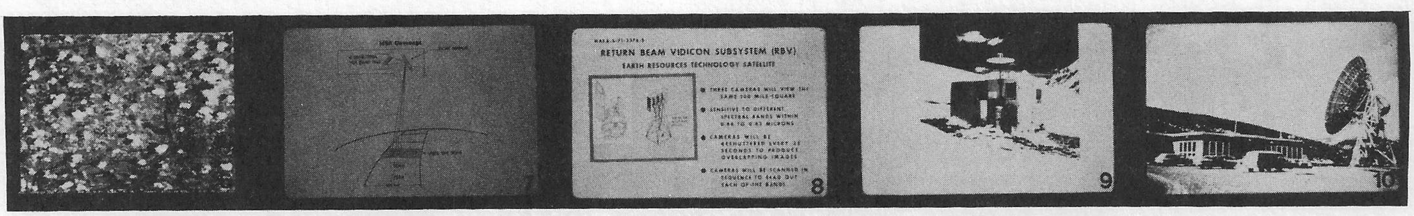
Cardboard template with hole: Four are printed on yellow cardboard in Appendix A of this manual. Cut out one and remove hole with razor knife. Others are spares if original is lost or damaged.

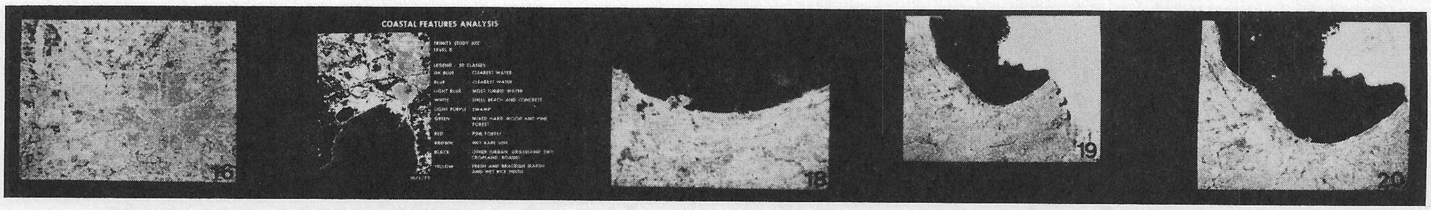
Overlay transparency identifying earth surface features of interest: One clear acetate overlay included in Appendix A of this manual along with master sheet for making additional copies with Thermofax or Xerox.

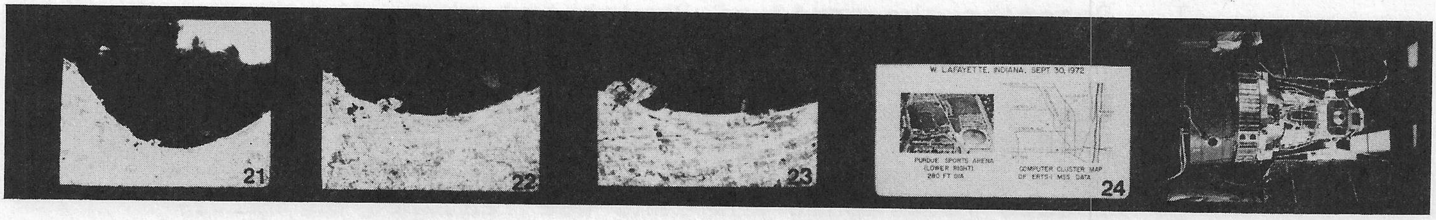
ADDITIONAL INSTRUCTOR'S NOTES

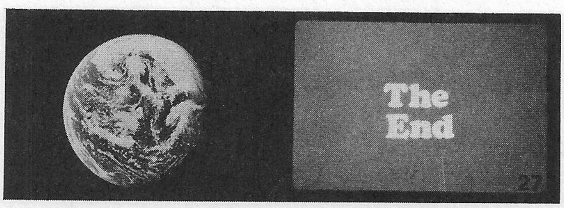
LANDSAT: AN EARTH RESOURCES SATELLITE SYSTEM






COASTAL FEATURES ANALYSIS
16
18
19
20


21
22
23
W LAFAYETTE, INDIANA, SEPT 30, 1972
PURDUE SPORTS ARENA (LOWER RIGHT) 280 FT DIA
COMPUTER CLUSTER MAP OF ERTS-1 MSS DATA
24


The End
27

SKYLAB: EARTH RESOURCES EXPERIMENT

SUMMARY

In presenting an overview of the Skylab Earth Resources Experiment Package, this minicourse describes the satellite's flight characteristics and the sensor systems designed to be a part of this package. The results of several data analysis experiments are described to highlight some important characteristics of Skylab data and their utility in earth resources studies.

OBJECTIVES

When you have completed this minicourse, you should be able to:

1. Describe the orbit of Skylab and state the percentage of the earth it could view.
2. Identify the general sensitivity range of each EREP sensor.
3. Locate geographic and land use features on multiband photographic images from Skylab.
4. Describe specific earth resources applications to which data from the middle infrared and the thermal infrared channels of the multispectral scanner have been especially useful.

TIME: 1 hour

-- PROJECT THE FIRST SLIDE --

-- START THE TAPE --

PREREQUISITES

Before beginning this minicourse, the student should have mastered the objectives for:

Remote Sensing: What is it?

The Physical Basis of Remote Sensing

COMPONENTS OF MINICOURSE

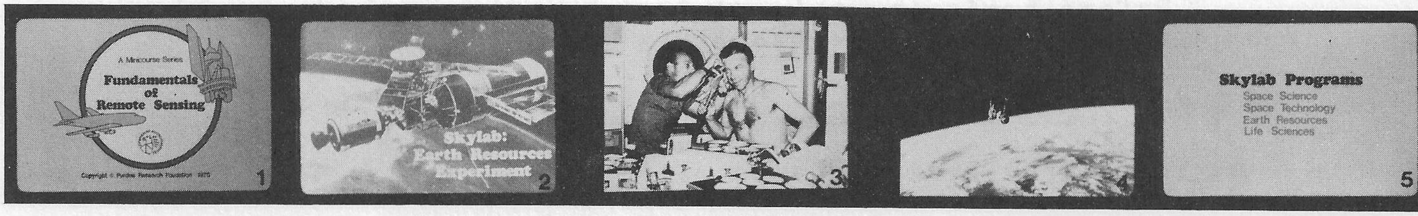
Study Guide for each student

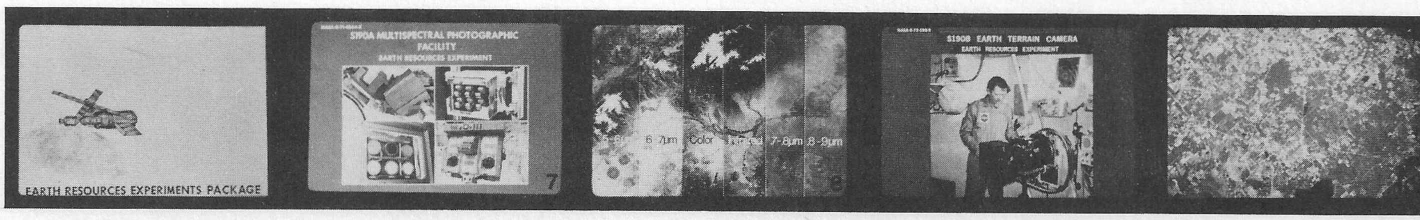
Set of 34 slides

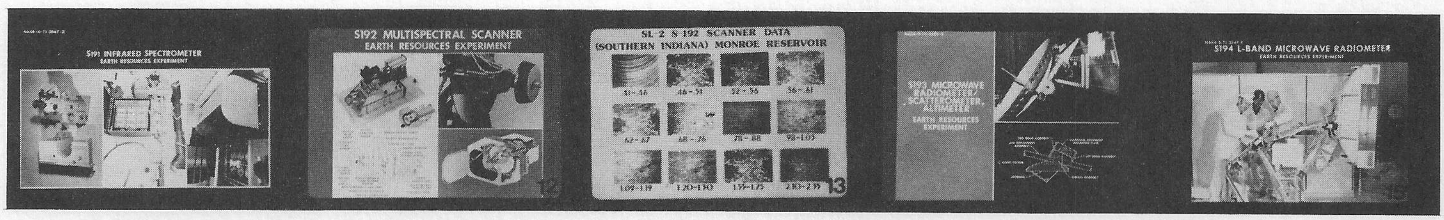
Audio Tape

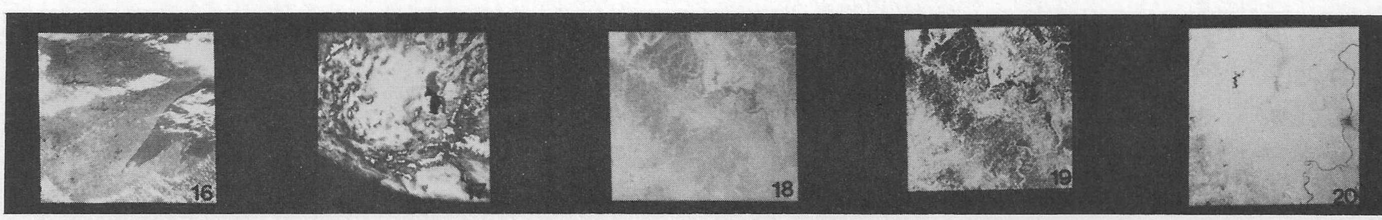
ADDITIONAL INSTRUCTOR'S NOTES

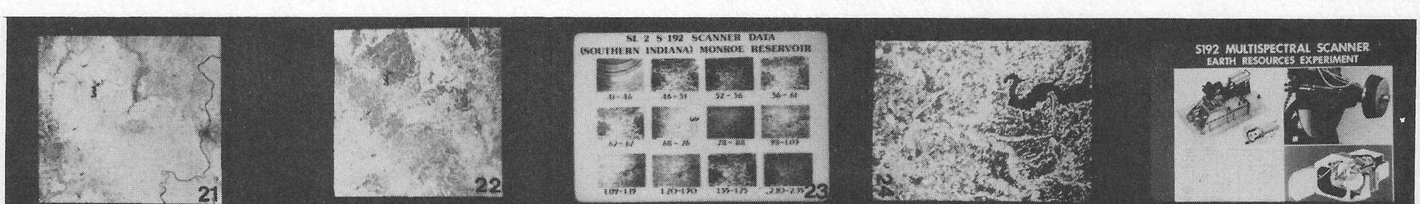
SKYLAB: EARTH RESOURCES EXPERIMENT

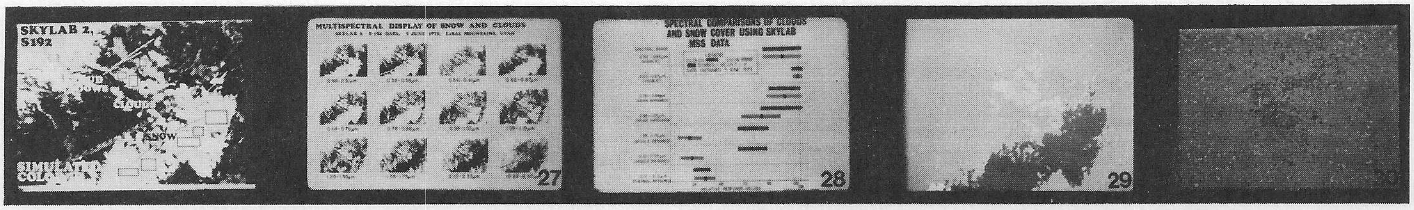











SKYLAB 2,
S192
CLOUDS
SIMULATED
COLOR
MULTISPECTRAL DISPLAY OF SNOW AND CLOUDS
27
SPECTRAL COMPARISONS OF CLOUDS
AND SNOW COVER USING SKYLAB
MSS DATA
28
29


31
32
EARTH RESOURCES EXPERIMENTS SENSORS
The
End
34

PATTERN RECOGNITION IN REMOTE SENSING

SUMMARY

This minicourse introduces you to the way in which a computer views the data from a multispectral scanner, namely, as a set of numbers called a data vector for each ground resolution element. The data vector concept is then used in an example to illustrate the ideas of training data, "distance" between training samples and decision boundaries. After a discussion of a pattern recognition model, several classification rules are presented. The application of computer-aided analysis of multispectral data is illustrated using results of a research study.

OBJECTIVES

When you have completed this minicourse, you should be able to:

1. Describe how a "data vector" is formed from the responses of a multispectral scanner.

2. For the two-dimensional case, plot data vectors on a graph and explain how this concept can be extended to 3, 4,.... n dimensions.

3. Draw decision boundaries between distinctly separable sets of training samples.

4. Classify an unknown data vector when the decision boundaries are given.

5. Describe the difference between supervised and unsupervised classification procedures. The description should include the types of classes which result.

6. Define the term algorithm and, for the two-dimensional case, apply the nearest neighbor classification algorithm to a data point to be classified.

TIME: 1 hour

-- PROJECT THE FIRST SLIDE --

-- START THE TAPE --

PREREQUISITES

Before beginning this minicourse, the student should have mastered the objectives for:

Remote Sensing: What is it?

The Physical Basis of Remote Sensing

Multispectral Scanners

COMPONENTS OF MINICOURSE

Study Guide for each student

Set of 31 slides

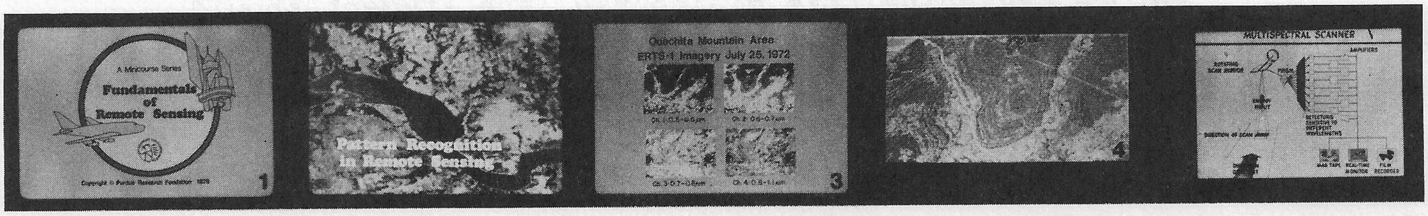
Audio Tape

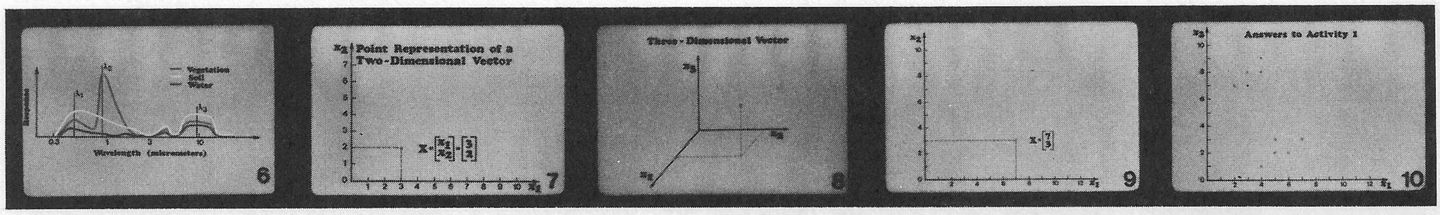
➡ Centimeter ruler at least 15 cm long: Suggest you put one in box with slides. However, a paper one is included in student's study guide if others are not available.

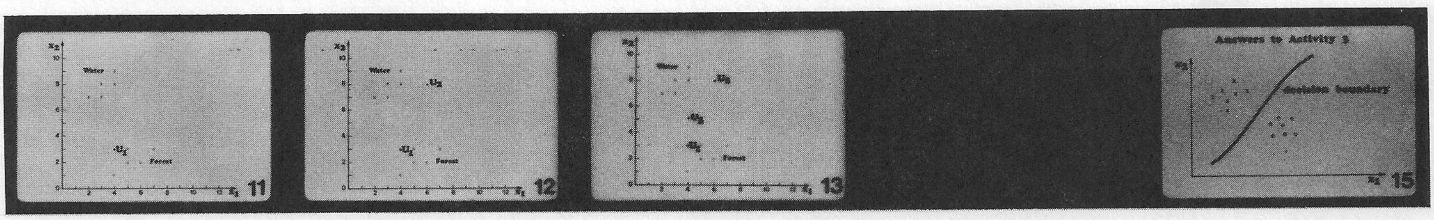
➡ (to be provided by instructor)

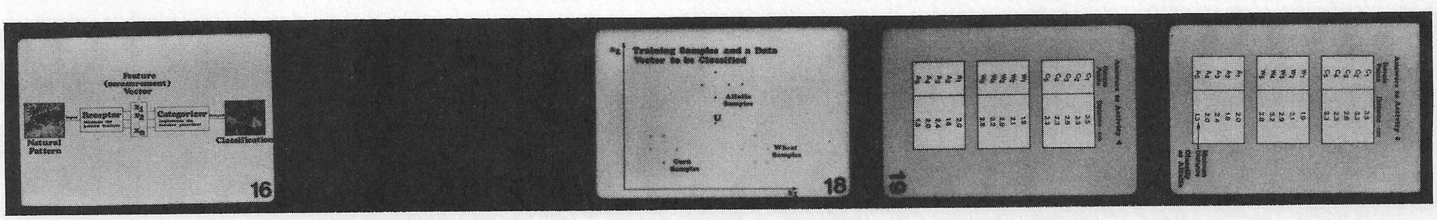
ADDITIONAL INSTRUCTOR'S NOTES

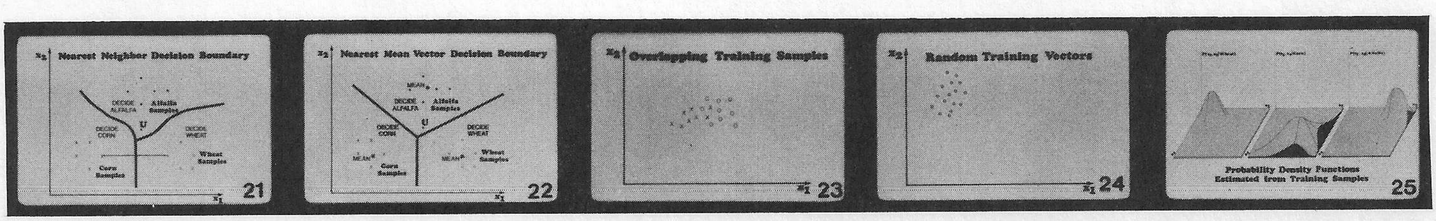
PATTERN RECOGNITION IN REMOTE SENSING

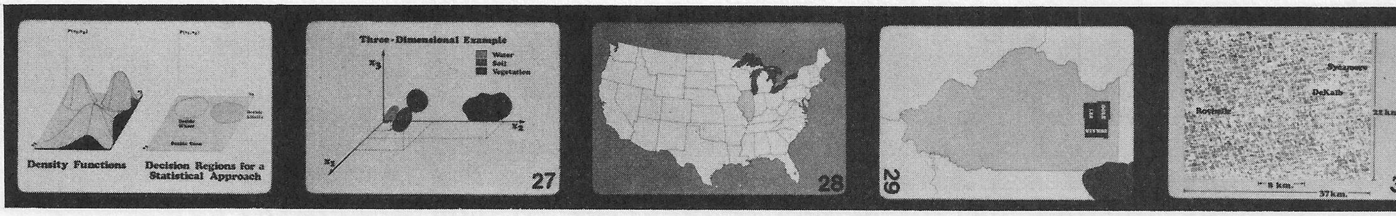


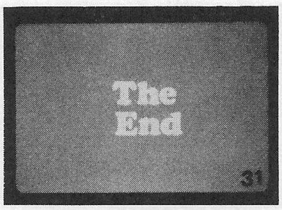









Density Functions
Decision Regions for a Statistical Approach
Three-Dimensional Example
Water
Soil
Vegetation
27
28
29
DeKalb
22 km.
8 km.
37 km.
30


The End
31

TYPICAL STEPS IN NUMERICAL ANALYSIS

SUMMARY

Procedures typical of those used to analyze multispectral scanner data using numerical pattern recognition techniques are presented and discussed in this minicourse. These procedures include defining the objectives of the analysis, examining the quality of the data, specifying the areas to be analyzed, selecting training samples, classifying the data, displaying the results, and evaluating the results of the analysis. The relationship between man (the analyst) and machine (the computer) for each step of the procedure is stressed so as to reveal this complex partnership.

OBJECTIVES

When you have completed this minicourse, you should be able to:

1. List the four types of information contained on a typical multispectral scanner data tape and describe the function of each.

2. Given a list of the typical steps in the numerical analysis of remotely sensed data, briefly describe the purpose and outcome of each step.

3. Describe the man-computer interaction at each step of the analysis.

TIME: 1 hour

-- PROJECT THE FIRST SLIDE --

-- START THE TAPE --

PREREQUISITES

Before beginning this minicourse, the student should have mastered the objectives for:

Remote Sensing: What is it?

The Physical Basis of Remote Sensing

Multispectral Scanners

Pattern Recognition in Remote Sensing

COMPONENTS OF MINICOURSE

Study Guide for each student

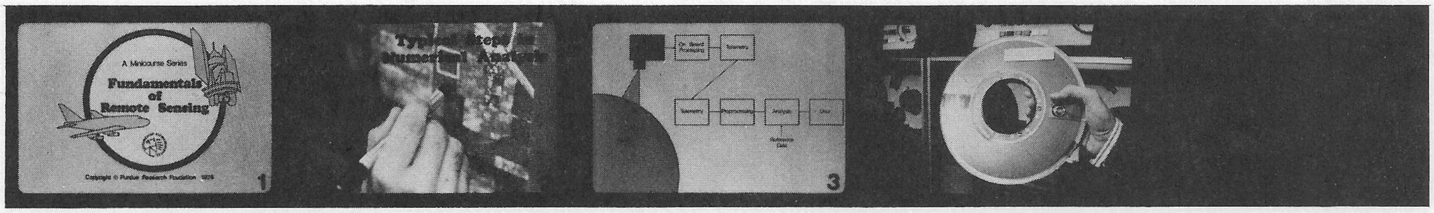
Set of 51 slides

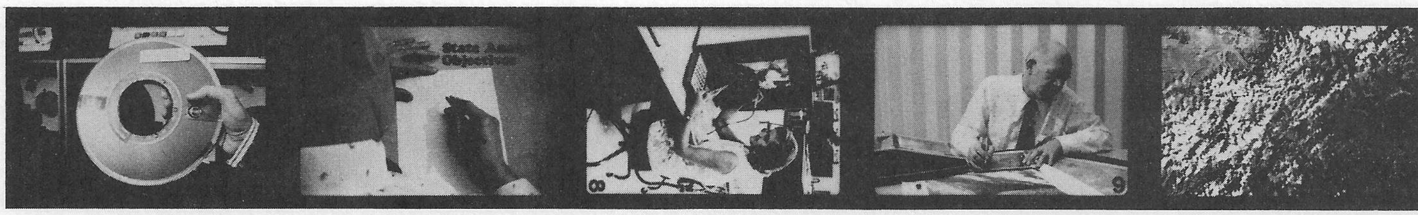
Audio Tape

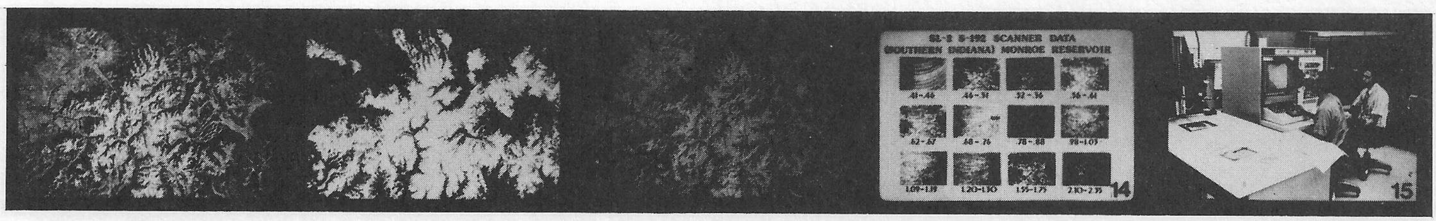
Transparent grid: One copy included in Appendix A of this manual. Use Thermofax or Xerox to make additional copies from master when needed.

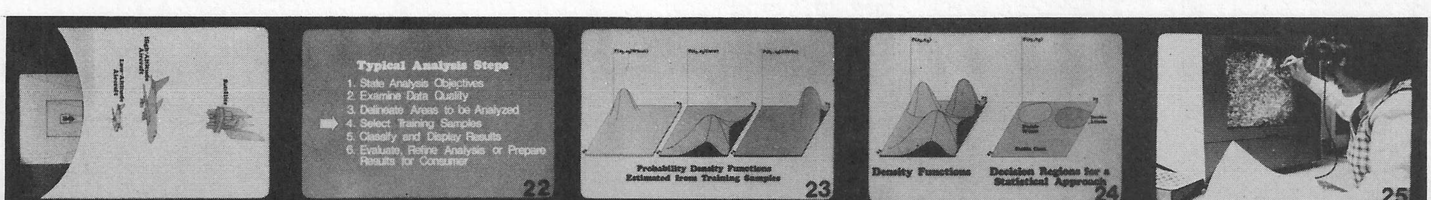
ADDITIONAL INSTRUCTOR'S NOTES

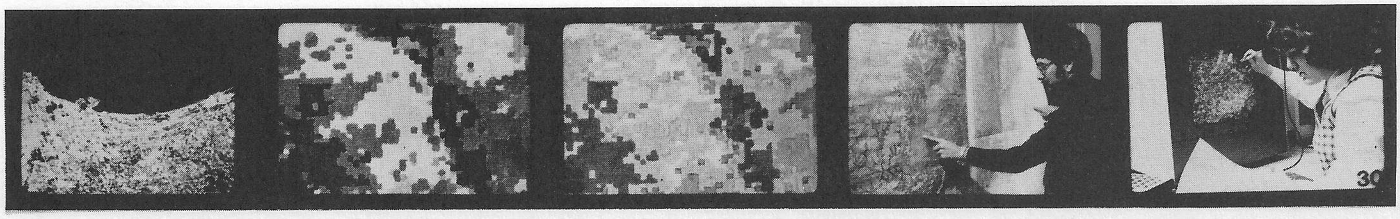
TYPICAL STEPS IN NUMERICAL ANALYSIS







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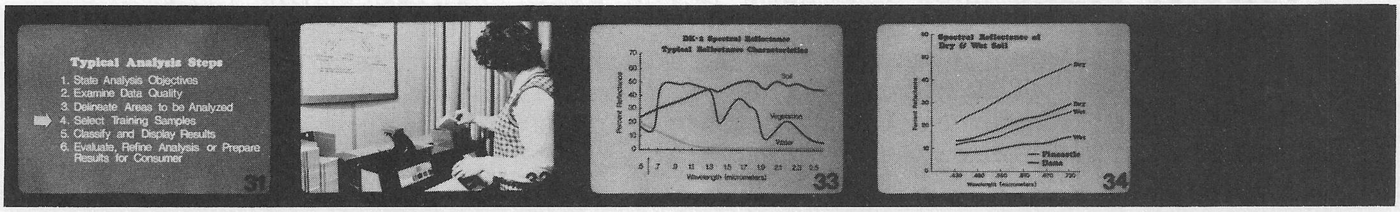
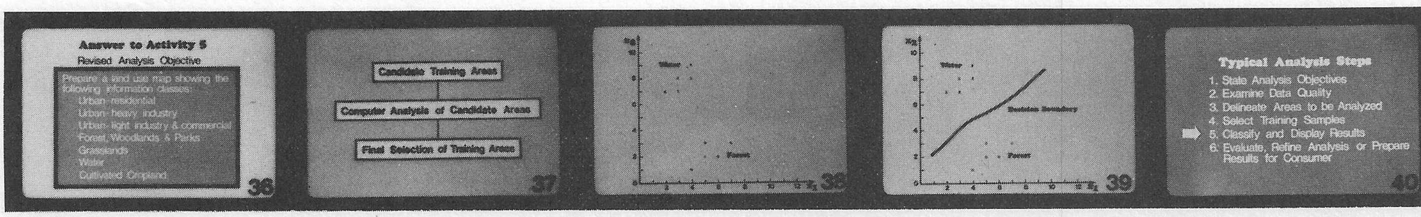
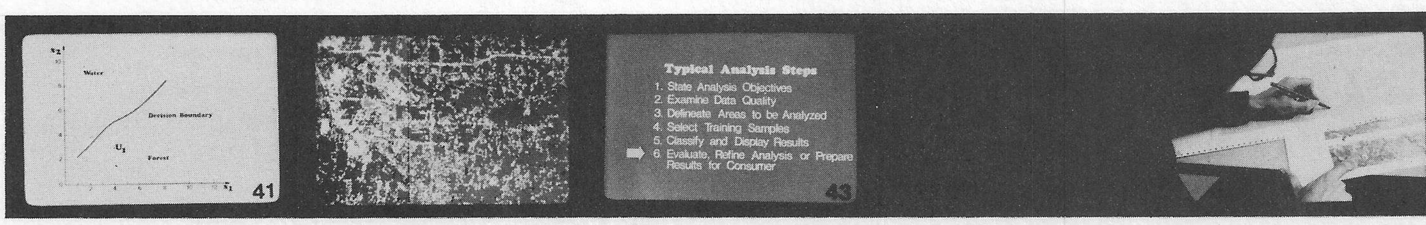
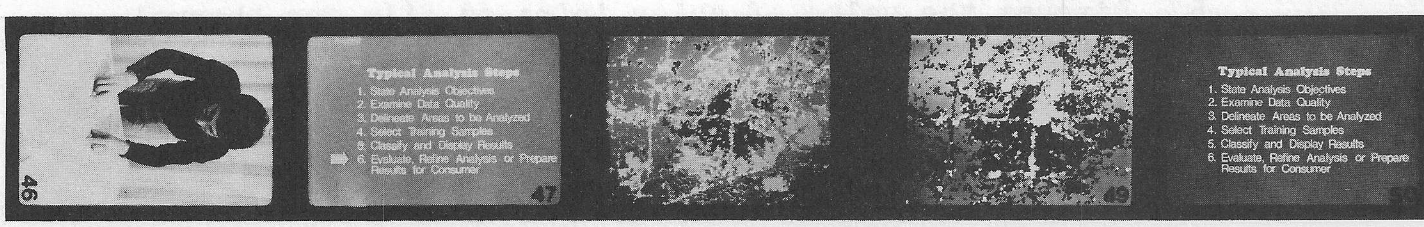
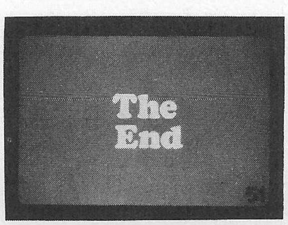

Typical Analysis Steps
1. State Analysis Objectives
2. Examine Data Quality
3. Delineate Areas to be Analyzed
4. Select Training Samples
5. Classify and Display Results
6. Evaluate, Refine Analysis or Prepare Results for Consumer
31
Typical Reflectance Characteristics
Soil
Vegetation
Water
Wavelength (micrometers)
33
Spectral Reflectance of Dry & Wet Soil
Dry
Wet
Wavelength (micrometers)
34


Answer to Activity 5
Revised Analysis Objective
Prepare a land use map showing the following information classes:
Urban-residential
Urban-heavy industry
Urban-light industry & commercial
Forest, Woodlands & Parks
Grasslands
Water
Cultivated Cropland
36
Candidate Training Areas
Computer Analysis of Candidate Areas
Final Selection of Training Areas
37
Water
Forest
38
Water
Decision Boundary
Forest
39
Typical Analysis Steps
1. State Analysis Objectives
2. Examine Data Quality
3. Delineate Areas to be Analyzed
4. Select Training Samples
5. Classify and Display Results
6. Evaluate, Refine Analysis or Prepare Results for Consumer
40


Water
Decision Boundary
Forest
41
Typical Analysis Steps
1. State Analysis Objectives
2. Examine Data Quality
3. Delineate Areas to be Analyzed
4. Select Training Samples
5. Classify and Display Results
6. Evaluate, Refine Analysis or Prepare Results for Consumer
43


46
Typical Analysis Steps
1. State Analysis Objectives
2. Examine Data Quality
3. Delineate Areas to be Analyzed
4. Select Training Samples
5. Classify and Display Results
6. Evaluate, Refine Analysis or Prepare Results for Consumer
47
49
Typical Analysis Steps
1. State Analysis Objectives
2. Examine Data Quality
3. Delineate Areas to be Analyzed
4. Select Training Samples
5. Classify and Display Results
6. Evaluate, Refine Analysis or Prepare Results for Consumer
50


The End
51

INTERPRETATION OF COLOR INFRARED PHOTOGRAPHY

SUMMARY

This minicourse discusses a number of the fundamentals involved in proper interpretation of color infrared film. Pairs of slides show the same scene with regular color film and then with color infrared film. A number of the advantages and limitations in the use of color infrared film for various applications will be discussed. When finished, you should be able to interpret the tonal characteristics seen on color infrared film nearly as well as the colors you see on regular color film.

OBJECTIVES

When you have completed this minicourse, you should be able to:

1. Describe how an object would appear on color infrared film if it has a very low reflectance in all portions of the spectrum except the a) blue, b) green, c) red, and d) reflective infrared.

2. Identify the color that would be found on color infrared film for tree leaves that are either green, yellow, or red (such as during the fall season).

3. Describe the general appearance on color infrared film of the following classes of objects: a) clear water, b) turbid water, c) light colored soil, d) dark or moist soil, 3) dead, brown vegetation.

4. State two primary advantages and two primary limitations of color infrared film as compared to normal color film.

5. Discuss the value of color infrared film for thermal mapping applications.

TIME: 75 minutes

-- PROJECT THE FIRST SLIDE --

-- START THE TAPE --

PREREQUISITES

Before beginning this minicourse, the student should have mastered the objectives for:

Remote Sensing: What is it?

The Physical Basis of Remote Sensing

Photographic Sensors

COMPONENTS OF MINICOURSE

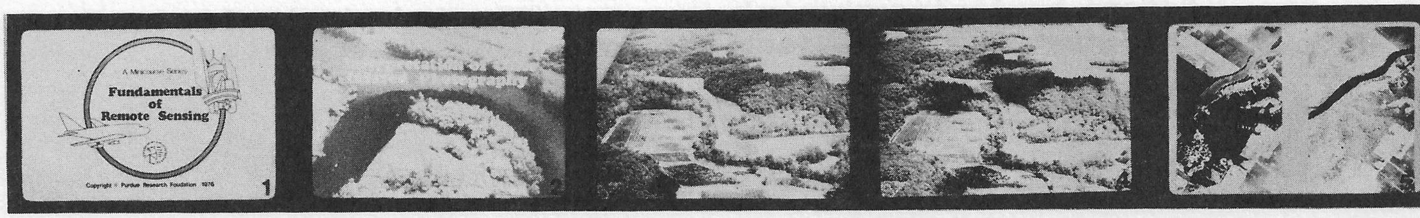
Study Guide for each student

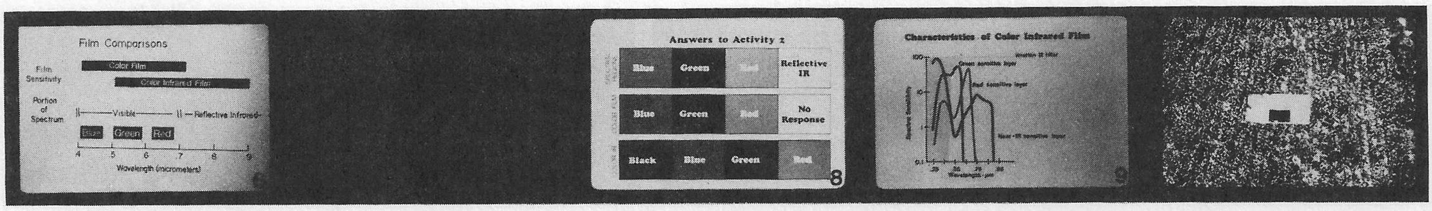
Set of 50 slides

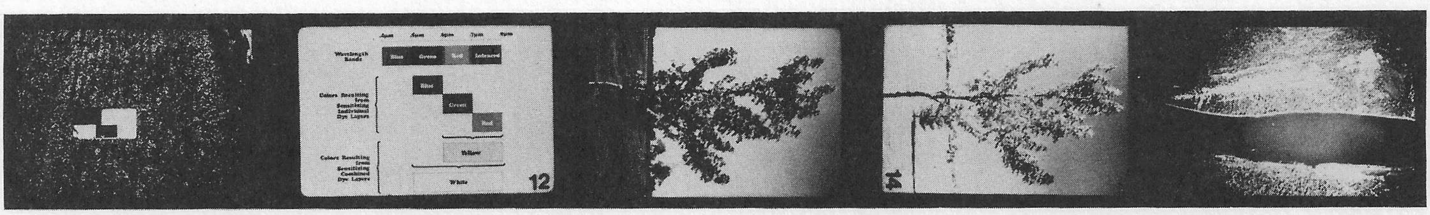
Audio Tape

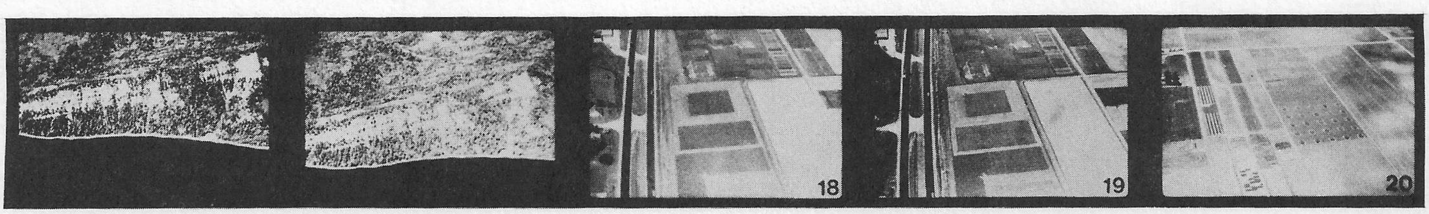
ADDITIONAL INSTRUCTOR'S NOTES

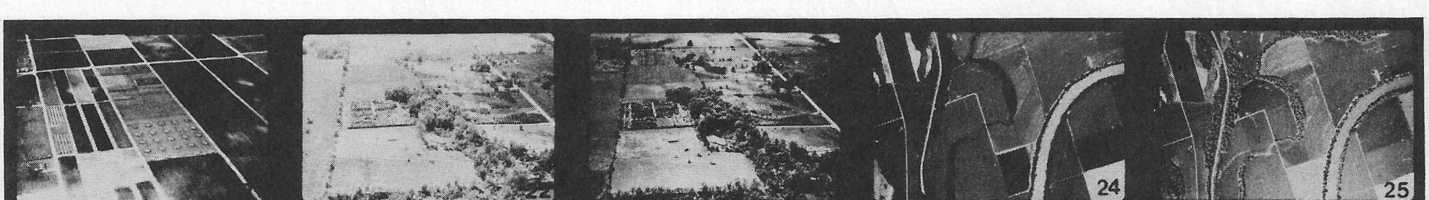
INTERPRETATION OF COLOR INFRARED PHOTOGRAPHY

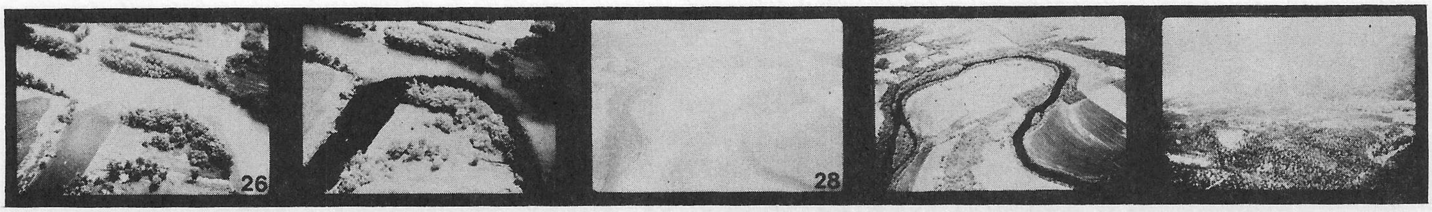


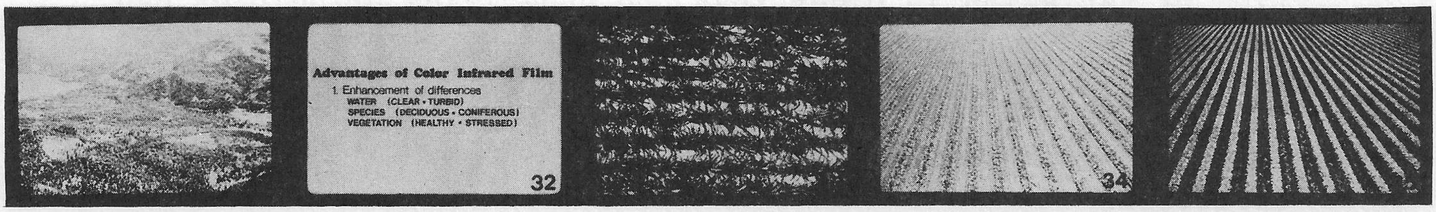


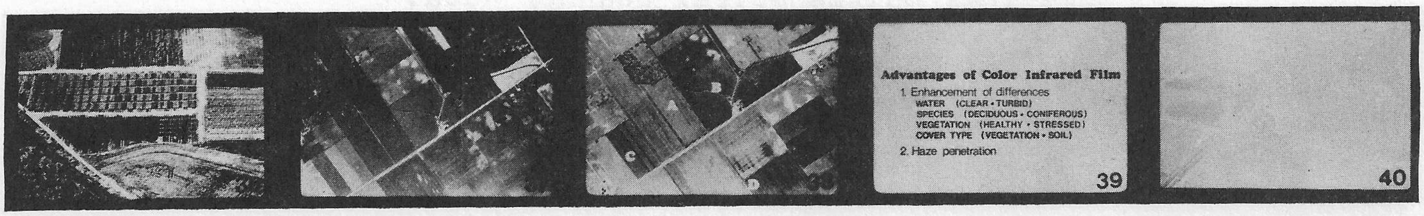


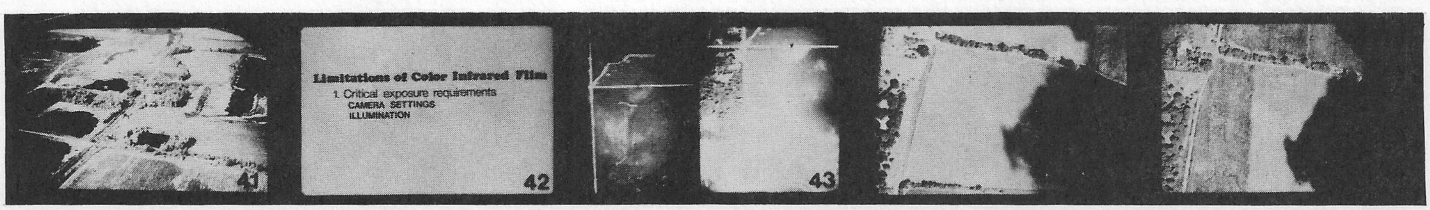


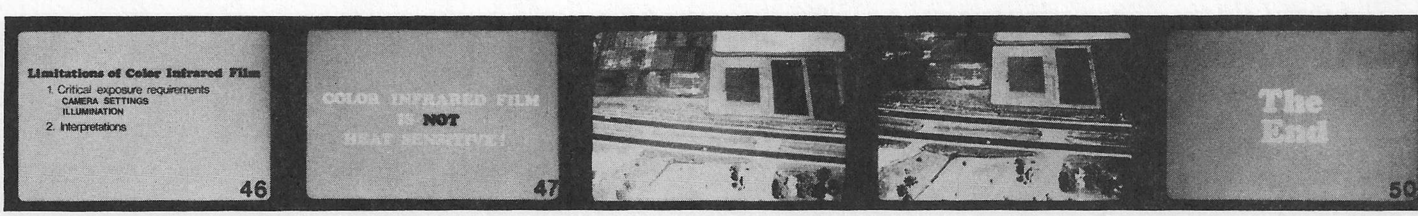



26
28


Advantages of Color Infrared Film
1. Enhancement of differences
WATER (CLEAR • TURBID)
SPECIES (DECIDUOUS • CONIFEROUS)
VEGETATION (HEALTHY • STRESSED)
32
34


Advantages of Color Infrared Film
1. Enhancement of differences
WATER (CLEAR • TURBID)
SPECIES (DECIDUOUS • CONIFEROUS)
VEGETATION (HEALTHY • STRESSED)
COVER TYPE (VEGETATION • SOIL)
2. Haze penetration
39
40


41
Limitations of Color Infrared Film
1. Critical exposure requirements
CAMERA SETTINGS
ILLUMINATION
42
43


Limitations of Color Infrared Film
1. Critical exposure requirements
CAMERA SETTINGS
ILLUMINATION
2. Interpretations
46
COLOR INFRARED FILM
IS NOT
HEAT SENSITIVE!
47
The
End
50

INTERPRETATION OF MULTISPECTRAL SCANNER IMAGES

SUMMARY

The general procedures used to generate images from multispectral scanner data are introduced, and the techniques used by remote sensing analysts to interpret multispectral images are illustrated by means of three examples. While an experienced analyst will attempt to make simultaneous use of spatial, spectral and temporal variations when analyzing multispectral scanner images, the examples used here have been selected to illustrate interpretations based on a single type of variation in order that the underlying principles can be emphasized. Activities are incorporated in the minicourse to give the student an opportunity to make interpretations based on spatial, spectral and temporal information.

OBJECTIVES

When you have completed this minicourse, you should be able to:

1. Describe the process used to generate an image from numerical multispectral scanner data.
2. Identify major ground cover types using spatial and spectral information.
3. Identify a field of bare soil in day and night thermal imagery.

TIME: 1¼ hours

-- PROJECT THE FIRST SLIDE --

-- START THE TAPE --

PREREQUISITES

Before beginning this minicourse, the student should have mastered the objectives for:

Remote Sensing: What is it?

The Physical Basis of Remote Sensing

Multispectral Scanners

COMPONENTS OF MINICOURSE

Study Guide for each student

Set of 20 slides

Audio Tape

Punched computer card with 7 numbered holes: One required, but several are included with slides. Keep extras as spares in case original is lost or damaged.

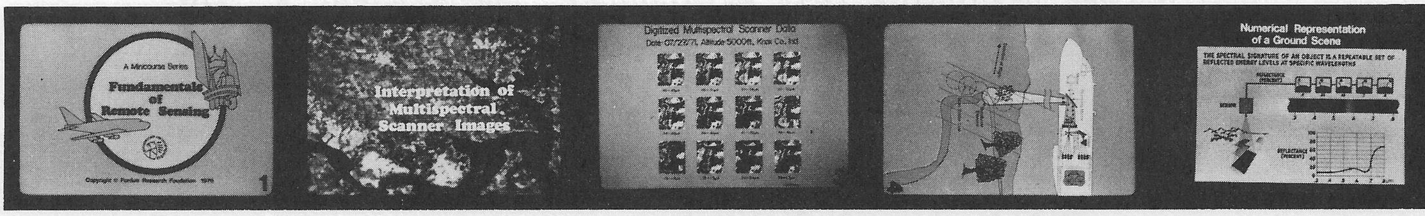
Triangular shield: Several are printed on orange cover stock in Appendix A. Cut out one and put it in the box with the slides. Others are spares if original is lost or damaged.

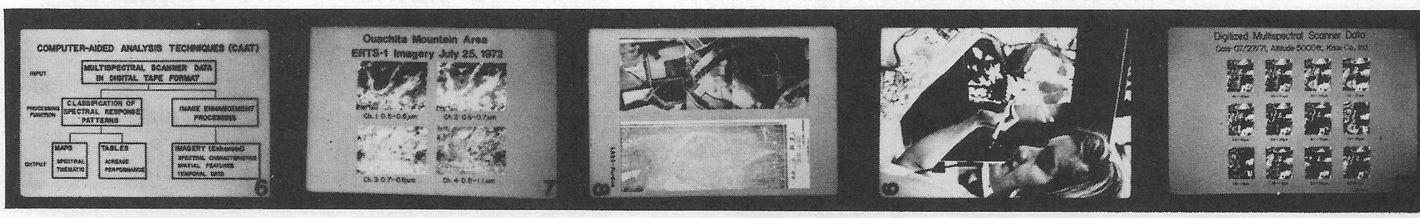
➡ Picture from newspaper: Any black-and-white newspaper photo is satisfactory, but it should have a good range of tones from light to dark. Approximately 3" x 5" is a convenient size.

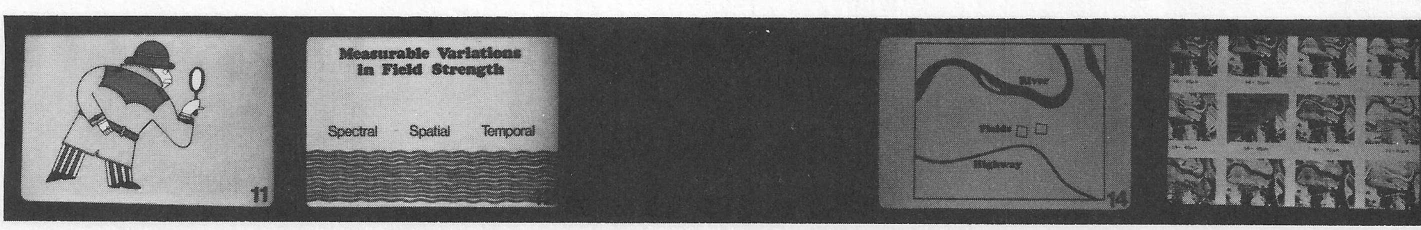
➡ (to be provided by instructor)

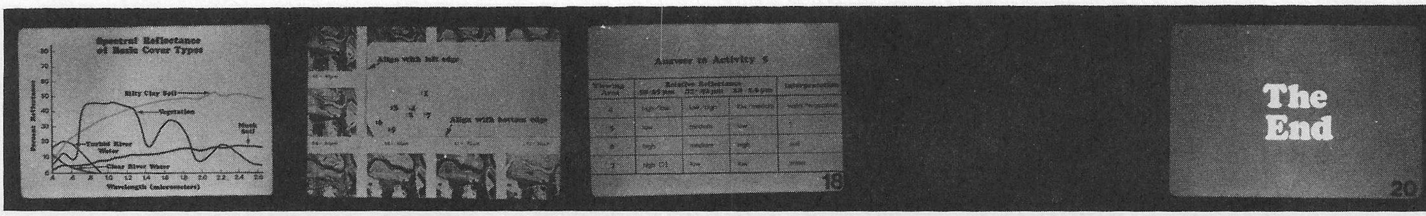
ADDITIONAL INSTRUCTOR'S NOTES

INTERPRETATION OF MULTISPECTRAL SCANNER IMAGES








Spectral Reflectance of Basic Cover Types
Silty Clay Soil
Vegetation
Turbid River Water
Clear River Water
Muck Soil
Percent Reflectance
Wavelength (micrometers)
Align with left edge
Align with bottom edge
Answers to Activity 5
18
The End
20

INTERPRETATION OF RADAR IMAGERY

SUMMARY

This minicourse provides insight into the fundamentals basic to the interpretation of radar imagery. It will introduce you to basic energy-matter interactions and to the characteristics of radar systems that must be taken into account when interpreting radar imagery. These fundamental concepts are first discussed and then demonstrated using examples of radar imagery. When finished, you should be able to interpret many earth surface features that appear on radar imagery.

OBJECTIVES

When you have completed this minicourse, you should be able to:

1. Define the general wavelength region of K, X, S and L-band radar systems.

2. List the three general factors controlling the amplitude of the radar signal returning from the ground scene.

3. List two key characteristics of surface materials that influence the radar return.

4. State the relationship between the dielectric constant of a material, its moisture content, and the radar return, assuming all other factors remain constant.

5. Describe the relative level of response of a K-band radar signal from the following earth surface features or cover types, and describe why the object has such a level of response: water; a paved road or a concrete airport runway; a forest canopy; buildings and most bridges; railroad tracks; mature corn vs. immature corn; corn vs. alfalfa or grass (both green, immature); exposed soil in either a wet or dry condition.

6. Identify the direction of flight of the airplane used in collecting radar data, based upon your interpretation of radar shadows.

7. Describe a major advantage and a major disadvantage of radar systems operating at relatively short wavelengths compared to those operating at relatively long wavelengths.

TIME: 1 hour

-- PROJECT THE FIRST SLIDE --

-- START THE TAPE --

PREREQUISITES

Before beginning this minicourse, the student should have mastered the objectives for:

Remote Sensing: What is it?

The Physical Basis of Remote Sensing

Side-Looking Airborne Radar

COMPONENTS OF MINICOURSE

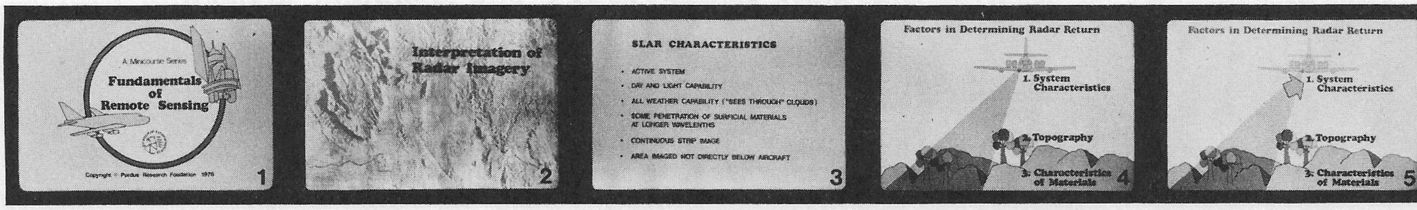
Study Guide for each student

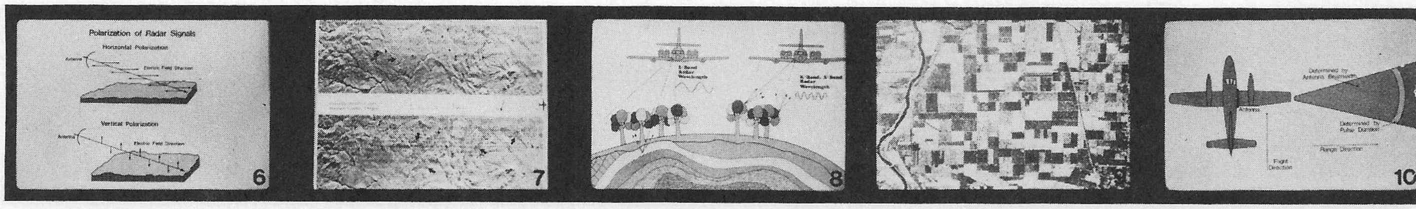
Set of 32 slides

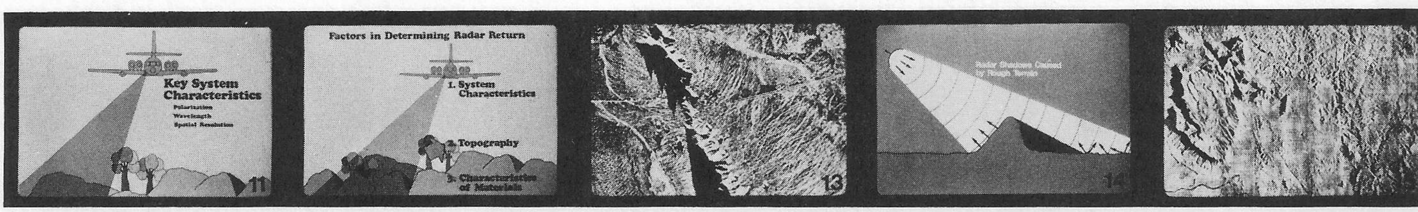
Audio Tape

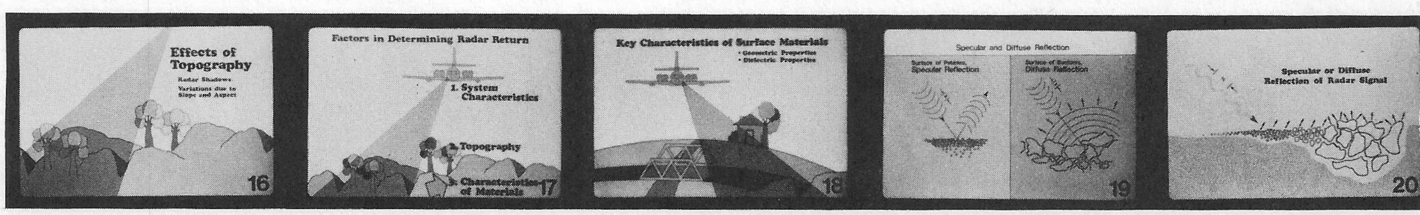
ADDITIONAL INSTRUCTOR'S NOTES

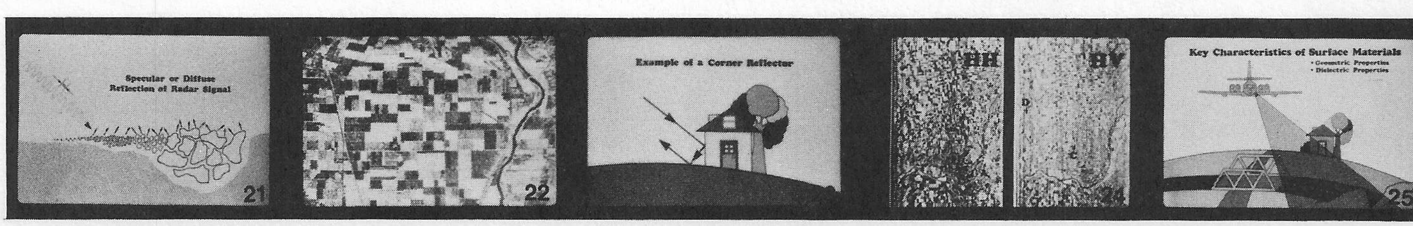
INTERPRETATION OF RADAR IMAGERY

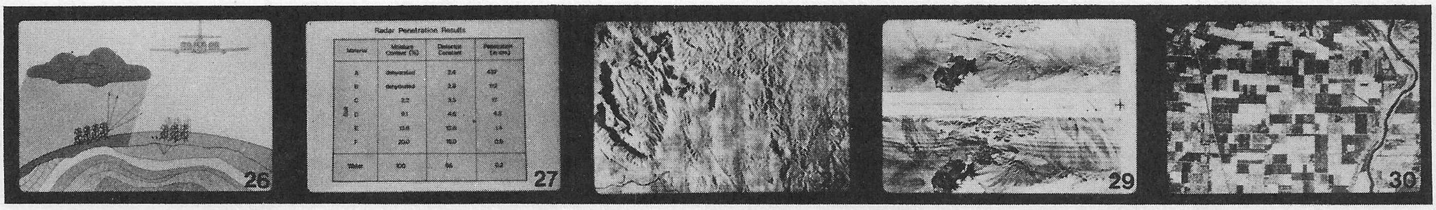


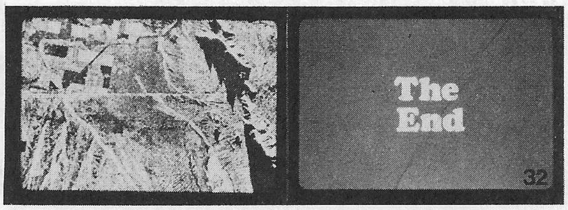









Radar Penetration Results
26
27
29
30


The
End
32

APPLICATIONS OF REMOTE SENSING IN FORESTRY

SUMMARY

Remote sensing is a useful tool for obtaining information about forested areas. Forest resource managers can draw on a wide variety of remote sensing data, choosing the data collection system best able to provide the kind of information they are seeking. In this minicourse a list of typical information needs for effective timber management provides the framework for a discussion of ways in which both photo-interpretation and the analysis of numerical data can help foresters.

OBJECTIVES

When you have completed this minicourse, you should be able to:

1. Describe a remote sensing technique appropriate for meeting each of the six listed informational needs of the timber resource manager.

2. Using a stereoscope, inspect stereo photography and draw inferences related to the forest cover.

3. List two considerations related to the natural setting of the forest that complicate the use of remote sensing by the forest resource manager.

4. Describe multi-stage sampling and state one advantage and one disadvantage of using this approach.

TIME: 1 hour

-- PROJECT THE FIRST SLIDE --

-- START THE TAPE --

PREREQUISITES

Before beginning this minicourse, the student should have mastered the objectives for:

Remote Sensing: What is it?

The Physical Basis of Remote Sensing

COMPONENTS FOR MINICOURSE

Study Guide for each student

Set of 40 slides

Audio Tape

Stereo photograph: Included with slides

➡ Stereoscope: There are many available commericially. An acceptable one is Pocket Stereo Viewer Model PS-2 from:

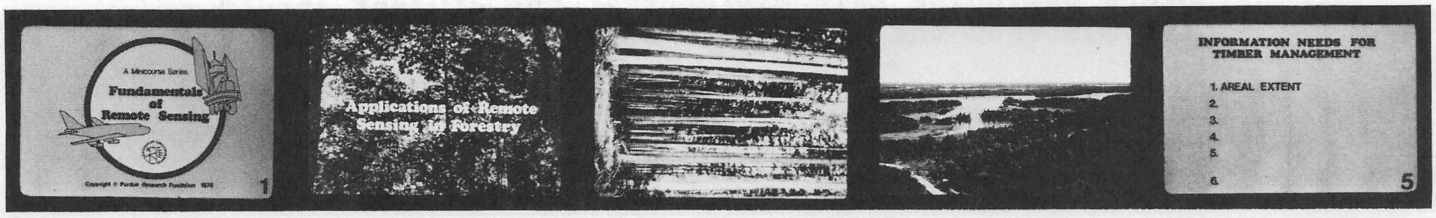
Air Photo Supply Corporation
Yonkers, New York 10705

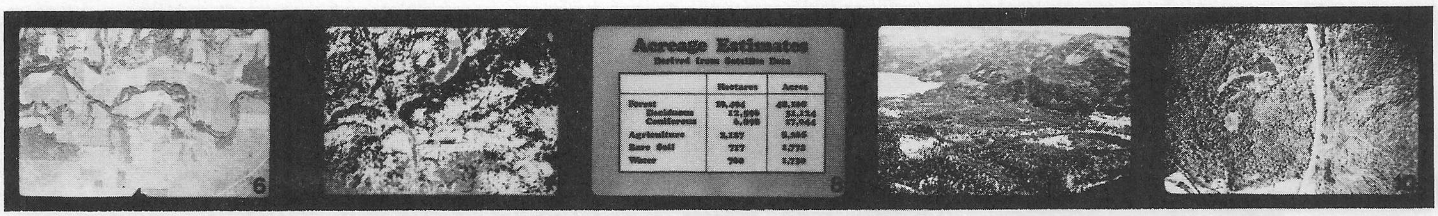
--1976 price was $10.95

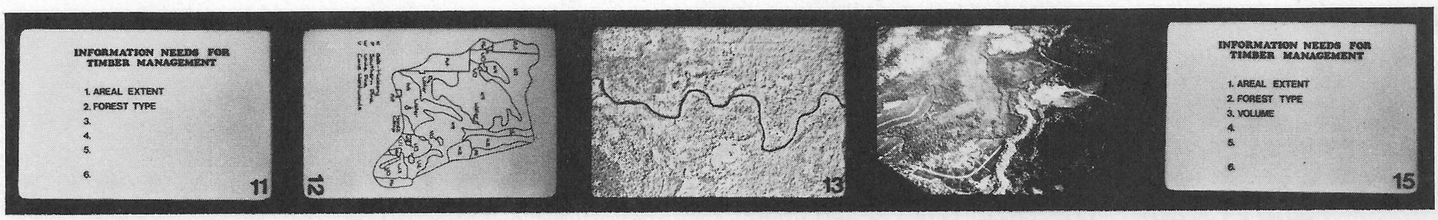
➡ (to be provided by instructor)

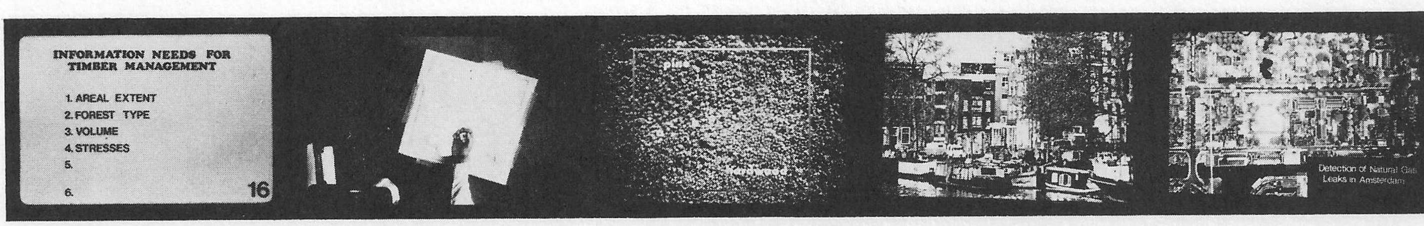
ADDITIONAL INSTRUCTOR'S NOTES

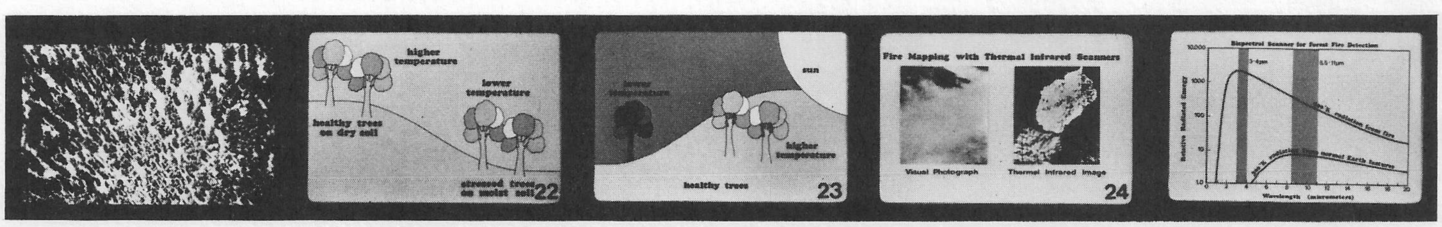
APPLICATIONS OF REMOTE SENSING IN FORESTRY

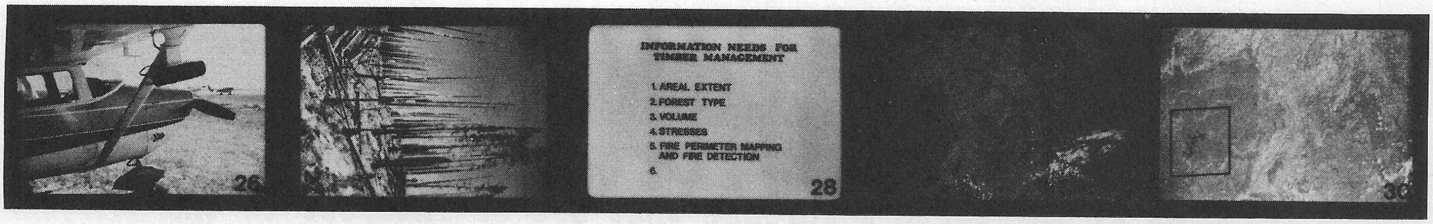


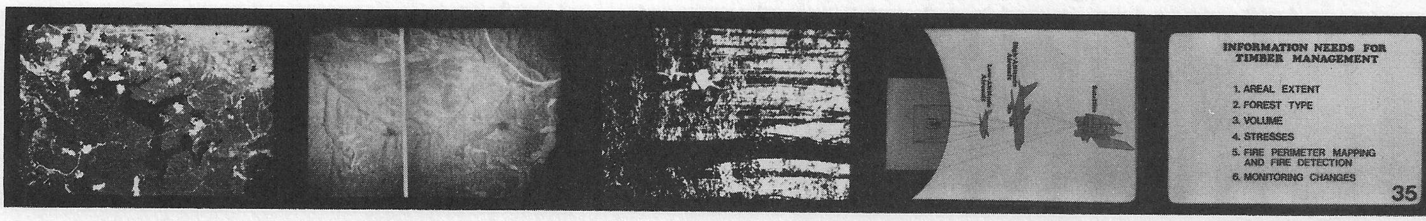









26
INFORMATION NEEDS FOR TIMBER MANAGEMENT
1. AREAL EXTENT
2. FOREST TYPE
3. VOLUME
4. STRESSES
5. FIRE PERIMETER MAPPING AND FIRE DETECTION
6.
28
30


INFORMATION NEEDS FOR TIMBER MANAGEMENT
1. AREAL EXTENT
2. FOREST TYPE
3. VOLUME
4. STRESSES
5. FIRE PERIMETER MAPPING AND FIRE DETECTION
6. MONITORING CHANGES
35


CHANGE DETECTION
CHANGES IN LAND USE CAN BE MONITORED USING COMPUTERIZED ANALYSES OF DATA FROM SEQUENTIAL REMOTE SENSING COVERAGE
36
INFORMATION NEEDS FOR TIMBER MANAGEMENT
1. AREAL EXTENT
2. FOREST TYPE
3. VOLUME
4. STRESSES
5. FIRE PERIMETER MAPPING AND FIRE DETECTION
6. MONITORING CHANGES
39
The End
40

APPLICATIONS OF REMOTE SENSING IN GEOLOGY

SUMMARY

Geology is a broad field, and hence the information needs of the geologist cover a wide range. Spectral data gathered through remote sensing can provide information about many features of the earth's surface that are of interest to the geologist. Furthermore, by combining surface observations with geologic knowledge and insights, he is able to make valid inferences about subsurface materials. Several examples are given that demonstrate how geologists can use information available through remote sensing.

OBJECTIVES

When you have completed this minicourse, you should be able to:

1. Define "geology" in terms of the present and historical features of interest to the geologist.

2. List five earth features that geologists can study directly from analysis of spectral data.

3. Describe the problem geologists face in using spectral data to study subsurface features.

4. Describe the way a geologist seeking to learn about subsurface features might use "clues" available to him through spectral data. Your description should include four "clues" he could use to locate an underground ore body, a sensor suitable for making each of these observations, and an explanation of what each clue reveals to him.

5. Define the term "synoptic view" and explain why this new capability is of importance to the geologist. Include a specific example of work done in conjunction with either mineral exploration or geomorphologic studies.

TIME: 1¼ hours

-- PROJECT THE FIRST SLIDE --

-- START THE TAPE --

PREREQUISITES

Before beginning this minicourse, the student should have mastered the objectives for:

Remote Sensing: What is it?

The Physical Basis of Remote Sensing

COMPONENTS OF MINICOURSE

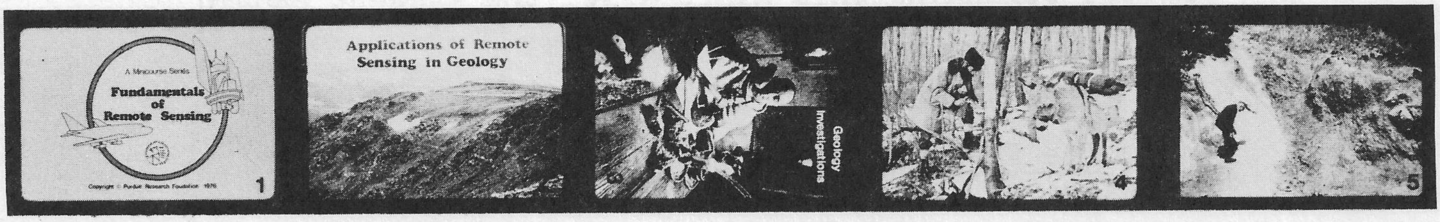
Study Guide for each student

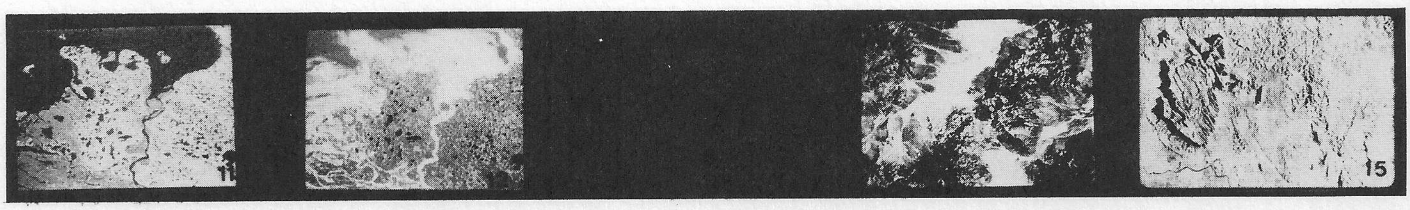
Set of 36 slides

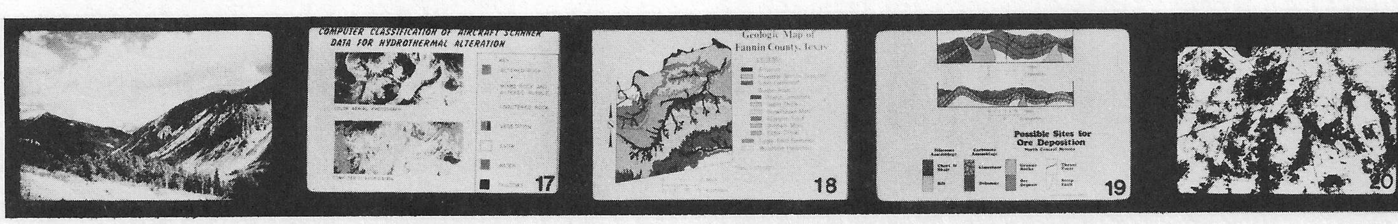
Audio Tape

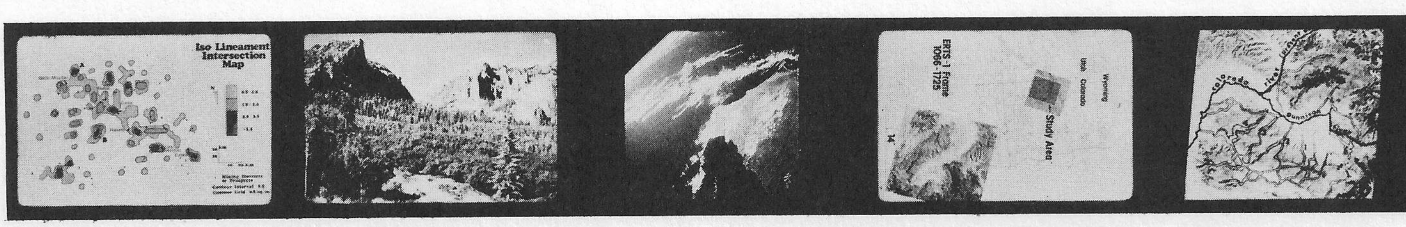
ADDITIONAL INSTRUCTOR'S NOTES

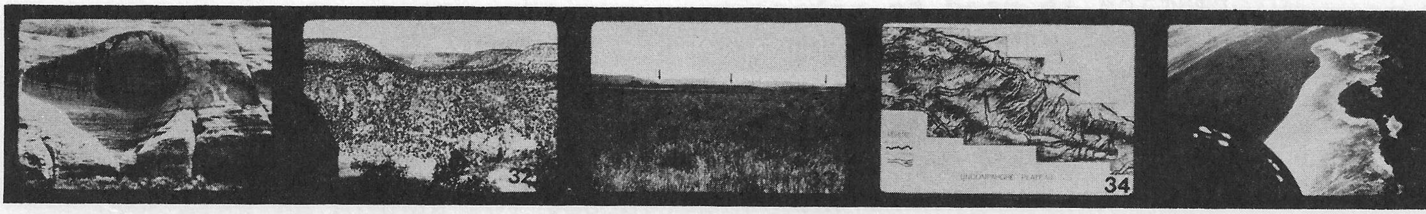
APPLICATIONS OF REMOTE SENSING IN GEOLOGY

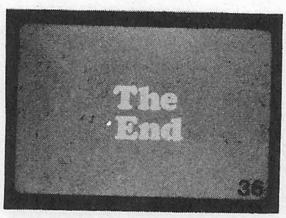









32
34


The
End
36

CROP SURVEYS THROUGH REMOTE SENSING

SUMMARY

Effective production and management of the world's food supply depends in part on man's knowledge of the current and potential food supplies and their location throughout the world. Remote sensing has been successfully used for making various kinds of crop surveys both in research and in operational projects. Both image-oriented and numerically oriented analysis approaches have been used to identify crops, to assess their vigor, and to determine the ground area of specific crops. This information is used to calculate production forecasts and production estimates.

OBJECTIVES

When you have completed this minicourse, you should be able to:

1. List three kinds of information about crops available through remote sensing.
2. Name two kinds of photography used in making crop surveys.
3. State two advantages and one disadvantage of using satellite data instead of aircraft data for crop surveys.
4. Explain by example how multispectral and multitemporal data can aid in crop identification.
5. Describe how remote sensing can be used to estimate the ground area of a crop.
6. Name the most useful spectral region for assessing crop vigor and explain why it is useful.
7. Name two kinds of information needed to make crop production estimates and describe how remote sensing can aid in acquiring this information.

TIME: 1¼ hours

-- PROJECT THE FIRST SLIDE --

-- START THE TAPE --

PREREQUISITES

Before beginning this minicourse, the student should have mastered the objectives for:

<u>Remote Sensing: What is it?</u>

<u>The Physical Basis of Remote Sensing</u>

COMPONENTS OF MINICOURSE

Study Guide for <u>each</u> student

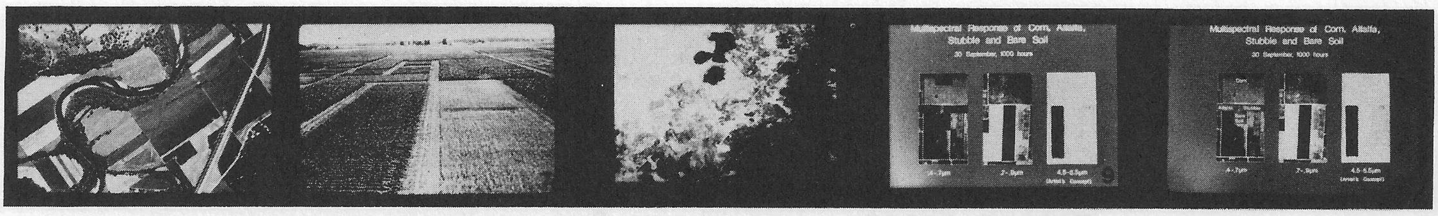
Set of 34 slides

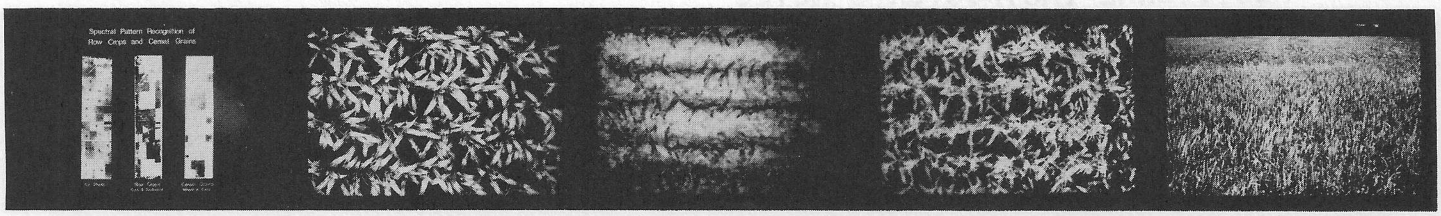
Audio Tape

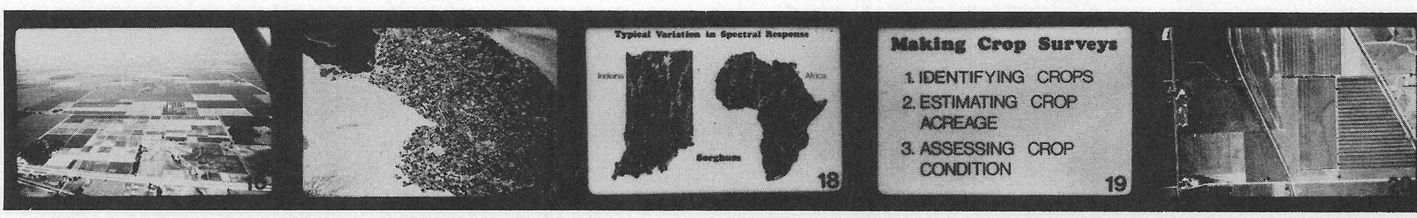
Acetate Overlay showing appearance of fields in May and November: One copy provided in Appendix A along with master sheet. Use Thermofax or Xerox to made additional copies.

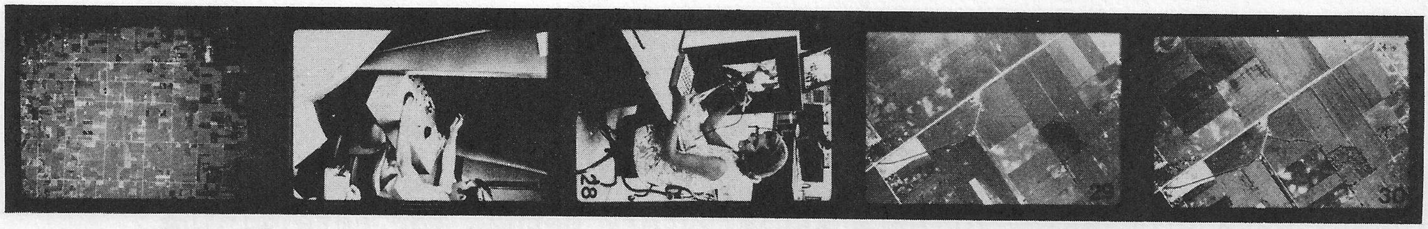
ADDITIONAL INSTRUCTOR'S NOTES

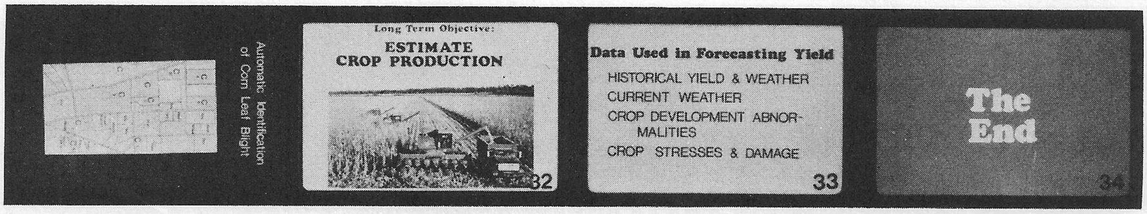
CROP SURVEYS THROUGH REMOTE SENSING








28
29
30


Automatic Identification
of Corn Leaf Blight
Long Term Objective:
ESTIMATE
CROP PRODUCTION
32
Data Used in Forecasting Yield
HISTORICAL YIELD & WEATHER
CURRENT WEATHER
CROP DEVELOPMENT ABNOR-
MALITIES
CROP STRESSES & DAMAGE
33
The
End
34

TEMPERATURE MAPPING OF WATER BY REMOTE SENSING

SUMMARY

In order to make decisions about water quality, rapid and accurate means of evaluating water pollution levels must be readily available. Remote sensing and computer-aided data processing offer a satisfactory method for determining water quality parameters, such as temperature, in a quantitative manner and over large geographic areas in a relatively short time. Internal calibration methods alleviate the need for ground-gathered data.

OBJECTIVES

When you have completed this minicourse, you should be able to:

1. Describe in sequence the four processing steps recommended for producing a water temperature map using remotely sensed data.

2. Explain the purpose of the "scan-line averaging" procedure and "layered classification."

3. Describe the characteristics of the spectral response of water beyond 0.9μm as compared to those for soils and vegetation.

4. State the major advantage of the "internal calibration" method.

5. Determine the temperature of a water body when given its relative radiance and the radiances and temperatures of the internal calibration plates.

6. Identify the optimum wavelength band and aircraft altitude for temperature mapping of water bodies.

TIME: 1 hour

-- PROJECT THE FIRST SLIDE --

-- START THE TAPE --

PREREQUISITES

Before beginning this minicourse, the student should have mastered the objectives for:

Remote Sensing: What is it?

The Physical Basis of Remote Sensing

Multispectral Scanners

COMPONENTS OF MINICOURSE

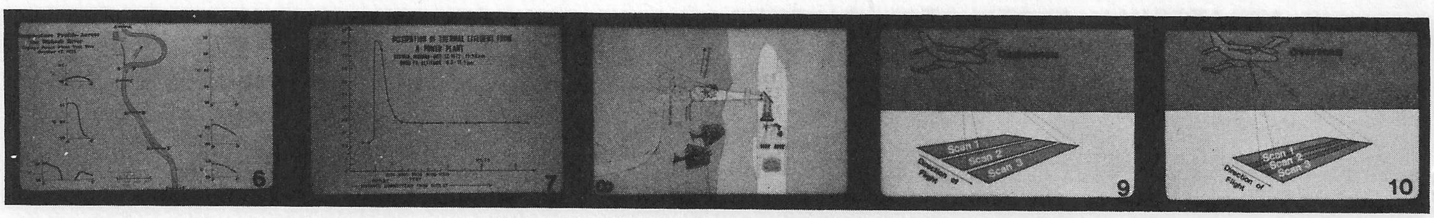
Study Guide for each student

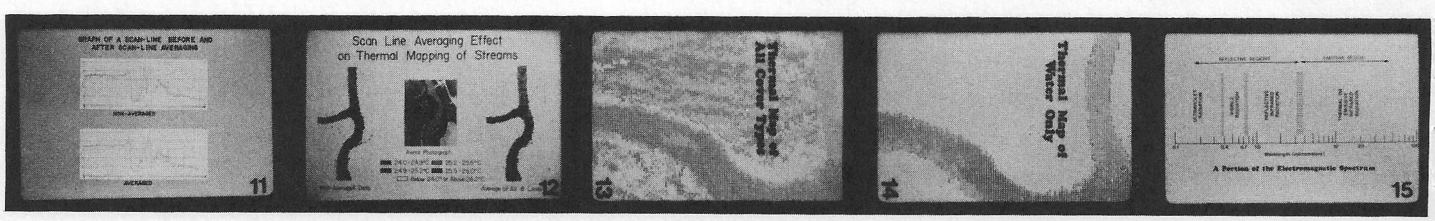
Set of 24 slides

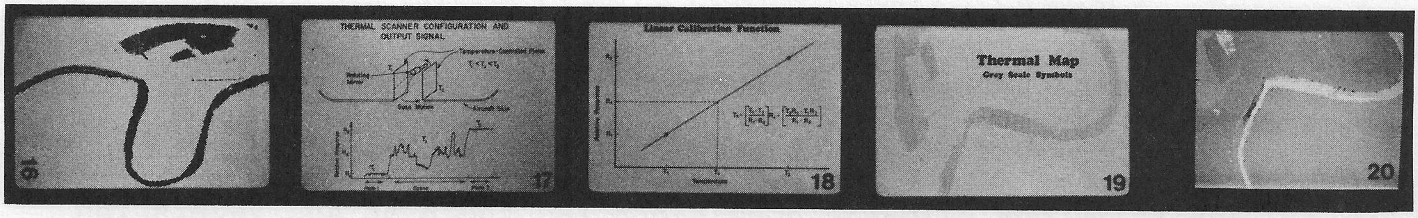
Audio Tape

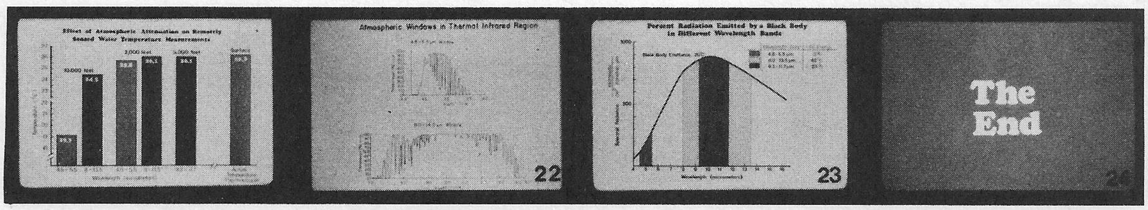
ADDITIONAL INSTRUCTOR'S NOTES

TEMPERATURE MAPPING OF WATER BY REMOTE SENSING






16
THERMAL SCANNER CONFIGURATION AND
OUTPUT SIGNAL
17
Linear Calibration Function
18
Thermal Map
Grey Scale Symbols
19
20


Effect of Atmospheric Attenuation on Remotely
Sensed Water Temperature Measurements
Atmospheric Windows in Thermal Infrared Region
22
Percent Radiation Emitted by a Black Body
in Different Wavelength Bands
23
The
End
24

SELECTING LANDSAT IMAGERY

SUMMARY

This minicourse is designed to help potential users of Landsat imagery select imagery that can best yield the kinds of information needed in various natural resource surveys. Through a step-by-step procedure, you will first learn how to determine what imagery is available for your survey area and then how to select the scenes that would be most useful to you. Analyzing the climatic conditions and the crop and vegetation cycles for the survey area are key steps in the procedure. Some guidance is given in selecting Landsat standard products appropriate to the facilities available and the expected level of mapping detail.

PREREQUISITES

This minicourse is designed for students who:

- have experience in natural resources surveying or a related field;
- have a basic knowledge of the methods of photo-interpretation
- have completed the three prerequisite minicourses in this series or have met the objectives through other study and/or experience.

OBJECTIVES

When you have completed this minicourse, you should be able to:

1. Describe one benefit to the user related to each of the three image characteristics of Landsat data.
2. Compare the spectral, spatial and temporal resolution of Landsat multispectral scanner imagery with that of small-scale aerial photography.
3. List the six criteria used in selecting Landsat imagery for analysis.
4. Construct a precipitation/temperature diagram and use it to select the best times of year for surveys, based on soil-moisture conditions.
5. Use a crop calendar to determine the best months for surveying specific crops and/or land-use patterns.
6. Determine through plotting coordinates whether correct image sidelap is present in the available Landsat imagery to provide image enhancement (e.g., multitemporal analysis, stereoscopic viewing.)
7. Decide which Landsat standard product(s) to order for analysis, taking into consideration the objectives of the survey and the facilities available for doing the analysis.

TIME: 1¼ hours

-- PROJECT THE FIRST SLIDE --

-- START THE TAPE --

PREREQUISITES

Before beginning this minicourse, the student should have mastered the objectives for:

Remote Sensing: What is it?

The Physical Basis of Remote Sensing

Landsat: An Earth Resources Satellite System

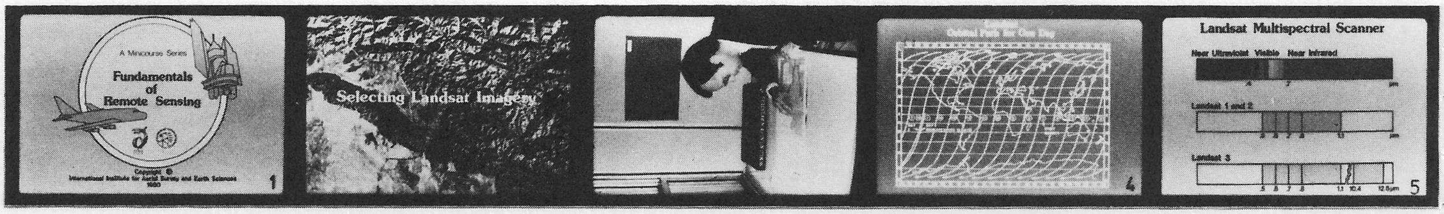
COMPONENTS OF MINICOURSE

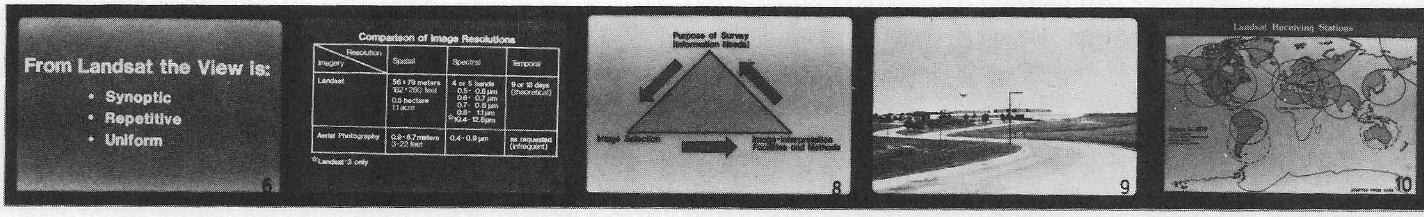
Study Guide for each student

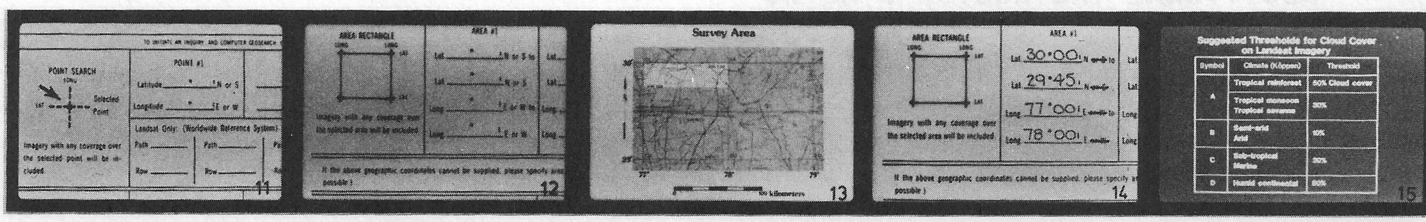
Set of 41 slides

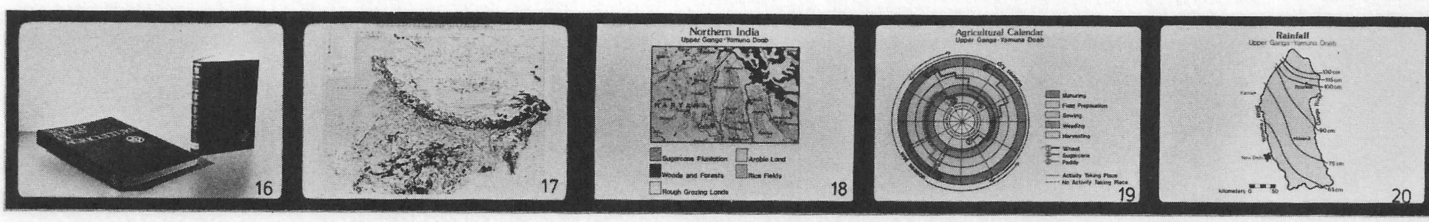
Audio tape

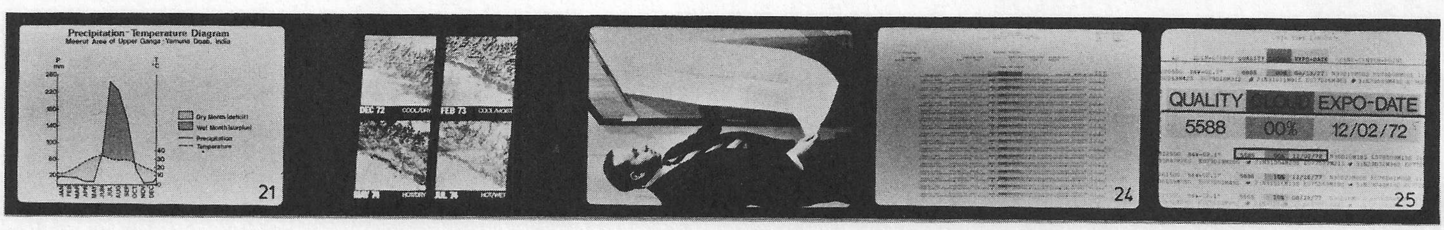
ADDITIONAL INSTRUCTOR'S NOTES

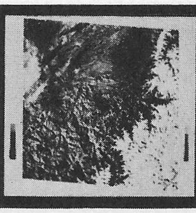

A Minicourse Series
Fundamentals of Remote Sensing
Copyright ©
International Institute for Aerial Survey and Earth Sciences
1
Selecting Landsat Imagery
Orbital Path for One Day
4
Landsat Multispectral Scanner
Near Ultraviolet Visible Near Infrared
Landsat 1 and 2
Landsat 3
5

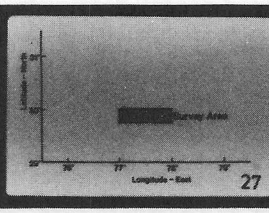

From Landsat the View is:
• Synoptic
• Repetitive
• Uniform
6
Comparison of Image Resolutions
Resolution
Imagery
Spatial
Spectral
Temporal
Landsat
56 × 79 meters
182 × 260 feet
0.5 hectare
1.1 acre
4 or 5 bands
9 or 18 days (theoretical)
Aerial Photography
0.9 - 6.7 meters
3-22 feet
0.4 - 0.9 µm
as requested (infrequent)
*Landsat 3 only
Purpose of Survey (Information Needs)
Image Selection
Image-Interpretation Facilities and Methods
8
9
Landsat Receiving Stations
10

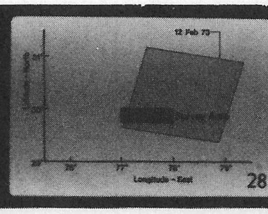

POINT SEARCH
POINT #1
Latitude
Longitude
Landsat Only: (Worldwide Reference System)
Path
Row
Imagery with any coverage over the selected point will be included.
11
AREA RECTANGLE
AREA #1
Imagery with any coverage over the selected area will be included
If the above geographic coordinates cannot be supplied, please specify area possible.)
12
Survey Area
Kilometers
13
AREA RECTANGLE
AREA #1
Lat 30°00'
Lat 29°45'
Long 77°00'
Long 78°00'
Imagery with any coverage over the selected area will be included
If the above geographic coordinates cannot be supplied, please specify area possible.)
14
Suggested Thresholds for Cloud Cover on Landsat Imagery
Symbol
Climate (Köppen)
Threshold
A
Tropical rainforest
50% Cloud cover
Tropical monsoon
Tropical savanna
30%
B
Semi-arid
Arid
10%
C
Sub-tropical
Marine
30%
D
Humid continental
60%
15

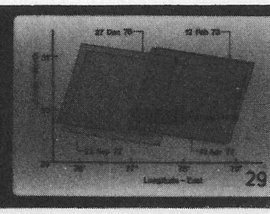

16
17
Northern India
Upper Ganga-Yamuna Doab
Sugarcane Plantation
Arable Land
Woods and Forests
Rice Fields
Rough Grazing Lands
18
Agricultural Calendar
Upper Ganga-Yamuna Doab
19
Rainfall
Upper Ganga-Yamuna Doab
20

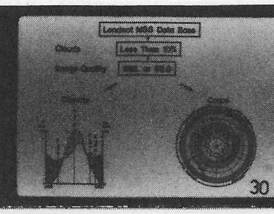

Precipitation-Temperature Diagram
Meerut Area of Upper Ganga-Yamuna Doab, India
21
DEC 72
FEB 73
MAY 74
JUL 74
24
QUALITY
CLOUD
EXPO-DATE
5588
00%
12/02/72
25

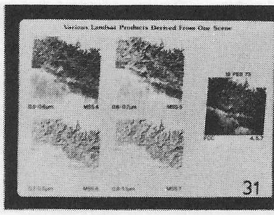


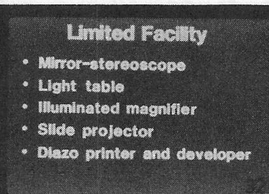

Survey Area
Longitude - East
27

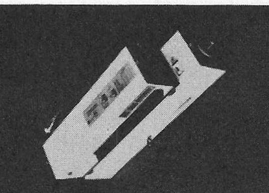

12 Feb 73
Longitude - East
28

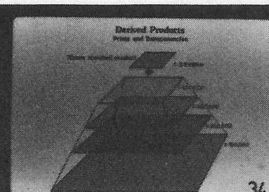

12 Feb 73
Longitude - East
29

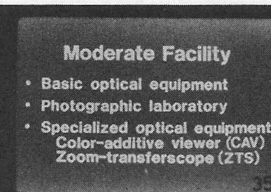

Landsat MSS Data Base
Less Than 10%
30

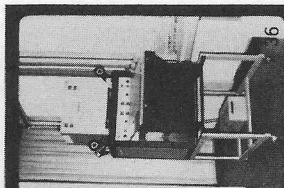

Various Landsat Products Derived From One Scene
31

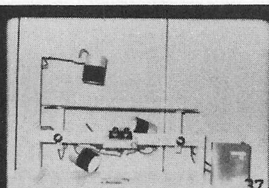

Limited Facility
• Mirror-stereoscope
• Light table
• Illuminated magnifier
• Slide projector
• Diazo printer and developer
32

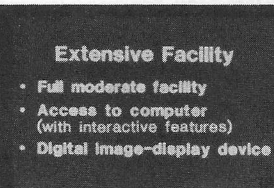


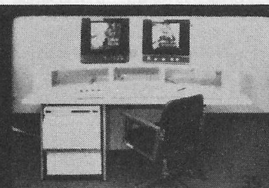

Derived Products
34

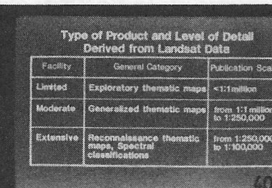

Moderate Facility
• Basic optical equipment
• Photographic laboratory
• Specialized optical equipment
Color-additive viewer (CAV)
Zoom-transferscope (ZTS)
35


36


37


Extensive Facility
• Full moderate facility
• Access to computer
(with interactive features)
• Digital image-display device
38


39


Type of Product and Level of Detail
Derived from Landsat Data
Facility
General Category
Publication Scale
Limited
Exploratory thematic maps
<1:1million
Moderate
Generalized thematic maps
from 1:1 million to 1:250,000
Extensive
Reconnaissance thematic maps, Spectral classifications
from 1:250,000 to 1:100,000
40


The
End
41

SPECTRAL MEASUREMENTS FOR FIELD RESEARCH

SUMMARY

Field research includes the study of scene characteristics in a controlled experiment under field or field-like conditions. The four phases of field research are: experiment design, acquisition, preprocessing, and analysis. The spectral characteristics of targets such as crops, water and soils can be determined through field research. Bidirectional Reflectance Distribution Function and Bidirectional Reflectance Factor describe the radiation interaction characteristics of a surface. The results of field research are used to develop improved techniques for estimating crop area and production, surveying soils, monitoring crop stresses and similar applications.

OBJECTIVES

When you have completed this minicourse, you should be able to:

1. Describe field research.
2. List in order and briefly describe the four phases of field research.
3. State the relationship between Bidirectional Reflectance Distribution Function (BRDF) and Bidirectional Reflectance Factor (BRF) and how they are used.
4. Identify five types of data collected during field research.
5. Describe the purpose and output of the preprocessing phase of field research.
6. Discuss examples of applications of field research for determining the spectral characteristics of natural targets.

TIME: 1 hour

-- PROJECT THE FIRST SLIDE--

-- START THE TAPE --

PREREQUISITES

Before beginning this minicourse, the student should have mastered the objectives for:

Remote Sensing: What is it?

The Physical Basis of Remote Sensing

Spectral Reflectance Characteristics of Vegetation

Spectral Reflectance Characteristics of Earth Surface Features

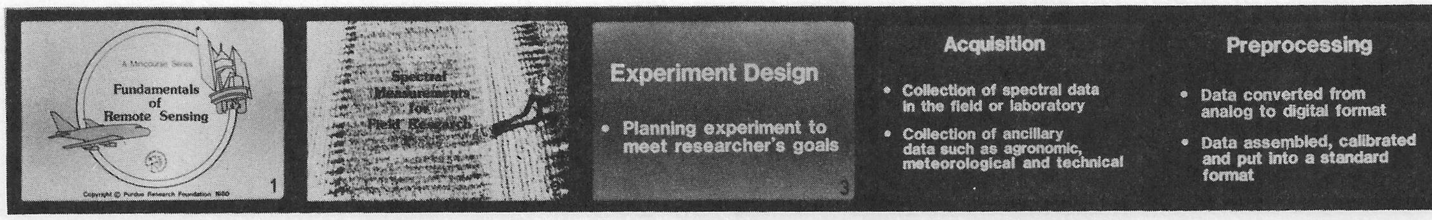
COMPONENTS OF MINICOURSE

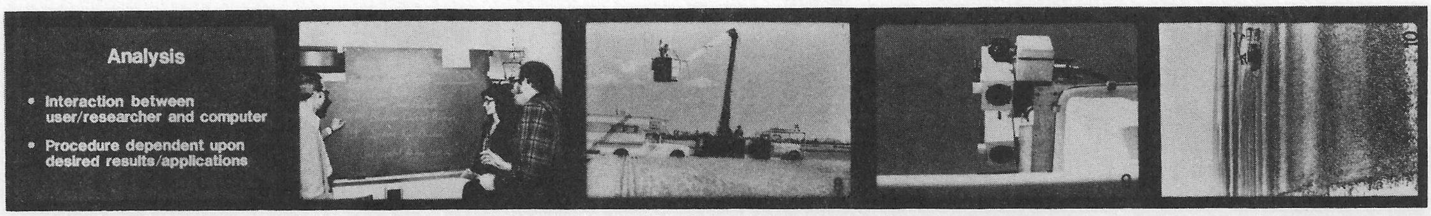
Study Guide for each student

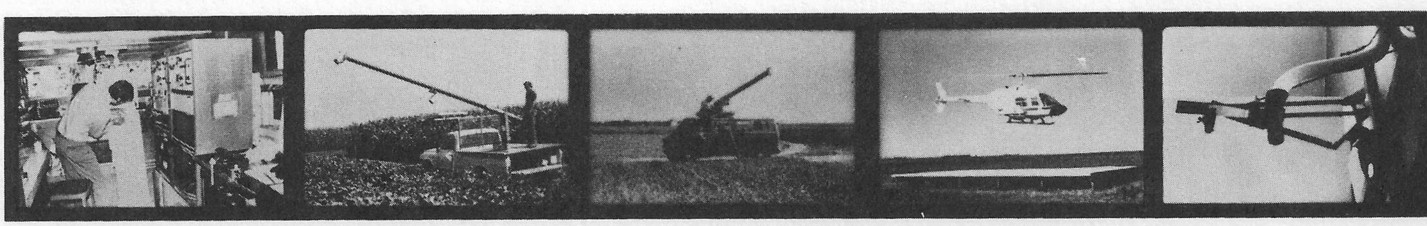
Set of 34 slides

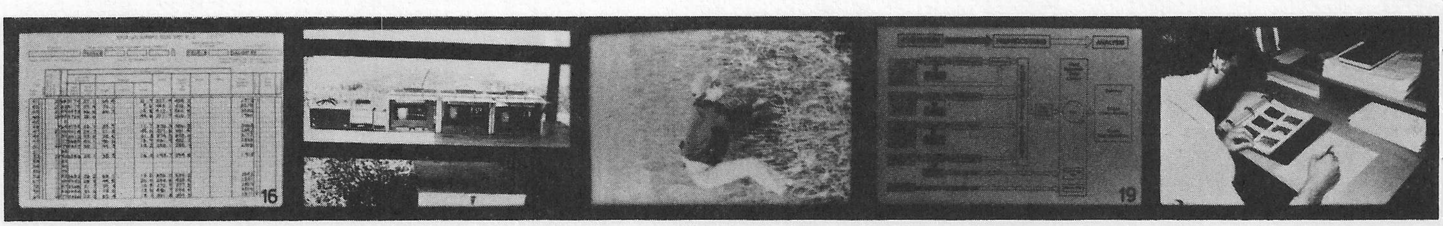
Audio tape

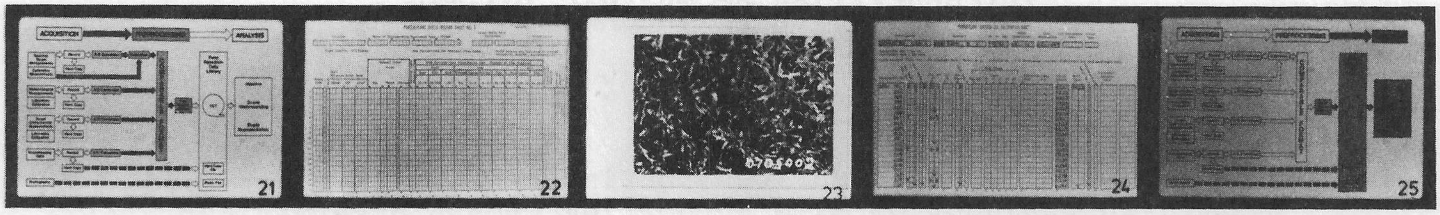
ADDITIONAL INSTRUCTOR'S NOTES

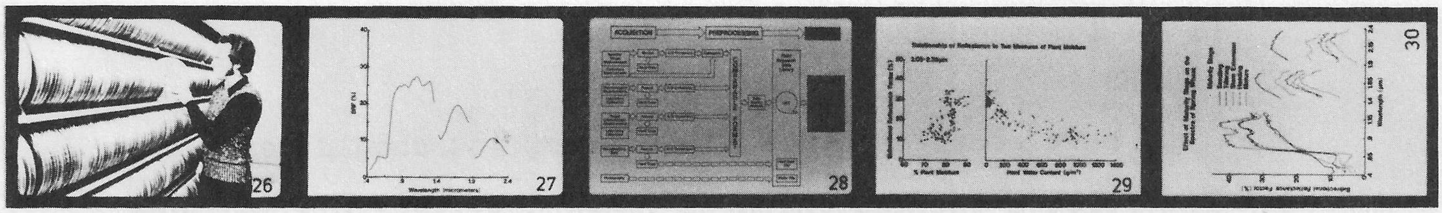

A Minicourse Series
Fundamentals of Remote Sensing
Copyright © Purdue Research Foundation 1980
1
Spectral Measurements for Field Research
Experiment Design
• Planning experiment to meet researcher's goals
3
Acquisition
• Collection of spectral data in the field or laboratory
• Collection of ancillary data such as agronomic, meteorological and technical
Preprocessing
• Data converted from analog to digital format
• Data assembled, calibrated and put into a standard format

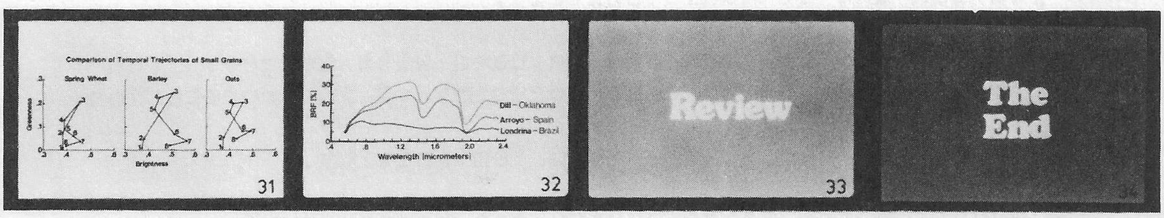

Analysis
• Interaction between user/researcher and computer
• Procedure dependent upon desired results/applications




16
19


ACQUISITION
ANALYSIS
21
22
23
24
25


26
27
ACQUISITION
PREPROCESSING
28
29
30


Comparison of Temporal Trajectories of Small Grains
Spring Wheat
Barley
Oats
Greenness
Brightness
31
BRF (%)
Dill – Oklahoma
Arroyo – Spain
Londrina – Brazil
Wavelength (micrometers)
32
Review
33
The
End
34

INTERPRETATION OF THERMAL IMAGERY

SUMMARY

This minicourse describes the interpretation of thermal imagery in conjunction with supporting ground observations. A review of thermal energy and its associated terminology is included. The relationship among the MSS parameters used in radiation detection is illustrated. The minicourse introduces the concepts of radiance, radiant exitance, emittance and emissivity. Applications of thermal imagery in heat-loss assessment, forest fire detection, water temperature mapping and thermal mapping of land use are included.

OBJECTIVES

When you have completed this minicourse, you should be able to:

1. Interpret a thermal infrared image qualitatively in terms of relative temperatures.
2. Define the following terms: radiance, irradiance and kinetic temperature.
3. Recognize when you can use thermal imagery quantitatively, and when you can use it qualitatively.
4. Describe how thermal imagery can be used with imagery from other spectral bands to increase accuracy of interpretation.
5. Distinguish between "emittance" and "emissivity."
6. Given the equation for noise-equivalent temperature and its relation to multispectral scanner parameters, calculate the effect of changing any one parameter on any other parameter.
7. Discuss two possible applications of thermal infrared imagery.
8. State the wavelength regions over which photon thermal detectors are usually operated.

SPECIAL EQUIPMENT NEEDED

Four aerial images of Fort Wayne, Indiana (three black-and-white and one color), marked acetate overlay, street map of Fort Wayne and Allen County, calculator (optional).

TIME: 1 hour and 30 minutes

-- PROJECT THE FIRST SLIDE --

-- START THE TAPE --

PREREQUISITES

Before beginning this minicourse, the student should have mastered the objectives for:

Remote Sensing: What is it?

The Physical Basis of Remote Sensing

Multispectral Scanners

COMPONENTS OF MINICOURSE

Study Guide for each student

Set of 28 slides

Audio tape

Three black-and-white and one color image of Fort Wayne, Indiana.

Acetate overlay marked to identify key features of the scene.

Street map of Fort Wayne and Allen County

The student may find it helpful to have a calculator to use for the exercises.

ADDITIONAL INSTRUCTOR'S NOTES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Fundamentals of Remote Sensing
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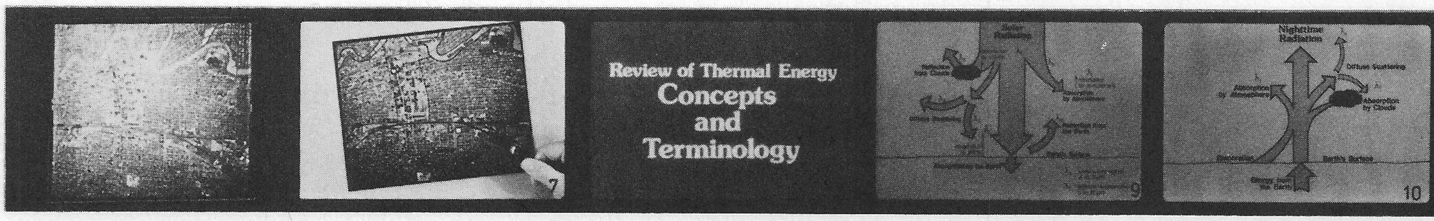
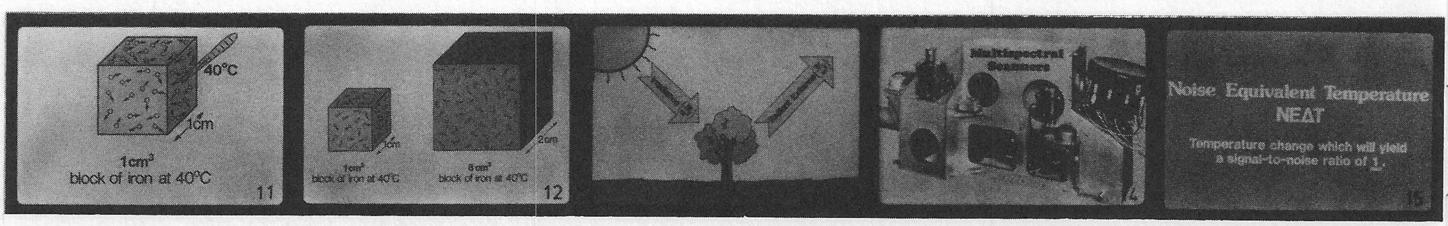
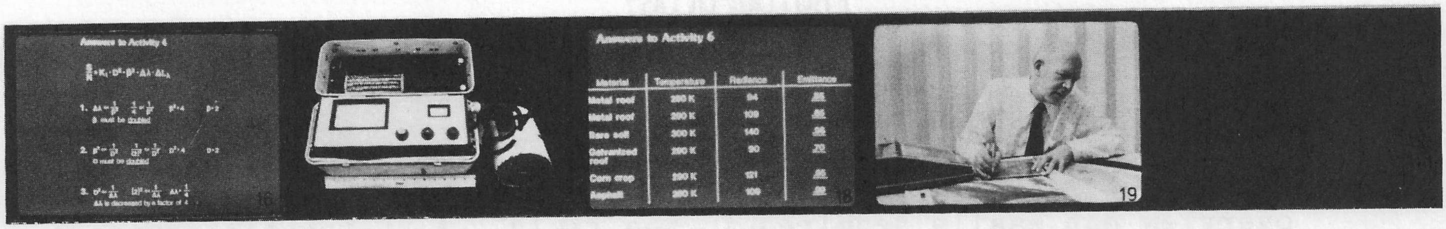
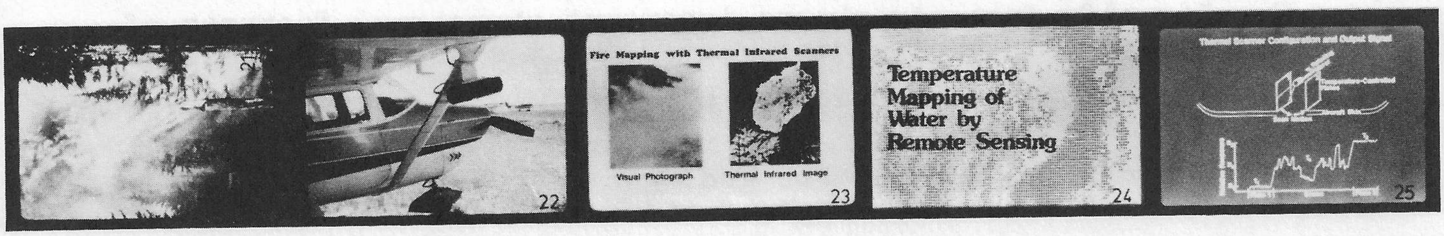
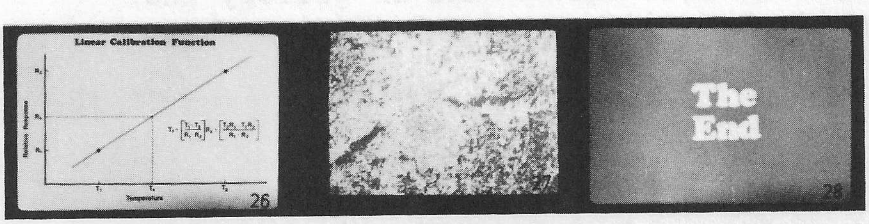
1
Interpretation of Thermal Imagery
5


7
Review of Thermal Energy
Concepts and Terminology
9
Nighttime Radiation
Diffuse Scattering
Absorption by Atmosphere
Absorption by Clouds
Earth's Surface
Energy from the Earth
10


40°C
1cm
1cm³
block of iron at 40°C
11
1cm³
block of iron at 40°C
8 cm³
block of iron at 40°C
2cm
12
Multispectral Scanners
Noise Equivalent Temperature
NEΔT
Temperature change which will yield a signal-to-noise ratio of 1.
15


Answers to Activity 4
16
Answers to Activity 6
Material
Temperature
Radiance
Emittance
Metal roof
Metal roof
Bare soil
Galvanized roof
Corn crop
Asphalt
18
19


22
Fire Mapping with Thermal Infrared Scanners
Visual Photograph
Thermal Infrared Image
23
Temperature Mapping of Water by Remote Sensing
24
Thermal Scanner Configuration and Output Signal
25


Linear Calibration Function
Temperature
26
27
The End
28

PHOTOGEOLOGY

SUMMARY

Through the interpretation of aerial photographs, geologists can quickly gain geologic information that is useful in planning subsequent field work. They can, as well, gain a regional overview not easily acquired in the field. A systematic approach based on the interpretation of image elements (tone, texture, pattern, shape and slope) and interpretation elements (outcrops, landforms, drainage, vegetation, and cultivation) enables geologists to deduce the probable lithologic and structural characteristics of the area of interest.

OBJECTIVES

When you have completed this minicourse, you should be able to:

1. Identify common rock types on air photo images of outcrops.
2. Identify from air photos important structural features of an area, including dips, anticlines, synclines and faults.
3. Sketch a cross-section of a selected area using a stereoscope and air photos.
4. Describe an approach to geologic image-interpretation that is useful where geologic features are obscured by vegetation.
5. Perform a geologic analysis that shows lithologic boundaries, drainage patterns, and basic structural features using air photos and a stereoscope.
6. Name the probable lithologies and structures in the area analyzed for objective 5, stating the reasons for your deductions and the degree of confidence you place in these deductions.

SPECIAL PREREQUISITES

Students will need to have a basic background in geology and be able to see stereoscopically using a pocket stereoscope and stereograms.

SUPPLIES NEEDED

- a pocket stereoscope
- annotated overlay transparency accompanying the minicourse
- a sheet of clear acetate and marking pens in red, black, and blue.

APPROXIMATE TIME: 2 hours with intermission at mid-point.

-- PROJECT THE FIRST SLIDE --

-- START THE TAPE --

PREREQUISITES

Before beginning this minicourse, the student should have mastered the objectives for:

Remote Sensing: What is it?

The Physical Basis of Remote Sensing

COMPONENTS OF MINICOURSE

Study Guide for each student

Set of 33 slides

Audio tape

Annotated transparent overlay supplied with minicourse

➡ Pocket Stereoscope--to be provided by the instructor. There are many models available commercially. An acceptable one is the Pocket Stereo Viewer, Model PS-2, from:

Air Photo Supply Corporation
Yonkers, New York 10705

➡ Marking pens in red, black, and blue--to be provided by instructor.

ADDITIONAL INSTRUCTOR'S NOTES


A Minicourse Series
Fundamentals of Remote Sensing
Delineation
Identification
3
5

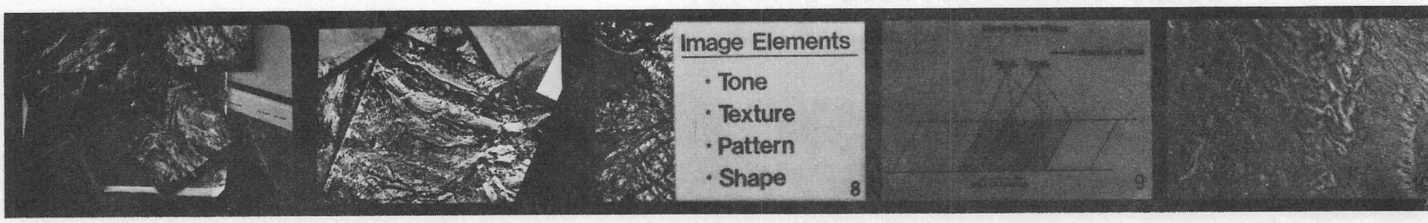
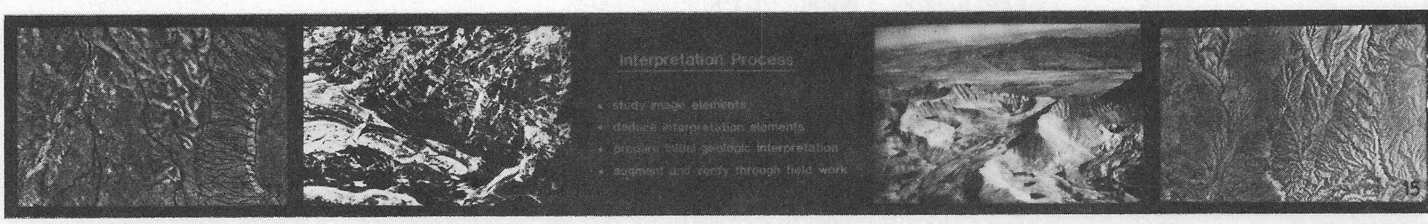
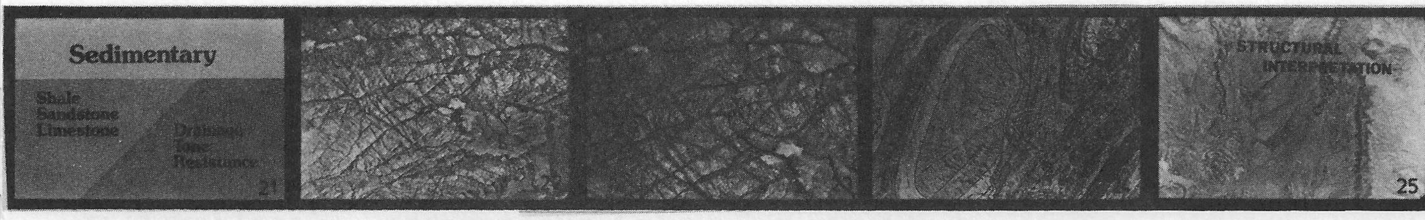


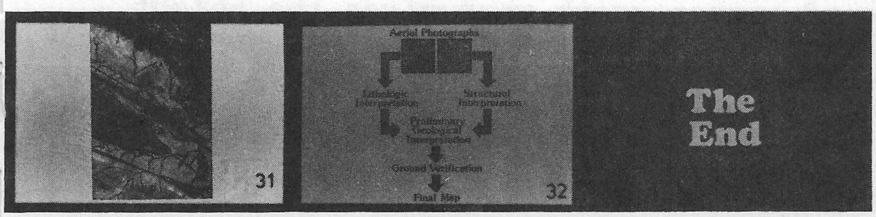
Image Elements
· Tone
· Texture
· Pattern
· Shape
8
9


Interpretation Process
study image elements
deduce interpretation elements
prepare initial geologic interpretation
augment and verify through field work
15


17
20


Sedimentary
Shale
Sandstone
Limestone
Drainage
Tone
Resistance
21
STRUCTURAL
INTERPRETATION
25


26
27
29
30


31
Aerial Photographs
Lithologic Interpretation
Structural Interpretation
Preliminary Geological Interpretation
Ground Verification
Final Map
32
The End

PRINCIPLES OF PHOTOINTERPRETATION

SUMMARY

This minicourse presents concepts basic to the interpretation and measurement of objects on aerial photographs. Consideration is given to the types of film available, typical scales used in photointerpretation and the procedures for calculating scale. The seven "key elements of photointerpretation" are used to identify a variety of features. Techniques for estimating area and measuring heights are described and accompanied by a basic exercise using a dot-grid and a stereoscope. Examples of the use of aerial photographs in forest management and soil survey provide a framework for the minicourse.

OBJECTIVES

When you have completed this minicourse, you should be able to:

1. State at least two ways that photointerpretation is used in forest management or soil surveys;

2. Explain the basic difference between negative and positive-emulsion films;

3. Calculate the scale of a photograph when given the height and focal length of the camera and then estimate the distance on the ground between two points on the photo;

4. Identify which of the seven key elements of photointerpretation you use to identify features on a photograph;

5. Use a dot grid to estimate the area of an irregularly shaped field;

6. Calculate the height of an object when you know the difference in parallax between the top and bottom of the object.

ADDITIONAL EQUIPMENT REQUIRED

Dot grid, pocket stereoscope.

TIME: 1½ hours

-- PROJECT THE FIRST SLIDE --

-- START THE TAPE --

PREREQUISITE

Before beginning this minicourse, the student should have mastered the objectives for:

Remote Sensing: What is it?

The Physical Basis of Remote Sensing

Photographic Sensors

COMPONENTS OF MINICOURSE

Study Guide for each students

Set of 40 slides

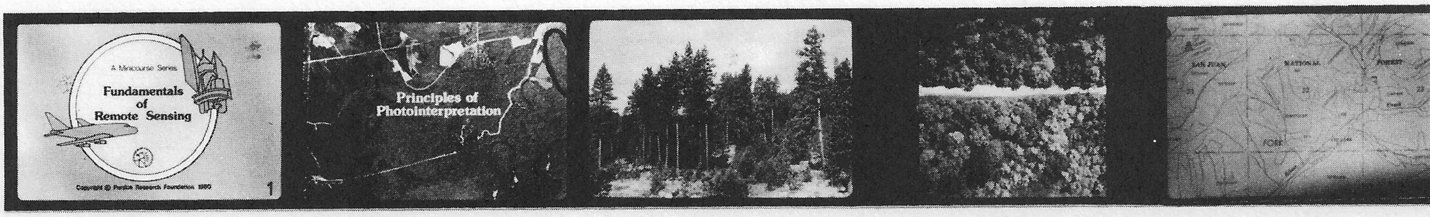
Audio tape

Dot grid supplied with minicourse

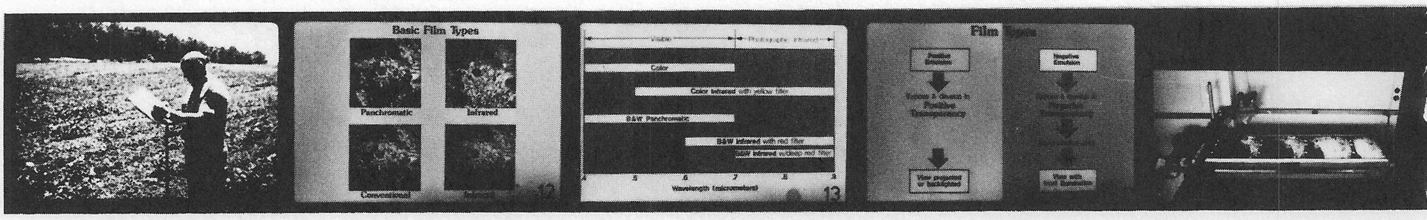
➡ Pocket Stereoscope--to be provided by the instructor. There are many models available commercially. An acceptable one is the Pocket Stereo Viewer, Model PS-2, from:

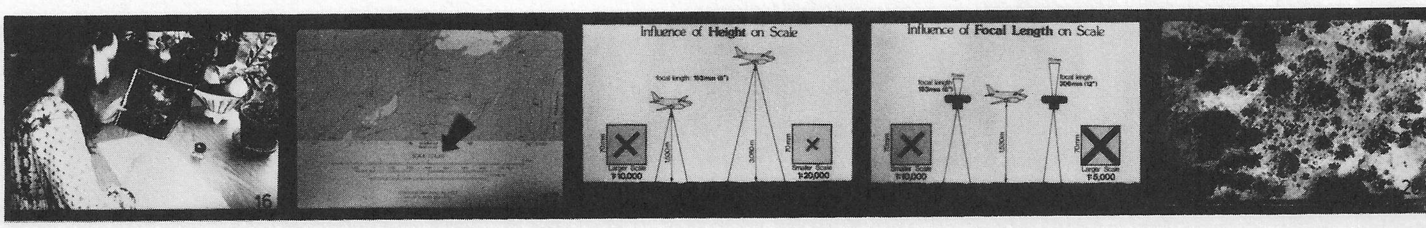
Air Photo Supply Corporation
Yonkers, New York 10705

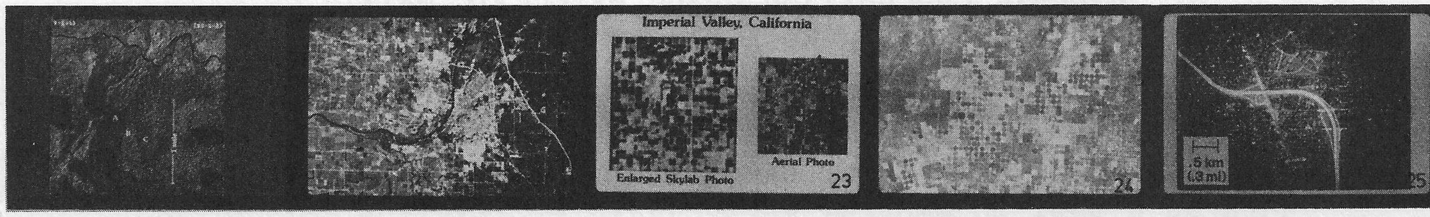
ADDITIONAL INSTRUCTOR'S NOTES

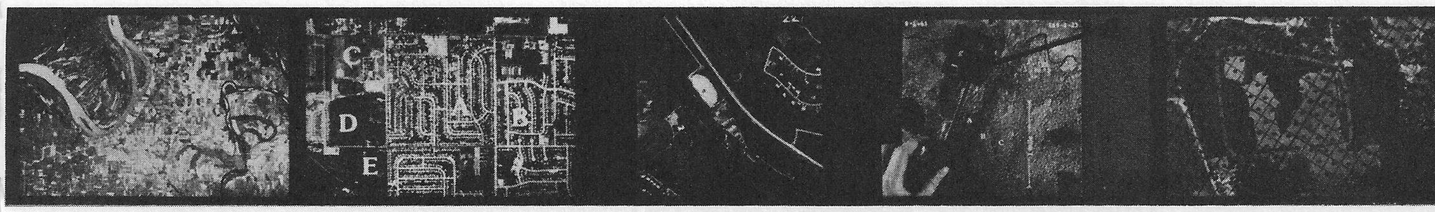

A Minicourse Series
Fundamentals of Remote Sensing
Copyright © Purdue Research Foundation 1980
1
Principles of Photointerpretation

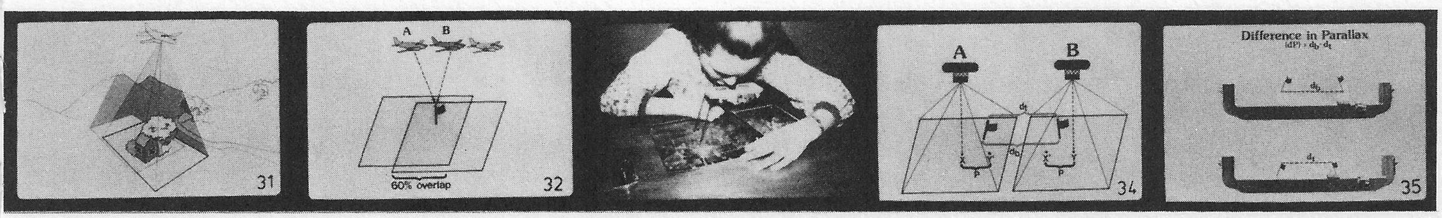

8
9
10

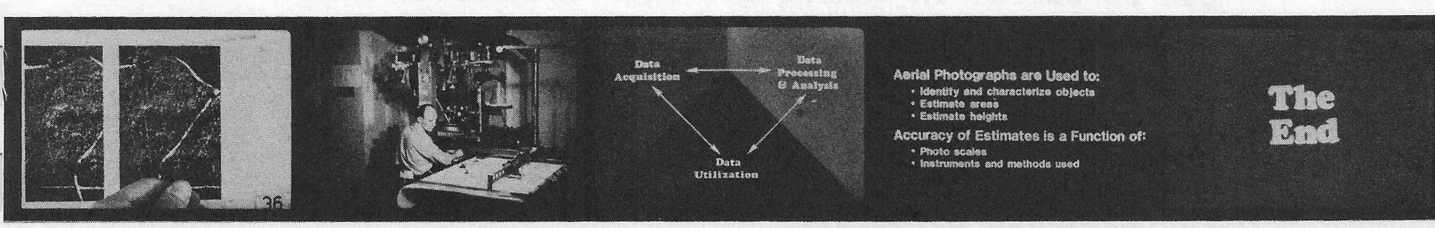

Basic Film Types
Panchromatic
Infrared
Conventional
12
Visible
Color
Color infrared with yellow filter
B&W Panchromatic
B&W infrared with red filter
.4
.5
.6
.7
.8
.9
Wavelength (micrometers)
13
Film Types
Positive Emulsion
Negative Emulsion
Positive Transparency


16
Influence of Height on Scale
Larger Scale
1:10,000
1:20,000
Influence of Focal Length on Scale
1:10,000
Larger Scale
1:5,000


Imperial Valley, California
Enlarged Skylab Photo
Aerial Photo
23
24
.5 km
(.3 mi)
25


C
D
E
A
B


31
A
B
60% overlap
32
A
B
34
Difference in Parallax
35


36
Data Acquisition
Data Processing & Analysis
Data Utilization
Aerial Photographs are Used to:
• Identify and characterize objects
• Estimate areas
• Estimate heights
Accuracy of Estimates is a Function of:
• Photo scales
• Instruments and methods used
The End

MINERAL EXPLORATION USING SATELLITE DATA

SUMMARY

The practical use of satellite-gathered remote sensing data as a tool in mineral exploration is becoming ever more feasible. Spectral information about geologic material is now widely available, and various enhancement techniques have been developed to accentuate important features. Furthermore, the possibility of combining spectral data from satellites with standard geologic maps and geophysical data inaugurates a new era of geologic investigation.

SPECIAL PREREQUISITE

In addition to completion of prerequisite minicourses, the student should have a basic knowledge of important geologic terminology and concepts, at the level of an introductory geology course.

A geologist new to remote sensing may also benefit from studying the minicourse "Applications of Remote Sensing in Geology," which treats the subject in a more generalized manner.

OBJECTIVES

When you have completed this minicourse, you should be able to:

1. List at least four geologic applications in which satellite remote sensing data can be used.

2. Describe three characteristics of geologic materials or data-collection capabilities that complicate the use of spectral remote sensing data for mineral exploration.

3. Give at least one example <u>each</u> of spectral, spatial, and temporal variations recorded in remote sensing data that can be useful in making geologic interpretations.

4. Briefly describe three types of image enhancements of use to geologists.

5. Name at least three types of ancillary data that can be used along with spectral data in computer-aided analyses for geologic purposes.

TIME: 1¼ hours

-- PROJECT THE FIRST SLIDE --

-- START THE TAPE --

PREREQUISITES

Before beginning this minicourse, the student should have mastered the objectives for:

Remote Sensing: What is it?

The Physical Basis of Remote Sensing

Applications of Remote Sensing in Geology

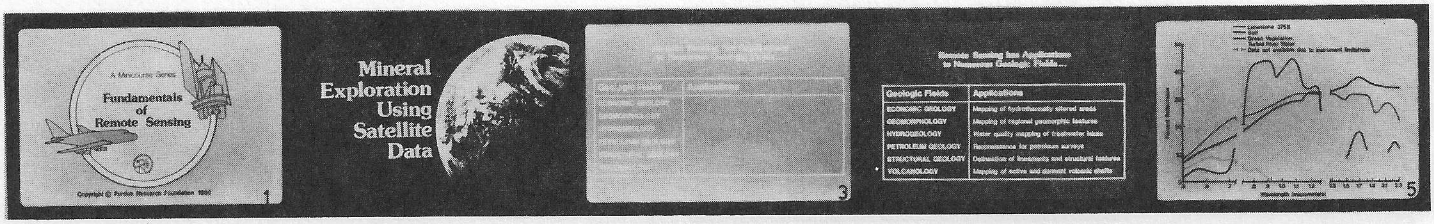
COMPONENTS OF MINICOURSE

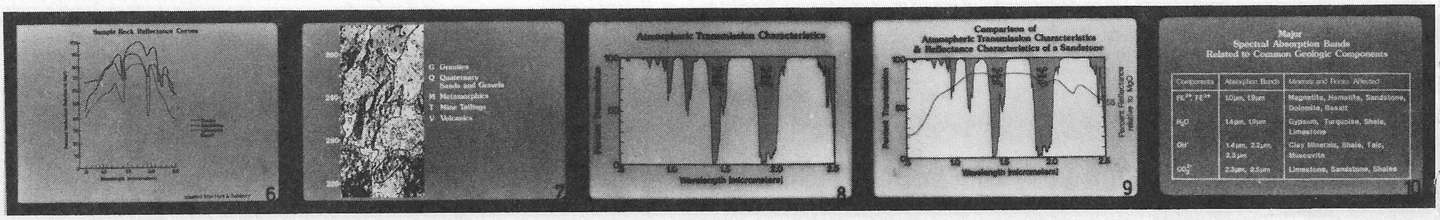
Study Guide for each student

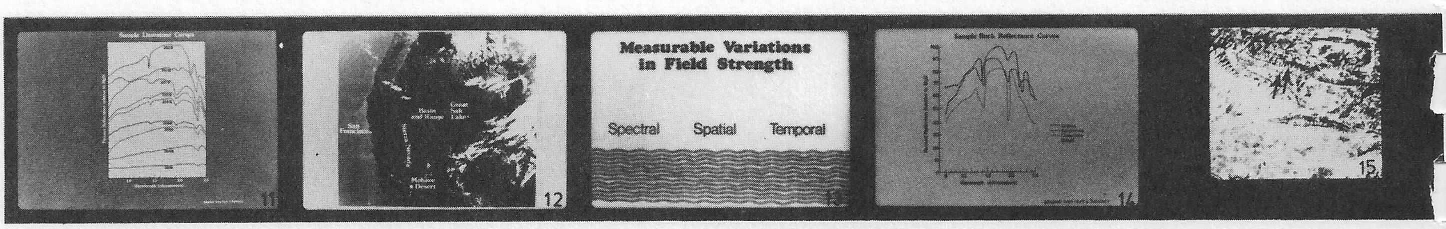
Set of 38 slides

Audio tape

ADDITIONAL INSTRUCTOR'S NOTES

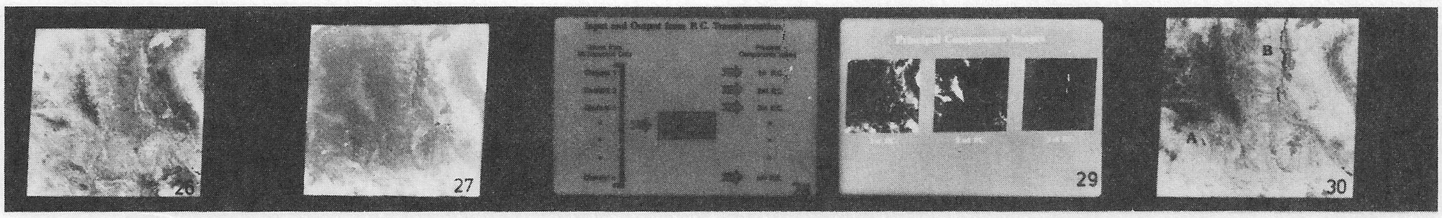

A Minicourse Series
Fundamentals of Remote Sensing
1
Mineral Exploration Using Satellite Data
3
Geologic Fields
Applications
ECONOMIC GEOLOGY
GEOMORPHOLOGY
HYDROGEOLOGY
PETROLEUM GEOLOGY
STRUCTURAL GEOLOGY
VOLCANOLOGY
5

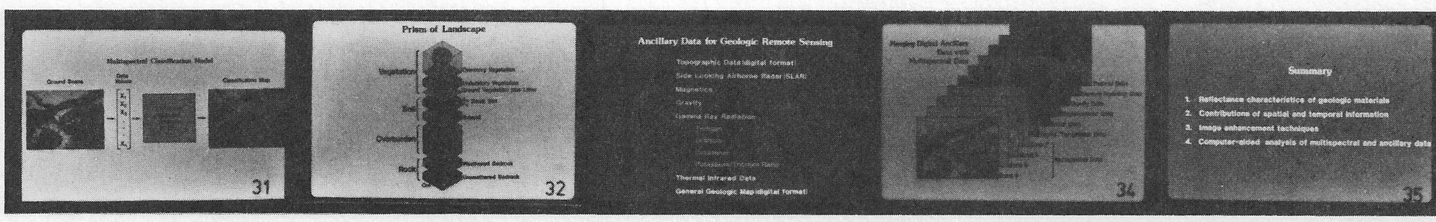

Sample Rock Reflectance Curves
6
G Granites
Q Quaternary Sands and Gravels
M Metamorphics
T Mine Tailings
V Volcanics
7
Atmospheric Transmission Characteristics
Wavelength (micrometers)
8
Comparison of Atmospheric Transmission Characteristics & Reflectance Characteristics of a Sandstone
Wavelength (micrometers)
9
Major Spectral Absorption Bands Related to Common Geologic Components
10


11
San Francisco
Basin and Range
Great Salt Lake
Mohave Desert
12
Measurable Variations in Field Strength
Spectral
Spatial
Temporal
13
Sample Rock Reflectance Curves
14
15


17
18
19
Effect of Sun Angle on Discriminability of Linear Features
4° Sun Angle
18° Sun Angle
Valdez, Alaska
20


Silver City, New Mexico
21
22
Creating Ratio Images
Band 4
Band 5
Ratio 4/5
24
Silver City, New Mexico
25


27
Principal Components Images
29
B
A
30


31
Prism of Landscape
Vegetation
Soil
Overburden
Rock
32
Ancillary Data for Geologic Remote Sensing
Topographic Data(digital format)
Side Looking Airborne Radar(SLAR)
Magnetics
Gravity
Gamma Ray Radiation
Thermal Infrared Data
General Geologic Map(digital format)
34
Summary
1. Reflectance characteristics of geologic materials
2. Contributions of spatial and temporal information
3. Image enhancement techniques
4. Computer-aided analysis of multispectral and ancillary data
35


The
End

The Landsat Thematic Mapper

SUMMARY

This minicourse reviews the history of the Landsat satellite series as it affects the development of a second generation remote sensing system called the Thematic Mapper (TM). The course summarizes the history of the Landsat sensor systems, presents information about the satellite/ground communication of TM data, compares the characteristics of the Landsat TM sensor system with the MSS, and lists satellite orbital characteristics that affect data collection. The results of several methods of analyzing TM data for quality and information content are presented and discussed. The course concludes with an example of TM thermal data used for temperature mapping of a water body.

OBJECTIVES

When you have completed this minicourse, you should be able to:

1. Summarize the history of Landsat remote sensing systems.
2. List the TDRS satellite/ground communication links.
3. Cite major differences between the TM and the MSS sensor systems.
4. Compare orbital characteristics of the Landsat -4 and -5 with those of earlier Landsat satellites.
5. Evaluate TM data for quality and information content.
6. Appreciate the value of TM data relative to MSS data.
7. Explain the calibration of thermal IR data in the temperature mapping of water bodies.

PREREQUISITES

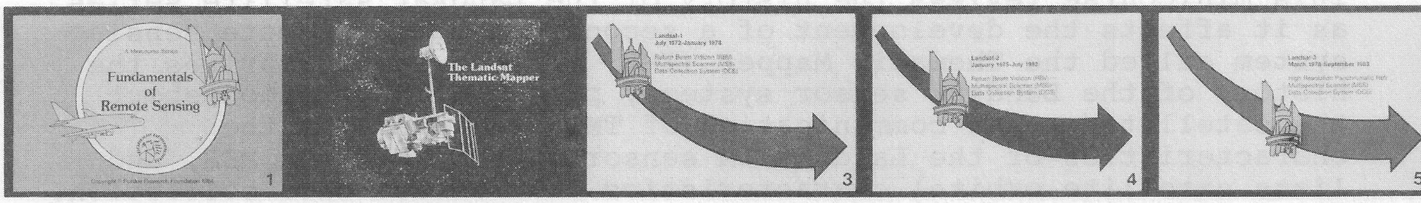
This minicourse is designed for students who have completed the two introductory minicourses in this series. The students should also have completed LANDSAT: AN EARTH RESOURCES SATELLITE SYSTEM, or have met the objectives of this course through equivalent study and/or experience.

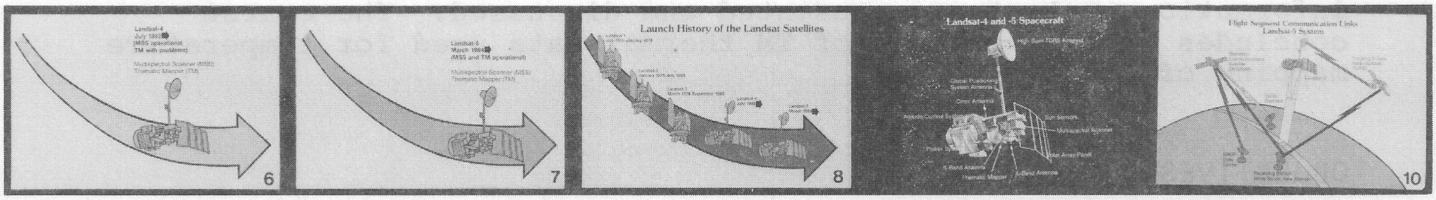
SUPPLIES NEEDED

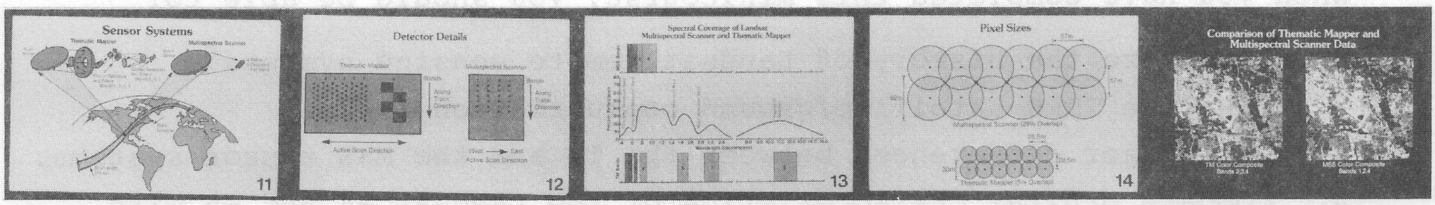
Pencil, map showing Landsat -4 Coverage, template, and acetate overlays showing TM and MSS characteristics. A calculator would be useful.

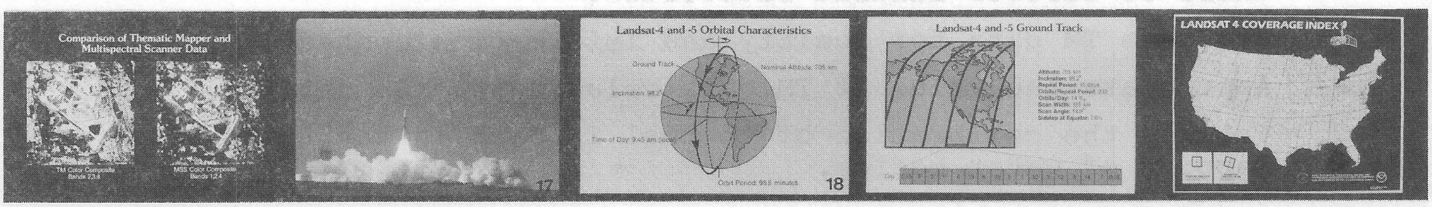
APPROXIMATE TIME: One hour and thirty minutes.

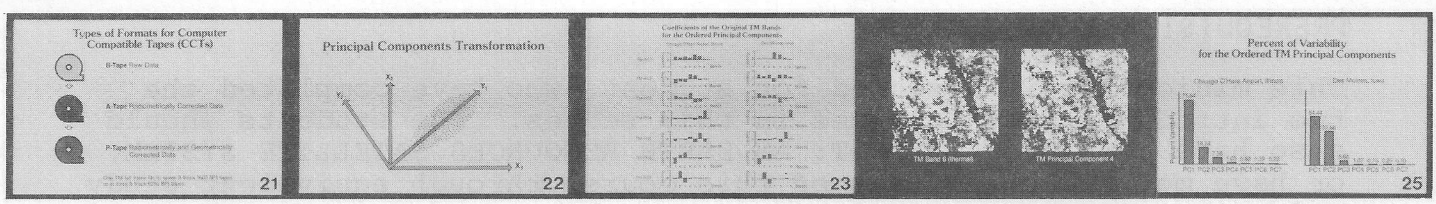
114-2

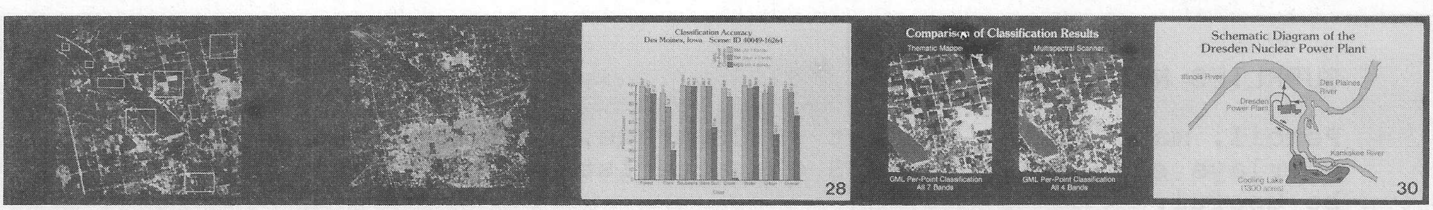

Fundamentals of Remote Sensing
The Landsat Thematic Mapper
Landsat-1
Landsat-2
Landsat-3
1
3
4
5

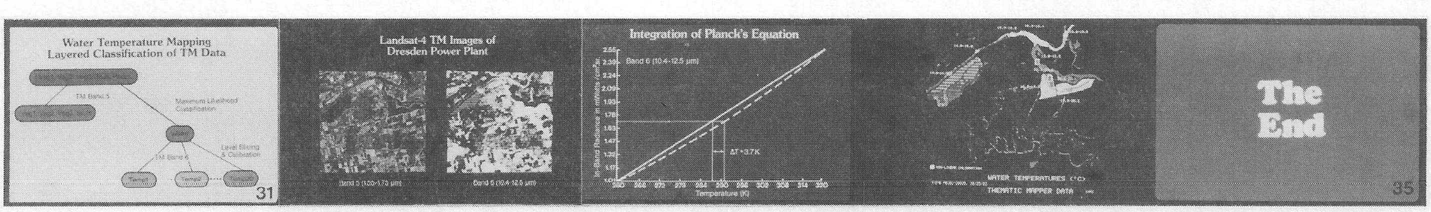

Landsat-4
Landsat-5
Launch History of the Landsat Satellites
Landsat-4 and -5 Spacecraft
Flight Segment Communication Links
6
7
8
10


Sensor Systems
Detector Details
Spectral Coverage of Landsat Multispectral Scanner and Thematic Mapper
Pixel Sizes
Comparison of Thematic Mapper and Multispectral Scanner Data
11
12
13
14


Comparison of Thematic Mapper and Multispectral Scanner Data
Landsat-4 and -5 Orbital Characteristics
Landsat-4 and -5 Ground Track
LANDSAT 4 COVERAGE INDEX
17
18


Types of Formats for Computer Compatible Tapes (CCTs)
Principal Components Transformation
Percent of Variability for the Ordered TM Principal Components
21
22
23
25


Classification Accuracy
Comparison of Classification Results
Schematic Diagram of the Dresden Nuclear Power Plant
28
30


Water Temperature Mapping Layered Classification of TM Data
Landsat-4 TM Images of Dresden Power Plant
Integration of Planck's Equation
The End
31
35

III. Remote Sensing Literature

The following list of published materials was compiled as as aid to persons new to remote sensing.[1]

Books

Alexander, Larry, Leo Eichen, et al. 1974
Remote Sensing - Environmental and Geotechnical Applications
Engineering Bulletin 45.
Dames and Moore, 445 S. Figueroa St., Los Angeles, CA

Colwell, R. N. (Ed.). 1960
Manual of Photographic Interpretation
American Society of Photogrammetry, 105 N. Virginia Ave., Falls Church, VA

Estes, John E. and Leslie W. Senger (Eds.). 1973
Remote Sensing - Techniques for Environmental Analysis
Hamilton Publishing Company, Santa Barbara, CA

Holz, Robert K. 1973
The Surveillant Science - Remote Sensing of the Environment
Houghton Mifflin, Boston, MA

Johnson, P.L. (Ed.). 1969
Remote Sensing in Ecology
University of Georgia Press, Athens, GA

National Research Council. 1970
Remote Sensing with Special Reference to Agriculture and Forestry
National Academy of Sciences, 2101 Constitution Ave., Washington, D.C.

Pouquet, Jean. 1971
Les Sciences de la Terra a L'heure des Satellites, Teledetection
Presses Universitaires de France, Paris
Translation (1974) - Earth's Resources from Satellite
D. Reidel Publishing Co., 306 Dartmouth St., Boston, MA

Reeves, R.G. (Ed.). 1975
Manual of Remote Sensing
American Society of Photogrammetry, 105 N. Virginia Ave., Falls Church, VA

Rudd, Robert. 1974
Remote Sensing - A Better View
Duxbury Press, 6 Bound Brook Ct., N. Scituate, MA

Wolff, Edward and Enrico P. Mercanti (Eds.). 1974
Geoscience Instrumentation
John Wiley and Sons, 605 Third Ave., New York, NY

[1] Lindenlaub, J. C., S. M. Davis and D. B. Morrison. Bringing Remote Sensing Technology to the User Community, LARS Information Note 051975, Purdue University, West Lafayette, Indiana, 1975.

Journals devoted to Remote Sensing

IEEE Transactions on Geoscience Electronics
Journal of the Geoscience Electronics Group of the Institute of Electrical and Electronics Engineers
345 East 47 St., New York, NY
Quarterly

ITC Journal
Journal of the International Institute for Aerial Survey and Earth Sciences
Enschede, The Netherlands
Five issues yearly

Photogrammetria
International Society for Photogrammetry
P.O. Box 1345, Amsterdam, The Netherlands
Bi-monthly

Photogrammetric Engineering and Remote Sensing
Journal of the American Society of Photogrammetry
105 N. Virginia Ave., Falls Church, VA
Monthly

Remote Sensing of Environment - An Interdisciplinary Journal
American Elsevier Publishing Co., 52 Vanderbilt Ave., New York, NY
Quarterly

Journals frequently carrying articles on Remote Sensing

Agronomy Journal
Journal of the American Society of Agronomy
677 S. Segoe Rd., Madison, WI
Bi-monthly

Annals of the Association of American Geographers
Quarterly

Applied Optics
Journal of the Optical Society of America
2000 L St., N.W., Washington, D.C.
Monthly

Aviation Week and Space Technology
McGraw-Hill, 1221 Avenue of the Americas, New York, NY
Weekly

Crop Science
Journal of the Crop Science Society of America
677 S. Segoe Rd., Madison, WI
Bi-monthly

IEEE Transactions on Computers
Journal of the Computer Society of the Institute of Electrical and Electronics Engineers (IEEE)
345 East 47 St., New York, NY
Monthly

Proceedings of IEEE
Institute of Electrical and Electronics Engineers (IEEE)
345 East 47 St., New York, NY
Monthly

Journal of Forestry
Journal of the Society of American Foresters
1010 16th St., N.W., Washington, D.C.
Monthly

Journal of Soil and Water Conservation
Soil Conservation Society of America
7515 N.E. Ankeny Rd., Ankeny, IA
Bi-monthly

Optical Engineering
Journal of the Society of Photo-Optical Instrumentation Engineers
338 Tejon Place, Palos Verdes Estates, CA
Bi-monthly

Soil Science Society of America Proceedings
Journal of the Soil Science Society of America
American Society of Agronomy, 677 S. Segoe Rd., Madison, WI
Bi-monthly

COMMENTS OR QUESTIONS?

If you have any questions about the use of the minicourses or if, after using them, you have comments or suggestions, please address them to:

Shirley M. Davis
Technology Transfer
Laboratory for Applications of
Remote Sensing
Purdue University
West Lafayette, Indiana 47907

Orders for other minicourses or additional study guides should be directed to:

Mr. G. W. O'Brien
Continuing Education Administration
116 Stewart Center
Purdue University
West Lafayette, Indiana 47907

Appendix A

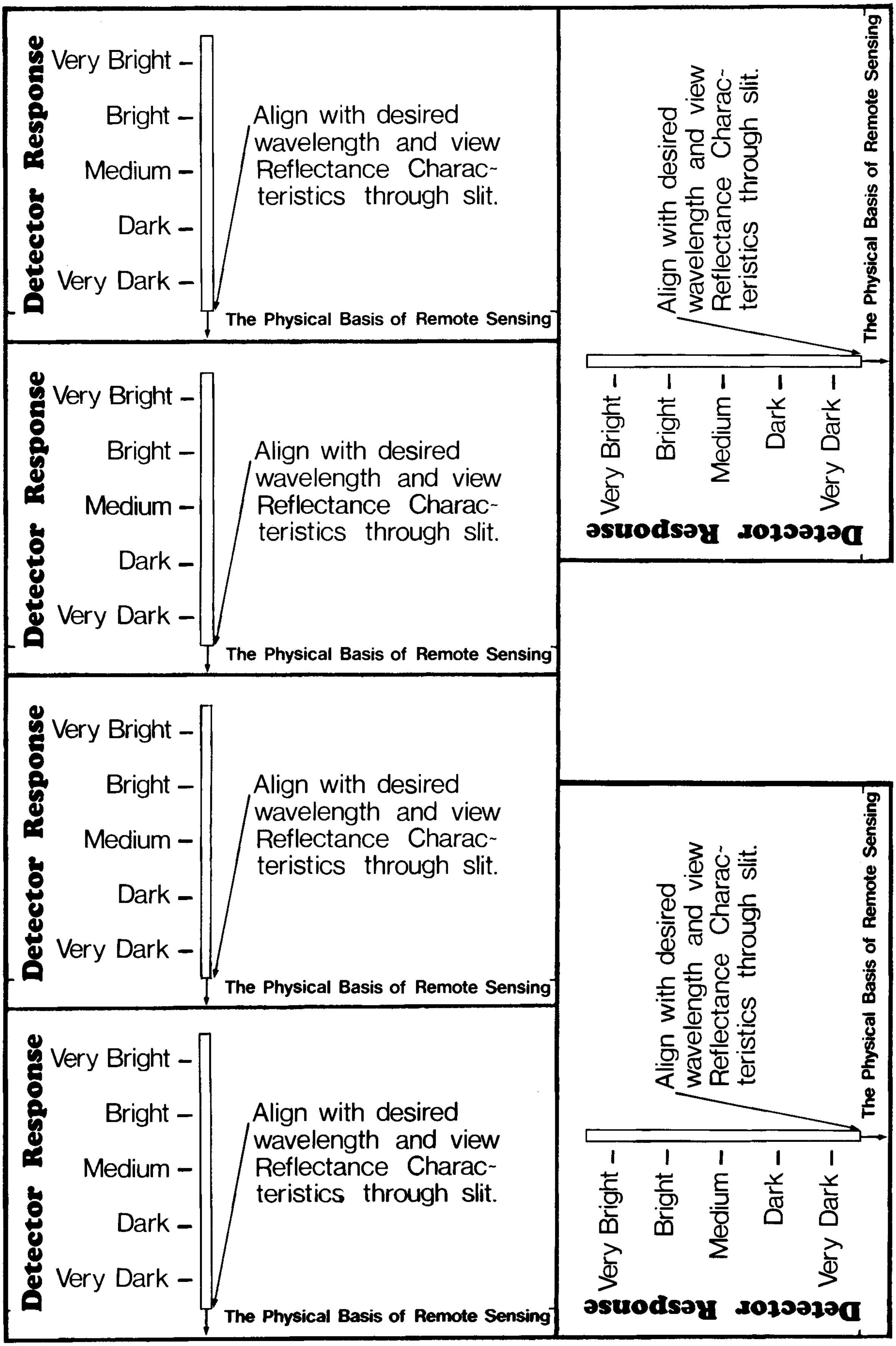
The following pages contain masters from which to make additional copies of many of the components of the minicourses.

Reproduce the following pages on card stock:

A-1 Physical Basis of Remote Sensing
A-2 Multispectral Scanners
A-3 Landsat: An Earth Resources Satellite System
A-6 Interpretation of Multispectral Scanner Images

Make a transparency (thermofax or xerox) of the following pages:

A-4 Landsat: An Earth Resources Satellite System.
A-5 Typical Steps in Numerical Analysis
A-7 Crop Surveys through Remote Sensing
A-8 Photogeology
A-9 Principles of Photointerpretation
A-10 Interpretation of Thermal Imagery


Detector Response
Very Bright
Bright
Medium
Dark
Very Dark
Align with desired wavelength and view Reflectance Characteristics through slit.
The Physical Basis of Remote Sensing

Use this card and the longer straw for Activities 2 and 3.
Use both straws for Activity 4.

Upon completion of the minicourse please return this card, the 2 straws and the map to the slide tray box.

Use this card and the longer straw for Activities 2 and 3.
Use both straws for Activity 4.

Upon completion of the minicourse please return this card, the 2 straws and the map to the slide tray box.

Use this card and the longer straw for Activties 2 and 3.
Use both straws for Activity 4.

Upon completion of the minicourse please return this card, the 2 straws and the map to the slide tray box.

Use this card and the longer straw for Activities 2 and 3.
Use both straws for Activity 4.

Upon completion of the minicourse please return this card, the 2 straws and the map to the slide tray box.

For use with "Multispectral Scanners"

For use with Single LANDSAT Coverage Map in LANDSAT: An Earth Resources Satellite System.

COVERAGE TEMPLATE

cut out

Inside Dimensions Reflect Actual Coverage

Please return to slide box when finished

For use with Single LANDSAT Coverage Map in LANDSAT: An Earth Resources Satellite System.

COVERAGE TEMPLATE

cut out

Inside Dimensions Reflect Actual Coverage

Please return to slide box when finished

For use with Single LANDSAT Coverage Map in LANDSAT: An Earth Resources Satellite System.

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cut out

Inside Dimensions Reflect Actual Coverage

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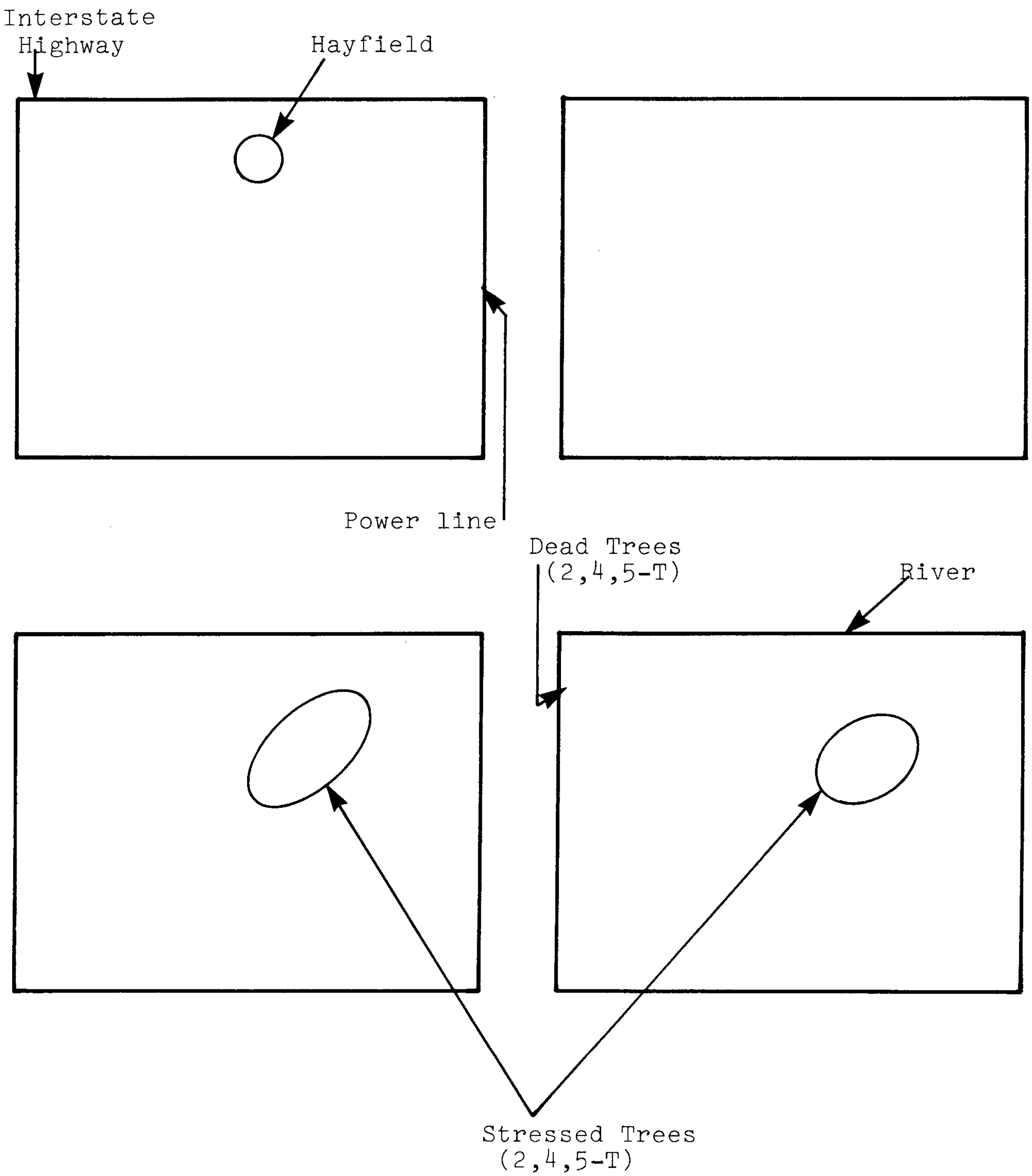
For use with Single LANDSAT Coverage Map in LANDSAT: An Earth Resources Satellite System.

COVERAGE TEMPLATE

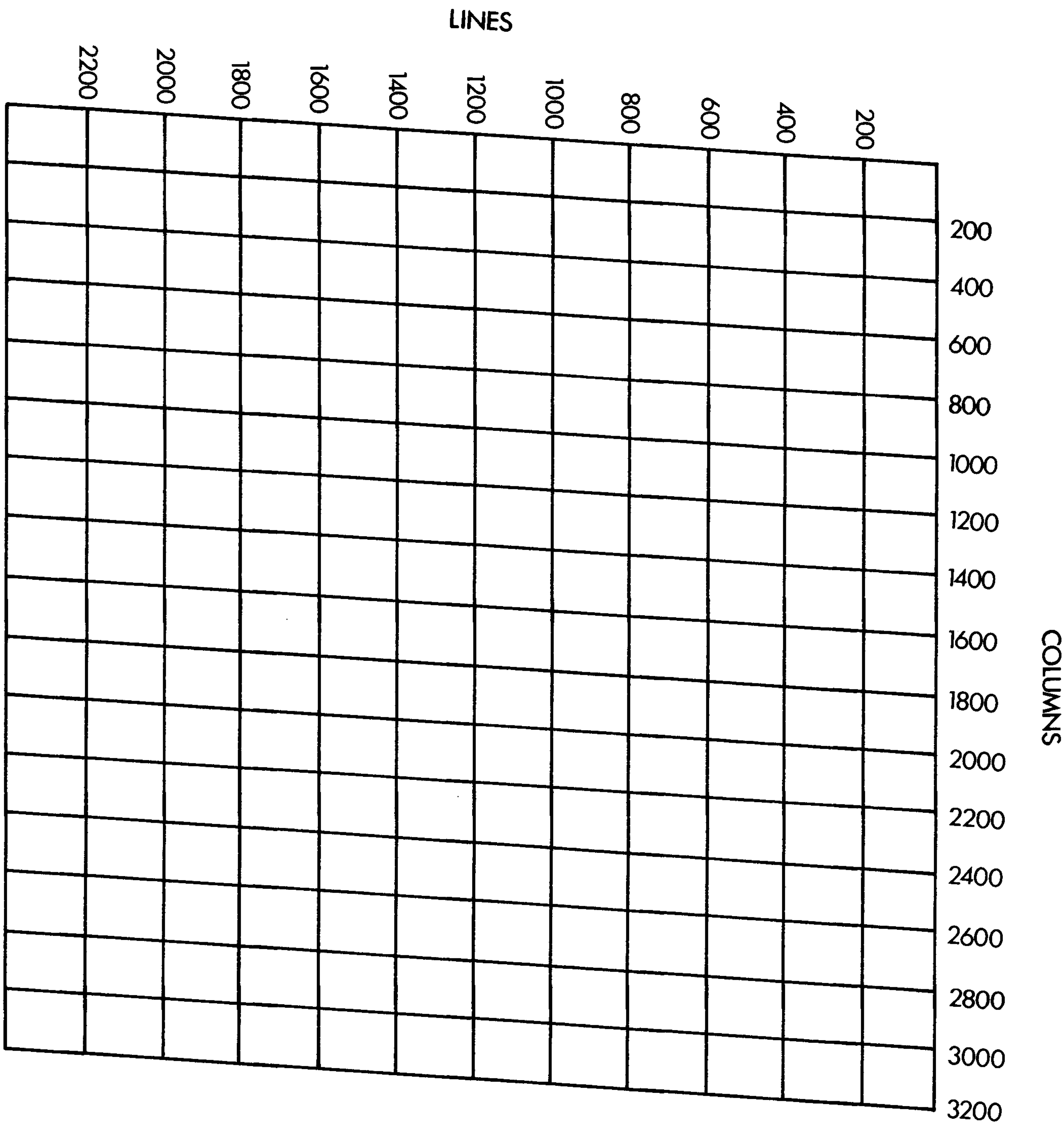
cut out

Inside Dimensions Reflect Actual Coverage

Please return to slide box when finished



For use with "LANDSAT: An Earth Resources Satellite System"



For use with "Typical Steps in Numerical Analysis"

Align with upper left corner.

Interpretation of Multispectral Scanner Images

Align with upper left corner.

Interpretation of Multispectral Scanner Images

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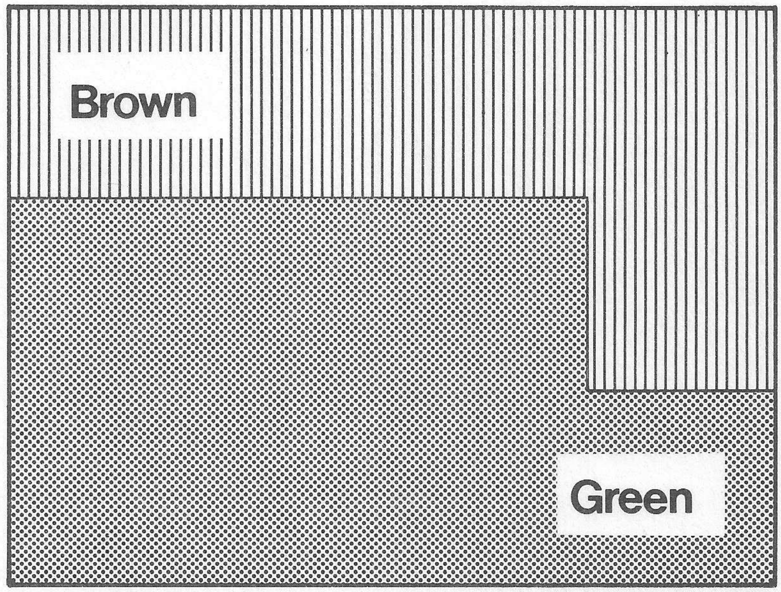
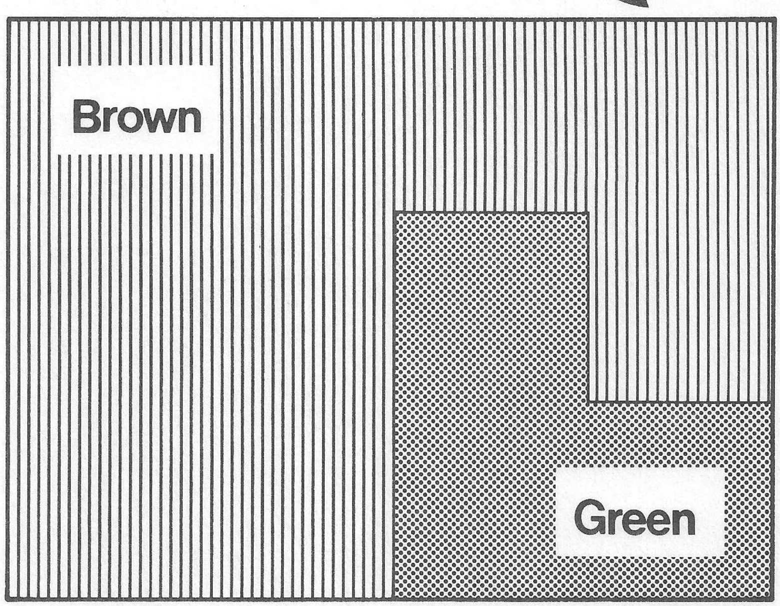
Interpretation of Multispectral Scanner Images

For use with "Interpretation of Multispectral Scanner Images"

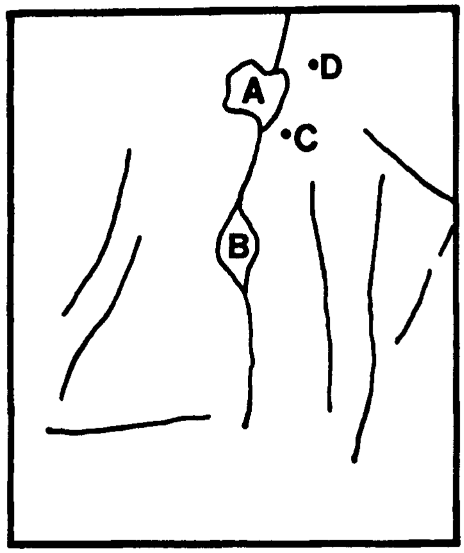
APPEARANCE OF FIELDS IN MAY



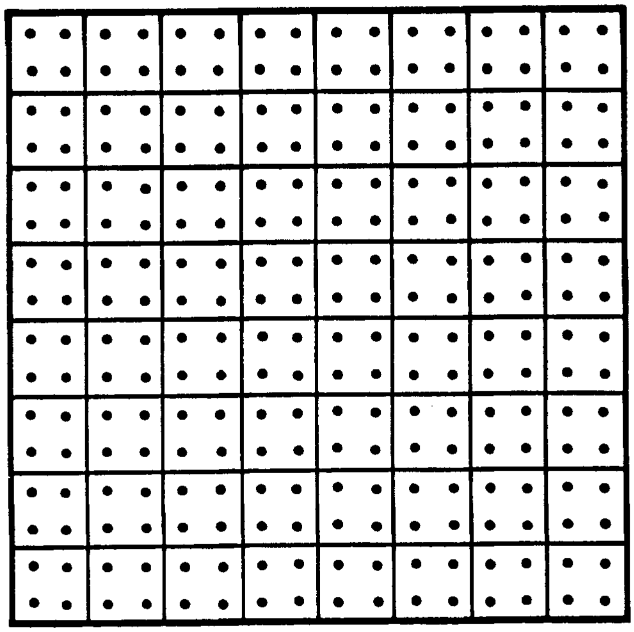
APPEARANCE OF FIELDS IN NOVEMBER



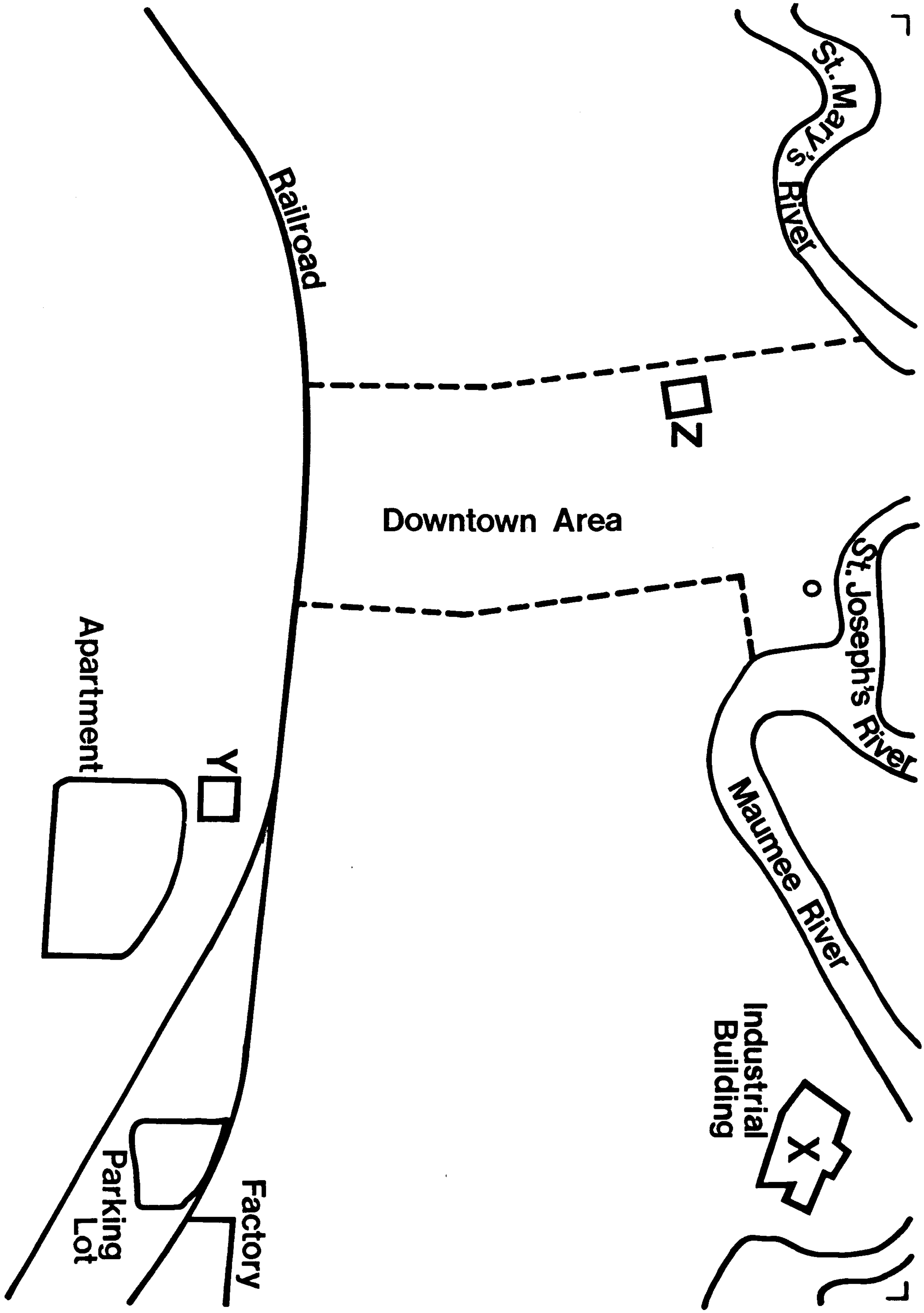
For use with "Crop Surveys through Remote Sensing"



For use with "Photogeology" minicourse.



For use with "Principles of Photointerpretation"



For use with "Interpretation of Thermal Imagery"

ABOUT THE AUTHOR

JAMES D. RUSSELL is Associate Professor of Education and Instructional Development Specialist at the Laboratory for Applications of Remote Sensing, Purdue University. A graduate of Indiana University with a dual major in Science Education and Instructional Systems Technology, Dr. Russell has over ten years of experience in the design, development and evaluation of instructional materials. He is the author of two textbooks Modular Instruction and Audio-Tutorial Systems along with over fifty articles on instructional development and evaluation.

Minicourse Series developed by:
Laboratory for Applications of Remote Sensing
Purdue University
West Lafayette, Indiana 47907 USA