INTERDISCIPLINARY APPLICATIONS AND INTERPRETATIONS OF REMOTELY SENSED DATA

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Abstract

Energy coming to the earth from the sun is reflected, scattered, or absorbed, and then radiated in the form of electromagnetic waves by objects on the earth. The wavelength of reflected or radiated energy is dependent upon the physical and chemical properties of the object. Modern instruments are capable of sensing and measuring this energy without being in physical contact with the object. Remote sensing can be accomplished from both aircraft and spacecraft, with each having distinct advantages. An interdisciplinary group at Pennsylvania State University is investigating the use of remote sensing for the inventory of natural resources and land use, determination of pollution sources and damage, and analysis of geologic structure and terrain. The geographical area of primary interest is the Susquehanna River Basin.

Introduction to Remote Sensing

All energy coming to the earth is produced by the sun. This energy is either reflected, scattered, or absorbed, and then radiated as electromagnetic waves by objects on the earth. Because these objects differ in their physical and chemical properties, the wavelength of energy they radiate or reflect may vary from very short, such as X-rays, to very long, such as radio waves. Modern instruments are capable of sensing and measuring energy reflected or emitted at various wavelengths of the electromagnetic spectrum. An example is the camera with color film that senses energy reflected only in the visible portion of the electromagnetic spectrum. These devices acquire information about objects that are not in physical contact with these data gathering devices. The technology involved with these types of data gathering or imaging devices is thus called remote sensing [1, 2]. The most common types of airborne remote sensing instruments are as follows:

1. Conventional Aerial Camera. Cameras photographically record the radiation reflected in the visible portion of the electromagnetic spectrum. By using various filters, the visible spectrum can be subdivided so that only portions of the electromagnetic spectrum are recorded on film. Energy reflected in only the blue portion of the electromagnetic spectrum, for example, may be recorded photographically by filtering out the other wavelengths. Through the use of special infrared films, electromagnetic radiation reflected at wavelengths longer than those discernible by the eye can also be recorded photographically.

2. Multiband Cameras. These cameras permit the taking of more than one photograph simultaneously, each with a different combination of lens and filter. This allows simultaneous exposures of exactly the same area, with each exposure representing the energy reflected in various portions of the visible- and near-infrared segment of the electromagnetic spectrum.

3. Optical Mechanical Scanner. Scanners collect and electronically record energy reflected and radiated at wavelengths that fall within the range of 0.4 to 20.0 μm. Since only that portion from 0.4 to 0.7 μm is in the visible spectrum, information can be obtained by scanners that is not discernible by the human eye. An example is the determination of water temperature differences near discharges from nuclear power plants, a task which can be done very accurately using optical mechanical scanners.

4. Radar. Radar systems are active devices; that is, they transmit their own energy and collect the portion of this energy that is reflected from the illuminated terrain. This is in contrast to the other remote sensing devices that do not supply their own energy source, but measure only reflected or emitted energy and are called passive systems. Radar operates at longer wavelengths than any of the devices previously described and has an all-weather, day-and-night capability. Radar also has the ability to penetrate vegetation and to sense the terrain beneath.

Remote sensing is presently being performed by aircraft and by spacecraft, each having distinct advantages. Airplanes have the advantage of being able to perform specific sensing tasks over selected areas and to obtain greater resolution from aircraft altitudes. However, an airplane cannot match the overall synoptic coverage or the stable, vibration-free platform of a satellite. The initial cost of orbiting a satellite would be much higher than initiating an aircraft mission. However, if large surface areas are to be sensed or if repetitive coverage is required, the cost differentials are reduced and, in some instances, the satellite sensing may be the most economical.

ERTS and Skylab

In 1972, NASA will launch the first Earth Resources Technology Satellite (ERTS) that will monitor the earth's resources on a global scale. The first launch, ERTS-A, will put a 1800-lb vehicle into a circular, near-polar orbit about 500 miles above the earth. The earth will be revolving beneath it, and by the time ERTS returns to the same spot on its next track, the earth will have revolved 1800 miles to the west. In 18 days it will have covered the world and begin making its second pass. This ability to monitor changes on the earth's surface that occur over time will be a valuable feature of satellite sensing.

ERTS will have a three-camera television system to provide imagery which can be converted to photos in three spectral bands — blue-green, red, and near-infrared. The camera operating in the blue-green portion of the spectrum will provide maximum penetration of water; the camera in the red portion will be useful for crop identification and delineation of soils; and the camera in the near-infrared portion will show maximum discrimination between land and water. Each of these photos will cover approximately 10 000 square miles.

ERTS-A and ERTS-B, which will be launched approximately 1 year after ERTS-A, also have multispectral scanners to measure energy radiated from the earth. ERTS-A will only be capable of measuring reflected energy, whereas ERTS-B will be able to measure both reflected and thermal energy.

Skylab will be another type of space platform for monitoring earth resources. This will differ from ERTS in that men will be placed into orbit and they will be collecting most of the data. Skylab or Earth Resources Experiment Package, as it is sometimes termed, will contain more sophisticated remote sensing devices than ERTS, resulting in a wider variety of remotely sensed data with better resolution. However, the amount of area covered by Skylab will be much less than that of ERTS.

Organization and Management

In 1970, an interdisciplinary group was established at Pennsylvania State University with the capability of participating in projects involving the use of remotely sensed data of earth resources. This interdisciplinary group is called the Office for Remote Sensing of Earth Resources (Fig. 1) and is composed of personnel from the following disciplines: agronomy, air pollution, civil engineering, climatology, economics, forestry, geology, geophysics, hydrology, meteorology, plant physiology, pattern recognition, regional planning, and soils. The Office for Remote Sensing of Earth Resources (ORSER) was formed as a division of, and with financial support from, the Space Science and Engineering Laboratory, which is a part of Pennsylvania State University's Intercollege Program (Fig. 1).

The Space Science and Engineering Laboratory (SSEL) was established on September 1, 1965, by the act of the Board of Trustees of Pennsylvania State University. Administered by the Office of the Vice-President for Research for the university, it functions as a subunit of the Institute for Science and Engineering. A major purpose of the SSEL is to give focus to research and graduate study in the space sciences and space-related sciences and engineering, to provide support services of a technical and administrative nature to programs operated in existing departments, and to administer funds for the support of new programs developed within departments or on an interdepartmental basis. Major financial support for the laboratory has come from the NASA Office of University Affairs through the Sustaining University Program.

The reason ORSER was established by SSEL was to encourage interdisciplinary research activities involving remote sensing. To insure that this group functions in an interdisciplinary nature, a problems-oriented approach has been taken so that each problem or task is directly represented in the organizational structure. This will allow associates from various disciplines to work together toward a common goal rather than have each discipline devoted to a specific project.

The organization of ORSER is indicated in Figure 2. An associate professor of soils and an associate professor of electrical engineering serve as codirectors. Each task has a principal investigator or coinvestigators and they jointly make up the Coordinating Committee along with the codirectors. This Coordinating Committee oversees the research efforts of ORSER and encourages and coordinates future research endeavors. This committee will also meet frequently with the Advisory Committee for consultation, advice, and reports of progress. The Advisory Committee includes the deans of interested colleges or their appointed representatives. There is also direct communication between the Coordinating Committee and potential users of the research results. Examples of these potential users are:

1. Soil Conservation Service
2. Northeast Watershed Research Center
3. Susquehanna River Basin Commission
4. U. S. Forest Service
5. Ten Regional Clearinghouses in Pennsylvania
6. Pennsylvania State Planning Board
7. Pennsylvania Department of Environmental Resources
8. Pennsylvania Department of Transportation
9. Regional Planning Commissions
10. County Planning Commissions
11. Local Planning Commissions.

Application and Interpretation

In applications of remote sensing techniques, consideration must be given to many factors, including amount, type, and quality of information to be collected, types of sensors available, and the type of platform (airplane or spacecraft) and its characteristics (altitude, speed, etc.). In the collection of remotely sensed data, various compromises must be made, and in many cases, airplanes and spacecraft may be used simultaneously to collect data.

Supporting information collected by other means is essential when evaluating and interpreting remotely sensed data. Such information is called "ground truth." Pennsylvania State University currently possesses a unique collection of ground-truth data for Pennsylvania. This will be an invaluable aid in establishing references and interpreting data obtained from spacecraft and other sources.

The primary objective of the interdisciplinary group at Penn State is to determine the usefulness of remote sensing techniques for the inventory of natural resources and land use, the determination of pollution sources and damages, and the analysis of geologic structure and terrain. The area selected for this study was a large river basin.

The Susquehanna River Basin as an Area of Application

Since spacecraft remote sensing is most useful for coverage of large land areas. Pennsylvania State University has selected the Susquehanna River Basin for application of remotely sensed data from ERTS and Skylab. The reasons for choosing the basin include the facts that it (1) contains a wide variety of soils, vegetation, water bodies, and geological structures; (2) is located in geographical proximity to Penn State; (3) has considerable ground-truth data already available, including an excellent Susquehanna River Study of June 1970 by the Susquehanna River Basin Study Coordinating Committee; and (4) is of interest to various agencies of the Federal Government and to the States of Pennsylvania, New York, and Maryland.

The Susquehanna River Basin is the largest, undeveloped watershed in the Northeastern United States. The present population of the basin is 3.5 million and is expected to increase to 9 million in the next 50 years. The Susquehanna supplies 85 percent of the fresh water that flows into the Chesapeake Bay above the mouth of the Potomac River and, thus, the ecological balance in the bay could be seriously affected by upstream development on the Susquehanna.

In addition, the basin is located directly between the Chesapeake Bay and Lake Erie and, thus, forms a geographical tie between these two bodies which are both of great ecological interest today. It will be necessary to insure the proper utilization of the basin because we, as a nation, are committed to the restoration and maintenance of a healthy and viable natural environment. It will be the intent of ORSER to determine and demonstrate the role remote sensing might play in the regional resource management of the Susquehanna River Basin. This will hopefully involve direct participation by the Office for Remote Sensing of Earth Resources with the new Susquehanna River Basin Commission, recently established by the enactment of Public Law 91-575 (Susquehanna River Basin Compact).

Portions of the basin are undergoing extensive and rapid urbanization and in other areas, strip-mining operations are increasing. Powerplants, which have a dynamic influence on the ecology of the river basin, are present on the Susquehanna and more are proposed. The upper reaches of the Susquehanna are almost completely forested and should offer study areas for phenological phenomena, recreation, and forestry. Extensive snowfields also exist in these areas and they have considerable impact on the hydrology of the Susquehanna. These are considered examples of some of the areas where spacecraft data should be applicable.

Interpretation of Spacecraft Data

A number of different tasks can be pursued because of the amount and variety of data to be collected by ERTS and Skylab, and because of the diversity of interests and backgrounds available in a university such as Penn State. The specific objectives of the work planned by ORSER in Pennsylvania and the Susquehanna River Basin are grouped into one of four areas of investigation as follows:

1. Inventory of Natural Resources and Land Use. The use of spacecraft data for purposes of inventory and survey of relatively large areas must be considered to have very great potential. The inventory of natural resources and land use offers great promise, not only to investigators in the various disciplines, but to planners and policymakers at all levels of the public sector. In the specific tasks listed below there is need for both detailed analysis by the individual investigators and for communication among investigators regarding their goals, analyses, and results. The specific tasks considered under this area of investigation are:

a. Identification and characterization of soil parameters

b. Location, inventory, and monitoring of strip-mining operations and pollution spoils

c. Survey and inventory of forest resources

d. Evaluation of potential recreation sites

e. Survey the initiation and progression of insect and plant disease epidemics

f. Collection and updating of data for multipurpose land use management

g. Development of natural resource inventory systems.

2. Geology and Hydrology. The geologically oriented tasks involve correlation and analysis of natural features associated with terrain analysis, as well as the effects of man-related ventures, such as mining operations and pollution spoils. Analysis of the orientation, distribution, shape, and type of the surface trace of geologic structures would follow the procedure of characterization, correlation to known geologic features, and application and utilization. From an inventory of known mineral and ground water deposits, their relationship to lineaments and fracture traces would be developed as a tool for area selection in mineral exploration and in ground water planning and utilization. Specific tasks for investigation are:

a. Characterization and analysis of geologic structures and terrain

b. Inventory of mineral resources and mines

c. Detection of ground water sources from drainage, lineaments, and fracture patterns

d. Determination of watershed runoff.

3. Pollution. The Susquehanna Basin is an area of contrasts with the upper reaches heavily forested and in an almost untouched condition, while the lower reaches are fairly well urbanized. This contrast in land use, along with extensive coal-mining operations, offers a unique area for pollution studies. It is the intent in this area of investigation to determine the role remote sensing might have in the detection of various types of pollutants, such as thermal pollution, acid mine drainage, and nutrient and chemical pollutants; the detection of the effects pollutants have on the environment; and the monitoring of pollutant types along with their environmental impacts. This area of investigation will involve the following tasks:

a. Monitoring the environmental effects of power generating plants

b. Detection of sources of acid mine drainage, monitoring seasonal discharges and determination of mixing patterns in other waters

c. Detection of air pollution damage

d. Definition and characterization of water quality problems in a large river.

4. Data Processing. The tasks in the area of data processing are of importance not only in their own right but also because of their usefulness to all other investigators. The tasks are primarily of an automatic or man-machine interactive nature, although visual photo-interpretive techniques are expected to be used extensively by many investigators. In addition to establishing format, specifications, programs, and procedures for all users of the automatic data processing facilities, pattern recognition techniques and programs are being developed and made available to all investigators. A joint university-industry task is planned in which a man-machine interactive system will be used for analysis of imagery.

Conclusion

The general objectives of this interdisciplinary effort in remote sensing include the application of remote sensing methods to various specific tasks, the development of interpretation techniques, and the application of remote sensing in regional resource management. The approach to be taken is interdisciplinary in nature, with individual investigators not only concentrating on tasks for which they are specifically trained but also working closely with others having similar or related interests. Tasks within each area of investigation will certainly be coordinated with each other, and in many cases, with tasks in another area. Investigators of the task on the inventorying of strip-mining operations, for example, will be working closely with personnel involved in the detection of acid mine drainage and both of these tasks are related to the task of inventorying mineral resources and mines. The tasks, involving forestry inventory, plant diseases and insects, air pollution damage, and environmental effects of power generating plants, can be expected to involve much interchange of information. In most tasks, the data processing and pattern recognition applications are expected to be similar. When investigating a large river basin it is not feasible to cover all possible problems within each area and, therefore, selected objectives or tasks, for which ORSER has a specific talent and capability, have been chosen. It is felt that these selected tasks do, however, represent major problems in the Susquehanna River Basin and can serve as the basis for a major unified interdisciplinary attack on problems using remotely sensed data.

The anticipated results, in general, will be important for making resource management and land-use policy decisions with the basin. In addition, certain results offer quick return possibilities, such as evaluation of structural lineaments for use as a tool in interpreting geological structures, inventorying of strip-mining and land use changes, and detection and monitoring of pollutants. University training in remote sensing at both the undergraduate and graduate level will be performed. The effectiveness of not only interdisciplinary but joint university-industry research will be evaluated.

References

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

2. Ecological Surveys from Space. National Aeronautics and Space Administration (NASA), Washington, D. C., 1970.

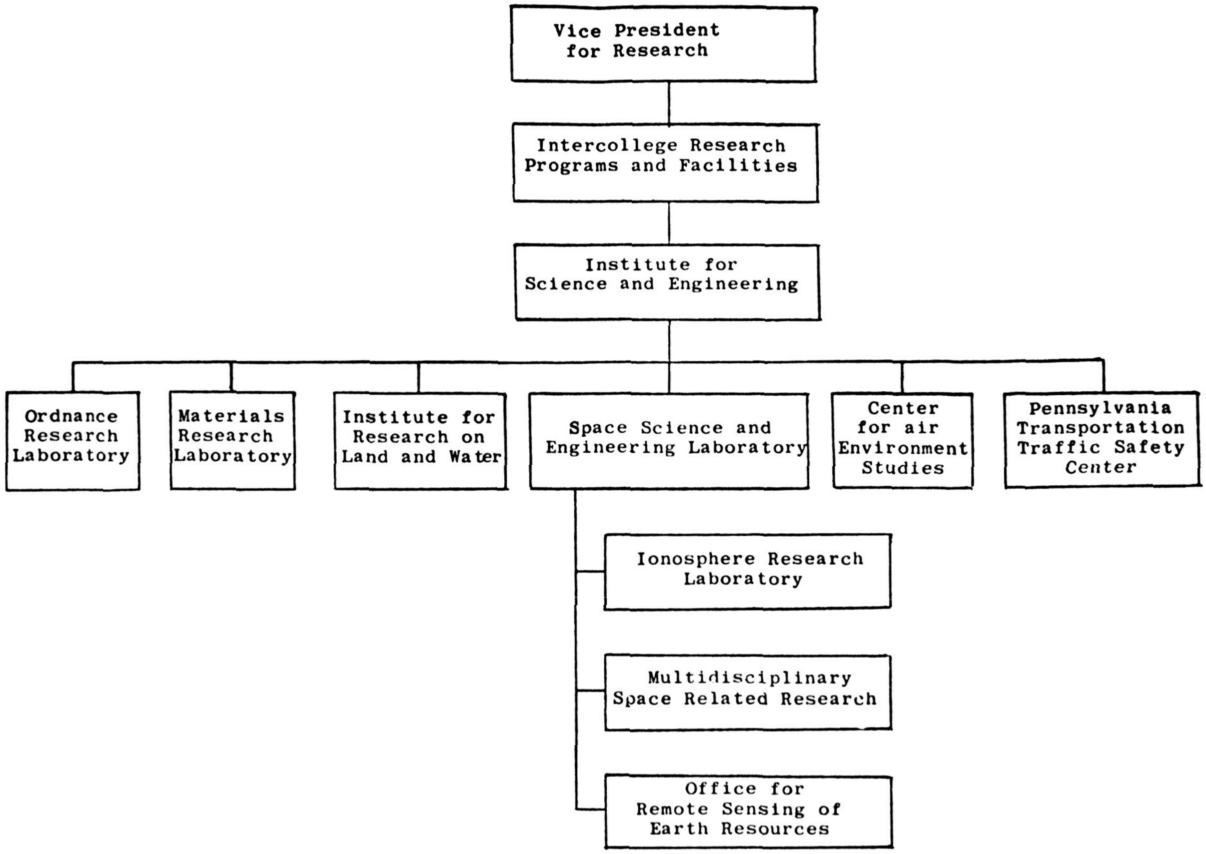

Figure 1. Organizational chart of Pennsylvania State University's Intercollege Program.

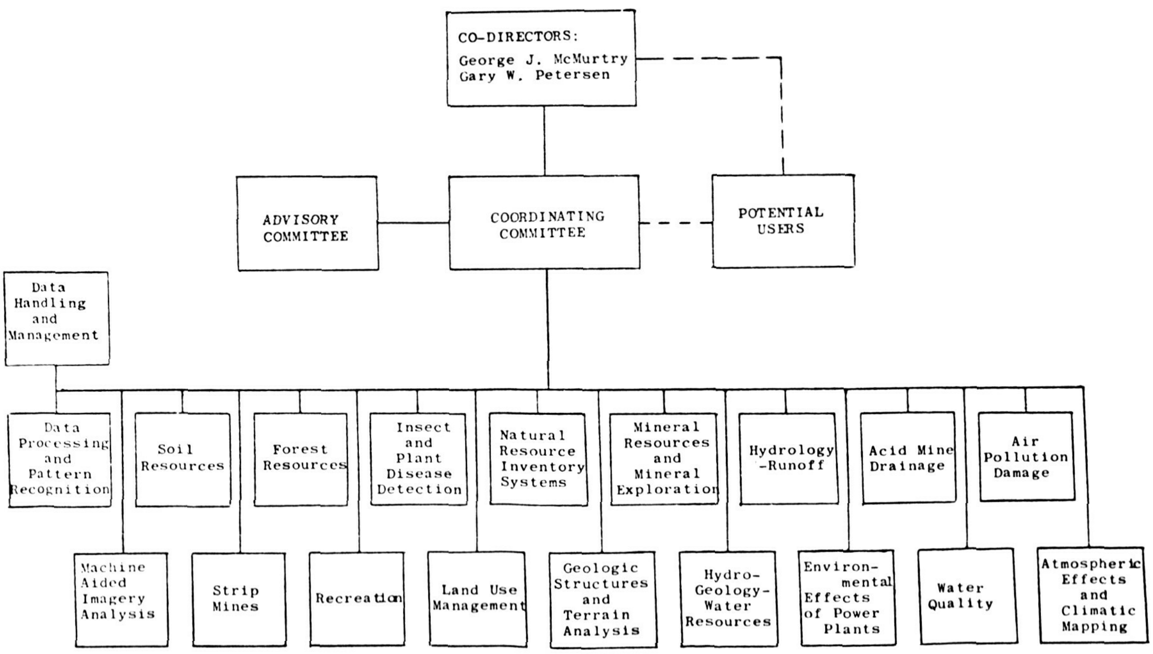

Figure 2. Organizational chart of the Office for Remote Sensing of Earth Resources (ORSER).