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Education and Training in Remote Sensing*

Functions of the EROS Data Center include training and assistance in the transfer of technology of extraction of information from remote-sensor data, and the application of remote sensing to resources and environmental problems.

Abstract: *The Earth Resources Technology Satellite, Skylab, and other programs of NASA and other Federal agencies have produced large amounts of data of the earth's surface. The Earth Resources Observation Systems Program of the Department of the Interior is designed specifically to collect and use aircraft and spacecraft remote-sensor data for natural resources and land-use investigations. To utilize existing instrument systems fully, user specialists need to be specifically trained in the techniques of extraction of information from the data and their application to resources and environmental problems. The EROS Program is conducting training courses at the EROS Data Center and elsewhere in the United States and world. These courses are designed primarily to train resources personnel in the use of ERTS and other remote-sensor data through practical exercises stressing the hands-on use of the data. These courses are especially aimed at resources scientists, engineers, and managers; land-use planners; and environmental specialists. The practical applications of remote sensing, rather than theory, are stressed in the various courses, but they differ in that the material used is selected to pertain to the specific resources/land-use/environmental problems and (or) geographic areas of the participants.*

Introduction

The groundwork for the civilian use of remote sensors from space to acquire data for the study and inventory of the earth's natural and cultural resources was laid by NASA. Other civilian agencies of the Federal government and a wide range of institutions, often in partnership with both civilian Federal agencies and military organizations, were working on specific applications of remote sensing, primarily from aircraft. The application to natural and cultural resources received considerable impetus in 1963 with the establishment of the NASA Advanced Missions Program; from this program evolved the present NASA Earth Resources Survey Program. Somewhat earlier, the National Oceanographic and Atmospheric Administration (NOAA) and NASA cooperated to develop systems of weather satellites and the ability to use the data for meteorological studies and weather prediction.

The Earth Resources Observation Systems (EROS) Program of the Department of the Interior was established in 1966, and throughout its existence has been closely allied with the NASA Earth Resources Survey and other programs. Working together, the EROS Program, NASA, and other Federal agencies identified the remote-sensor data needs of the user community and jointly specified the

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types of instruments to acquire these data. These specifications were translated into the Earth Resources Technology Satellite (ERTS) by NASA—Goddard Space Flight Center engineers, and engineers and scientists in private industry under contract to NASA and the EROS Program. The successful launch on July 23, 1972, of ERTS-1 provided the data acquisition capability, and the establishment in late 1971 of the EROS Data Center in Sioux Falls, South Dakota provided the means to distribute those data to the user public. Both NASA and the EROS Program recognized the necessity for training in the use of remote-sensor data, especially these new data.

This paper was prepared following extensive discussion with William A. Fischer and Raymond W. Fary, Jr., of the EROS Program staff; Nicholas M. Short of the Goddard Space Flight Center; and William E. Williamson, then a member of the Office of Science and Technology of the Executive Office of the President. The stimulating discussions with these knowledgeable scientists and resulting ideas on education and training, and their critical review of this paper, are gratefully acknowledged. In addition to discussions, Raymond W. Fary and the late Don L. Kulow, then EROS Program Training Officer, also reviewed the paper; their reviews are greatly appreciated.

One of the most valuable activities of the Advanced Missions Program was the formation of teams of instrument scientists/engineers and user specialists. Those charged with formulating programs to acquire and use remote-sensor data from aircraft and, especially, spacecraft recognized early that very few, if any, engineers or scientists had expertise in both instrumentation and earth-science disciplines. This was particularly true in remote sensing outside of the visible portion of the spectrum. Those with the greatest interest and most experience in the design of and use of instruments to measure and record electromagnetic radiation (EMR) and its interaction with natural and man-made materials were the physicists and electronic engineers. The agronomists, geographers, geologists, hydrologists, oceanographers and other user scientists and specialists, although highly competent in their disciplines and knowledgeable about the problems that needed to be solved, generally were unfamiliar with any but the most rudimentary remote sensing and sensors. The Advanced Missions Program sponsored teams of specialists in the design and operation of an instrument, such as radar, and user specialists who foresaw a use for the instrument. These teams pointed up the need for, and advantages of, cooperation among the various specializations. They also pointed up the difficulties of communication between instrument specialists and user specialists, stemming mainly from one group's unfamiliarity with the other's methods, objectives, and terminology. The team meetings and activities resulting from them served to educate those involved, and many of those now supervising research in and teaching remote sensing were involved in these activities, and profited greatly from them.

Courses and Programs in Remote Sensing

At the beginning of the NASA program in the early 1960's, remote sensing, except for photo interpretation, was taught only rarely in the colleges and universities. Even photo interpretation courses were few until the decade of the 1950's*. However, as the teams of instrument and user specialists met, were informed, and held meetings, and as each side became aware of the problems and techniques of the other, the need for education in remote sensing became apparent. This resulted in several institutions starting courses and programs in remote sensing, generally based on a single discipline, such as agriculture or geology, and the instrument specializations of the engineers and physicists. For example, the University of Kansas favored the disciplines of geography and geology and the microwave portion of the spectrum, specifically radar, whereas Stanford University specialized in infrared and the disciplines of geology and hydrology. Others, such as Purdue University and the University of Michigan pioneered in the extraction of information from the data, using both analog and digital methods for agricultural applications†.

As the program grew and spread from NASA to other organizations, a large number of scientists and resource specialists in government agencies, academic institutions, and private industry desired to learn more about remote sensing. Short courses in remote sensing were held by academic institutions and professional societies; some covered all

*According to statistics in the Manual of Photographic Interpretation (Cheney, 1960, p. 817), courses in photo interpretation numbered only 12 in 1944 and 14 in 1946, but by 1954 had increased to 173 in 102 colleges and universities.

†Mention of several institutions here or later is in no way intended to imply that they are the only institutions offering remote sensing education, or that their courses are necessarily the best.

or most earth resources disciplines, others were limited to one or two. These courses were for the most part attended to the announced capacity. Total enrollment was probably in excess of 1000. A number of symposia have been held; again, these have been well attended. An increasing number of colleges and universities now are giving courses in remote sensing and several have full-blown graduate programs in remote sensing and its application to one oı more resources fields.‡.

Although courses in academic institutions, short courses, and symposia, and the papers at professional societies' meetings have introduced some resources managers, engineers, and scientists to the possibilities of remote sensing, and a few are fully qualified in its use, those who can make maximum use of the remote-sensor data being obtained are far fewer than needed. The usefulness of remote-sensor data, especially as acquired from space, is clearly apparent, particularly if these data are placed in the hands of skilled interpreters. Therefore, steps must be taken to train sufficient resources personnel to utilize these data; not to do this would permit a large amount of very valuable and useful data, collected at considerable expense, to go unused or, at best, be underutilized. To overcome this lack of trained personnel, a number of steps may be taken. Before detailing the steps, let us look at the kinds of people involved, and the types of training necessary or desirable for them.

- *Program and project managers:* the executives, administrators, and supervisors who will plan overall programs or important segments of programs and missions. These individuals must be generalists, thoroughly trained in engineering or a physical science and (or) one of the resources disciplines, and broadly knowledgeable. A few key individuals of this caliber exist; they are playing the leading roles in the programs presently in being or under development. Although these individuals are primarily managers, and have acquired the necessary management skills either through education, experience, or a combination of these, many have not had the opportunity to become versed in the broad application of remote sensing to the resources disciplines.

- *Instrument specialists:* the engineers and scientists who develop the remote sensors needed to acquire the data. In addition to competence in instrument design, they should have an appreciation of the scientific and technical disciplines for which the data will be used. This is especially true of those supervising the instrument design work. Some of the engineers and physicists in remote-sensing instrument design should be introduced to the use of the data for earth resources investigations. These engineers and scientists then would help bridge the gap between resources-oriented specialists and the design engineers and physicists, and ultimately might work directly with the user specialists in the interpretation of data for specific investigations.

- *Data specialists:* the managers and engineers and other specialists operating the data systems. This system as considered herein includes all of the equipment and facilities needed to transfer the data from the remote sensor by which they are acquired to the user specialist who will interpret them. For electronically generated data, this involves onboard storage and (or) transmission to a ground receiving station where the data are received. At the ground receiving station, the signal is recorded and either processed there to an image, or retransmitted or sent in tape form to a processing center. For film-recorded data, this can involve onboard development of the film, conversion to electronic signal, and then the steps suggested for electronically generated data, or return of undeveloped film to a processing center and development, enhancement, analysis, and other steps to provide the user specialist with a picture or other display having the optimum information content.

In addition to the product of the remote sensor, often much other information must be correlated with and added to attain the desired end product. The acquisition and timely provision of this ancillary information may require sophisticated data gathering and

‡Eitel (1972) lists 62 courses in remote sensing and 18 courses in photo interpretation or photogrammetry that include remote sensing, in 57 institutions. Also listed are 5 remote-sensing graduate programs, which represented less than half of those in existence at the time the article was published. As part of its activities, the Remote Sensing and Interpretation Division's Education Committee, chaired in 1973 by Dr. Robert Baker of Stephen F. Austin University, is going to conduct a survey of colleges and universities to determine the number of courses in remote sensing and photo interpretation, and graduate programs permitting specialization in remote sensing, either as a major in itself or as applied to a specific discipline or disciplines. It is contemplated that the results of their survey will be published in *Photogrammetric Engineering*. Professional societies, such as the American Society of Photogrammetry and the Geological Society of America have emphasized remote sensing by devoting entire sessions to it.

storage and retrieval (information) systems. At a minimum, a system that enables the conjunction of the ground data and aerial and space remote-sensor data in a central repository, and means for its retrieval, duplication, and dissemination to researchers and for training, is needed. In those parts of the system concerned with processing, analysis, and furnishing the end product to the user specialists, the data specialists should have a clear understanding of the discipline or disciplines for which the data are being used. It is safe to say that the success or failure of airborne and spaceborne remote-sensing programs will hinge on an adequate data system; this was recognized by the EROS Program leaders when they planned and built the EROS Data Center. The managers of this system should be thoroughly conversant with the use to which the data are being put.

- *User scientists and specialists:* the geologists, mineral exploration engineers, hydrologists, oceanographers, marine biologists, agronomists, foresters, land planners, and many other earth-resources scientists, engineers, and other specialists who will use the data. Remote-sensor products include spatial/spectral data obtained from cameras and imaging radars; physical data, such as temperature, chemical composition, electrical properties, obtained by radiometers, spectrometers, and radars; and combinations of both types of data. Therefore, their use can be considered as ranging from an extension of photo interpretation on one end to an extension of applied physics on the other. User specialists should understand EMR theory, interaction of EMR with earth materials, instruments by which data are acquired, data systems, final processing and analysis, and interpretation techniques.

The user specialists play a most important role. It is for their investigations that the data are acquired, and they have to interpret those data. Therefore, they must identify the problems for which the data will be used; specify the kinds of data needed, conditions under which it should be taken, and form in which it is desired.

ERTS is an excellent example of a data-collection system designed to collect the most meaningful data for the intended users, resources managers, scientists, and engineers. This includes spectral, temporal, resolution, and coverage considerations.

The following discussion on education and training is directed towards user specialists and program and project managers, although recognizing that it is applicable to other specialists as well. The discussion also is directed towards those who completed their education before either remote sensing or photo interpretation were widely taught.

Education and Training of User Specialists and Managers

The methods that can be used to educate and train user specialists and program and project managers on remote sensing include:

- ★ Formal individual courses in colleges and universities.
- ★ Short courses of 6 weeks or less.
- ★ Institutes of 6 to 12 weeks.
- ★ Full-time academic programs of at least a year's duration; may or may not lead to a degree.

FORMAL COURSES

A number of academic institutes teach remote sensing; generally these are in a traditional department or school such as geography, agriculture, oceanography, geology, natural resources, or range management. If these schools are near a concentration of user specialists, as for example the proximity of the Colorado School of Mines to a large number of geologists in the Denver area, and if the course is offered in the evening or other suitable time when working professionals can attend, many do or would enroll with the proper incentives. Single formal college/university courses are useful ways in which to train user specialists.

These courses tend to be a single exposure to the subject, with emphasis on theoretical rather than practical aspects. Nonetheless, they serve as an excellent point of departure for user specialists who will be applying remote sensing to resources investigations. Experience at a number of colleges and universities indicates that these courses are most useful if the individual goes back to his organization and almost immediately becomes actively involved in using remote-sensor data. Those who do not become actively involved may not retain much or most of what they were taught. Many formal courses do not stress the practical problems involved in executing a remote-sensing program. Likewise, many students do not have the proper educational background in mathematics and physics to take full advantage of what they are being taught, nor the time to acquire the background, although they can absorb enough to pass the course. Even so, a formal course, or two or three, is one way to learn remote sensing on a part-time basis. Naturally, if the individual is working in a remote-sensing program and is willing to continue his studies on his own, the formal course makes an excellent beginning.

SHORT COURSES

Short courses of two or three days provide an introduction to remote sensing—*what it is*, what it can do, and where to turn for additional information. They may serve as an excellent point of departure for self education for those who have or will acquire the necessary background, have the necessary resources, and the motivation to learn on their own. Many of the shorter short courses tend to be very intensive, and more material than ordinarily can be assimilated in the brief duration may be presented. Again, for those who are becoming actively engaged in remote sensing programs, a short course may be an excellent way to get started. Short courses may last from two days to several weeks and, of course, grade into long courses or institutes.

INSTITUTES*

An institute involving extensive laboratory and field work, in conjunction with an aircraft or spacecraft overflight, is one way to train selected user specialists. At a specially equipped facility, such as the EROS Data Center, the students are provided with imagery which they interpret on equipment of the type they may reasonably expect to have available in their home organization. Introduction to imagery interpretation can be presented using images of the local area as a basis for theoretical discussion and practical exercises. The results of the interpretation can then be field checked, at least in most seasons of the year. In some areas, rigorous winter or summer conditions may preclude or limit field checks. The institute can be structured so that geologists work on geologic problems, foresters on forestry problems, etc., each under instructors from his own field. Because many of the problems are common to two or more user disciplines, or one discipline is influenced by one or more other disciplines, *multidisciplinary or interdisciplinary* problems using the team approach also should be included.

An institute could be divided into three parts: a two- or three-week basic part for those with no or very weak backgrounds in *remote sensing*; an advanced part of three or four weeks for those who have the equivalent of a combination of experience and previous education of the basic part or who took the *basic part*; and a *discipline-oriented session* of two or three weeks. Both the basic and advanced parts would include laboratory sessions, mainly using remote-sensor data from many sources for instructional purposes. The discipline-oriented part would stress application to the particular discipline and would include laboratory and field work, obtaining aircraft, ground remote sensor, and other data as applicable, and integrating the interpretation of these data with the main problem.

An institute as envisioned could conveniently and efficiently be offered by an institution or group of institutions already engaged in remote-sensing research and education at a nearby test site, and experienced in carrying out field and aircraft programs. Likewise, the EROS Data Center is planning a series of technique- and discipline-oriented courses that approximate the institute concept.

A sequence of two courses held several times a year permits considerable flexibility on the part of both students and instructors, and may be considered as analogous to modular construction; only those modules that are necessary are used, and various combinations of modules can be put together to meet the requirements of any given time.

FULL-TIME ACADEMIC PROGRAMS

Full-time graduate programs of one year or longer certainly are among the best ways to train personnel in remote sensing. It is by these programs that research engineers and scientists traditionally are educated. Future generations of remote-sensing specialists, both in instrument development and application, can be expected to be educated in this manner. Only occasionally, however, can a resources professional spend a year or more away from his job. Nonetheless, where this is possible, it is an excellent way to provide training in remote sensing. In general, the younger staff members, with or without advanced degrees, find it easier to get away for a year or two than do the older, more experienced professionals, many of whom have greater management responsibilities. Those who are able to complete a graduate program stand an excellent chance of becoming full-time researchers in remote sensing or users of remote-sensor data, and the future leaders in the field.

*The institute concept was developed while the author was a member of the Colorado School of Mines faculty. Many of the ideas stemmed from discussions with W. A. Fischer, U. S. Geological Survey; N. M. Short, Goddard Space Flight Center; W. E. Marlatt, Colorado State University; and P. N. Slater and P. B. Newlin, University of Arizona. Although crediting them with many of the ideas herein presented, I fully absolve them from all defects or shortcomings, which are solely my responsibility.

Training at the EROS Data Center

Among the primary functions at the EROS Data Center are training and assistance in the transfer of technology of extraction of information from remote-sensor data, and the application of remote sensing to resources and environmental problems. These are accomplished by organized training courses, by assistance provided during visits or telephone calls to the Data Center, or by visits of Data Center staff to other organizations. The following discussion emphasizes the organized training courses.

The principal objectives of EROS Data Center training are:

- To train experienced resources personnel who graduated from colleges and universities before remote sensing was widely taught and thus were unable to or did not take courses in it.
- To provide in-depth training in the use of remote-sensor data of widespread availability; especially that provided by ERTS-1.
- To transfer specific techniques for extracting information from ERTS and other data and apply the resulting information to a particular problem, such as land-use classification.

Care is taken to avoid duplication of standard college courses in remote sensing, or short courses held periodically under the auspices of professional societies or by colleges and universities.

To meet these objectives, training courses at the EROS Data Center emphasize the interpretation of data and minimize theoretical aspects of remote sensing. The courses are built around specific problems designed to provide basic instruction in imagery interpretation and to show specifically how remote sensing can be applied to a particular problem. Two types or levels of courses are planned: technique-transfer courses and courses aimed at a particular discipline or several closely related disciplines.

Facilities

The EROS Data Center (EDC) contains a large classroom with a seating capacity of about 150, two smaller classrooms, and four project work rooms. The smaller classrooms and project work rooms contain large work tables, or drafting tables, which provide adequate space for working with mosaics and large maps. The large classroom can be divided by retractable partitions into four smaller ones, each capable of holding 30 lecture chairs.

Major equipment available for training courses includes color-additive viewers, an image-density analyzer, zoom transfer scopes, and interpretation stations with 60× stereo magnification. Mirror stereoscopes, folding pocket stereoscopes, light tables, and drafting equipment also are available for use by the participants.

The resources of the main U. S. Geological Survey library at the National Center in Reston, Virginia and Regional Center libraries at Denver and Menlo Park, California, and technical libraries at educational institutions are available through interlibrary loan.

Instructional Staff

Training courses are organized by the Chief of the Training Section, EDC, assisted by other EDC personnel. Instruction is conducted by EDC personnel, augmented by specialists from the U. S. Geological Survey, other governmental agencies, and educational institutions. Every effort is made to obtain the best possible instructors, and to provide them with the necessary materials to ensure a successful course.

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