will be relatively slow as governed by the availability of computing power, and complementary resources, unless new aproaches to this difficult problem are found.

In conclusion, I am pleased to have been able to report here on the application of advanced technology to several agricultural weather research and service activities. Further progress in understanding weather for agricultural and other types of weather services require that we continue to use the latest satellite and computer technology states-of-the-art. NOAA intends to continue its innovative efforts in this area.

Chairman HUMPHREY. Thank you very much, Dr. White.

Our next witness is Dr. John DeNoyer.

STATEMENT OF DR. JOHN DeNOYER, DIRECTOR, EROS, U.S. GEOLOGICAL SURVEY, DEPARTMENT OF THE INTERIOR

Dr. DENOYER. Mr. Chairman and members of the Technology Assessment Board, I am glad to have the opportunity to appearbefore this Board to discuss remote sensing programs in the Department of the Interior that relate to food production.

Even though the Department of Interior is not directly responsible for food production, Interior does have man-y activities in terms of data gathering, information dissemination, and management responsibilities that relate directly to food production.

Some of these management activities include the leasing and use of public lands, leasing and monitoring of petroleum production on Federal lands and the Outer Continental Shelf, operation of systems of reservoirs for the combined purpose of recreation, power generation, and water availability for irrigation and management of wildlife resources. Information gathering and distribution of data include baseline data on water availability and quality, mapping of flood-prone areas and mapping of actual floods, geologic information to assist in the exploration for minerals, such as phosphates, needed for agriculture and preparation and distribution of topographic and land-use maps that are basic tools for planning.

Remote sensing technology has demonstrated capabilities or potential for applications in all of these areas. The Earth Resourses Observation Systems (EROS) program was established in the Department to be a focal point for uses of remote sensing throughout the various bureaus and to work with other agencies in applying and planning for remote sensing capabilities that are needed to carry out the departmental responsibilities.

The paper I have submitted to the Technology Assessment Board discusses, in some detail, the ways in which remote sensing is being used in the Department and points out the relation of these uses to food production. I would like to add that similar discussions could be written with other topics as the central focus. Remote sensing allow us to make observations and to preserve these observations in a quantitative and objective way. These data are then useful for many purposes.

The fact that so many diverse disciplines are using remote sensing data sources as tools is having a significant effect on the development of interdisciplinary natural sciences. The fact that Landsat and the NOAA satellites have worldwide coverage capabilities is also encouraging collaboration between scientists in different countries. The importance of improving these types of interdisciplinary and international communications cannot be underestimated when problems such as world food production are considered.

Much has been accomplished since the launch of Landsat-I in July 1972. The research programs have demonstrated many capabilities. Some of these are already being incorporated into the regular functions of governmental agencies and industry. We have also learned a lot in terms of what we should do next.

An improved data processing system that will serve Landsat is being implemented by NASA at the Goddard Space Flight Center. The Department of the Interior is upgrading its capabilities at the EROS Data Center in Sioux Falls, S. Dak., to accept the improved data formats that NASA will be producing and to provide for data reproduction and distribution to users.

These complementary capabilities have been made possible through cooperation in detailed technical planning between NASA and Interior, close coordination at the management levels, and the support of this Congress. We expect to have these improved data processing systems in operation to handle the data from Landsat-C. The result will be that users will be able to obtain much higher quality data in formats that will be easier to use, and the time between acquisition by the satellite and availability to users will be reduced from the present 6 to 8 weeks to 2 to 3 weeks.

The Department of the interior is also working closely with NASA and other participating agencies to define the technical characteristics of follow-on systems that will be needed in the 1980's. We, like the other user agencies recognize the importance of continuity to programs of this type. If there is a single factor that has discouraged full scale use, it is the lack of assurance of continuity.

The interest in receiving training in the capabilities and methods of using remotely sensed data by scientists and managers has been large and is increasing. A full schedule of workshops, structured training courses, and cooperative demonstration projects is being conducted at the EROS Data Center and at applications assistance facilities that are operated by the EROS program.

The purpose of these training and demonstration projects is to transfer technology to organizations and individuals to accomplish their missions more effectively through the use of remotely sensed data. There are also capabilities to satisfy information needs that may not have been practical or possible in the past but are now relatively easy to accomplish through the use of remote sensing.

Mr. Chairman, satellite technology has opened the windows of space to see ourselves as we are and to direct our scientific search for solutions to food and other resource problems. Remote sensing has given us the capability. to monitor many of our environmental conditions and to measure, significant changes. The realization of the importance of these developments is not apparent to all. I am, however, encouraged that the Technology Assessment Board is familiarizing itself with this program.

Thank you. Mr. Chairman.

Chairman HUMPHREY. Thank you.

[The following paper was requested from EROS by OTA:]

SUMMARY OF THE PAPER--REMOTE SENSING PROGRAMS IN THE DEPARTMENT OF INTERIOR THAT RELATE TO FOOD PRODUCTION

(BY John M. DeNoyer)

The Earth Resources Observations (EROS) Program was established in 1906 as a departmental program under the direction of the Geological Survey. As an integral part of the program, an EROS data center was established at Sioux Falls South Dakota which maintains remote sensing archives, including retrieval facilities, and conducts training programs on the use of remote sensing data.

The objectives of this program are: (1) to develop remote sensing capabilities applicable to solving natural resource problems within the department; (2) to conduct and encourage research in remote sensing methods; and (3) to serve as a focus for technical exchanges with other agencies.

The Department of Interior has primary responsibility for the derivation of information relating to energy from water, fossil fuels, and the related environmental effects of development. Its responsibilities relating to food production include: (1) Management of public lands, (2) Management of surface water, (3) Providing baseline information on water availability, quality, and use, (4) Mapping of flood prone areas and actual floods, (5) Conduct of experimental programs in weather modification, and (6) Searching for critical minerals such as phosphates.

Remote sensing data are being used in experimental programs in each of these areas. Preliminary reports indicate that remote sensing data are useful in developing improved management plans for the public lands. They also have been found to be useful in each of the other areas listed.

Many capabilities of remote sensing have been demonstrated. Others are still in the research stage, More areas of application will be discovered as scientists become more familiar with the data and with analytical techniques for processing these data.

The EROS Program has been cooperating with most of the Latin American countries and with Iceland in the use of LANDSAT and other remote sensing methods. In each country the remote sensing data have been utilized to provide information on land use, agricultural development and related areas.

Experience in the EROS program indicates that one of the major deficiencies at the present time is the delay in obtaining data and analyses after the data have been recorded. It often has been impossible to get the information to the program manager at the time he needed it to make his decision.

More emphasis needs to be placed on physical models to turn data into useful information, and more experience needs to be gained in using this information for real management decisions.

Agencies are concerned about becoming dependent on LANDSAT data until there is assurance of continuity beyond 1980. Also too often the data are not available soon enough to be used in making time-critical decisions; and standard photographic products contain less than the complete data, thus precluding their use in some applications.

These latter deficiencies are technical and can be corrected with improved technology. An important result of this program, often overlooked, is the unifying influence of a global data base with uniform characteristics that services scientists in many disciplines in many countries.

REMOTE SENSING PROGRAMS IN THE DEPARTMENT OF THE INTERIOR THAT RELATE TO FOOD PBODUCTION

(By John M. DeNoyer, Director, Earth Resources Observation Systems (EROS) Program, Geological Survey, U.S. Department of the Interior)

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EXECUTIVE SUMMARY

The Earth Resources Observation Systems (EROS) Program is a departmental program, managed by the Geological Survey for the Department of the Interior. The primary functions are--

to conduct and encourage research in remote sensing technology;

to assist in implementing uses of remote sensing technology to operational programs;

to provide a mechanism for technology transfer; and

to provide for data archiving, retrieval, reproduction and distribution of remotely sensed data and related information.

Some important functions of the Department of the Interior that relate to food production are-

management of public lands;

management of surface water;

to provide baseline information on water availability and quality;

mapping of flood prone areas and mapping of actual floods;

conducting experimental programs in weather modification;

searching for critical minerals such as phosphates;

management of petroleum and natural gas production on Federal lands;

management of wildlife resources;

preparation and distribution of topographic maps; and

compilation and distribution of land use maps and related information.

Remote sensing technology has ***some*** demonstrated or potential applications to all of these functions.

Significant progress has been made in using remote sensing technology or demonstrating its applicability for:

water availability;

weather modification;

irrigated land inventories;

impacts of changing land use on agriculture;

rangeland management;

flood mapping;

indications of climatic change:

exploration for phosphates for" fertilizer production; and

energy resources.

Training in the uses of remote sensing technology for agricultural and other disciplines needs additional attention.

Major problems and deficiencies in the current remote sensing program are-

lack of assurance of data continuity;

data are not available soon enough for management decisions or environmental and emergency applications;

standard photographic products should be of higher quality;

inadequate physical models to use the remotely sensed data; and

inadequate management models to use information derived from remotely sensed data.

Global remote sensing has-

improved interdisciplinary scientific communication;

improved international scientific communication; and

made new types of global scientific studies possible.

INTRODUCTION

The Earth Resources Observation Systems (EROS) Program was established in 1968 as a departmental program to: (1) develop remote sensing capabilities applicable to solving natural resource problems within the department, (2) conduct and encourage research in remote sensing methods, (3) work with the various bureaus of the department in implementing uses of remote sensing technology into operational programs, and (4) serve as a focus for interagency technical and programmatic exchange with other agencies, In addition to these functions, the EROS Data Center is a major facility for remote sensing data archiving, retrieval, reproduction and distribution that is operated at Sioux Falls, South Dakota. Emphasis is also placed on technology transfer of uses of remotely sensed data through applications assistance, technique development appropriate for operational uses, demonstration projects and training programs, In the intensive agricultural practices of the United States, the availability of energy and the production of food are inexorably linked. The Department of the Interior has a prime responsibility for the derivation of information relating to energy from water, fossil fuels, and the related environmental effects of development. In addition, the department has other responsibilities that relate to food production that include:

Management of public lands.—The Bureau of Land Management is responsible for realty activities on all national resources lands, the Outer Continental Shelf, and large areas of Federal land under other agency surface management (e.g., national forests.)

This area comprises more than 182 million hectares (450 million acres) still in Federal ownership, as well as the publicly owned mineral resources on about 25 million hectares (61 million acres) of privately owned lands, and the Outer " Continental Shelf.

Management of surface water.—The Bureau of Reclamation and the Bonneville Power Administration are directly responsible for management of major quantities of water that is used for irrigation of agricultural lands in the western ~ United States.

Providing baseline information on water availability, quality, and use.— The Geological Survey is the primary agency for collection of water data and for compiling ground water and surface water data collected by other agencies. The rapid growth in the use of ground water for irrigation emphasizes the importance of this activity.

Mapping of flood prone areas and mapping of actual floods.--- *The* Geological Survey conducts many of these flood mapping activities. Such maps have direct applications to agricultural planning and damage assessment to crops.

Conduct experimental proqrams in weather modification.-- The Bureau of Reclamation is conducting experimental programs in weather modification to increase water availability and for hail suppression. Both of these objectives have a direct bearing on water availability for irrigation and minimizing crop damage.

Searching for critical minerals such as phosphates.— The use of phosphates to improve agricultural production is increasing. The location of phosphate deposits requires basic geologic information of the type that the Geological Survey prepares.

Management of petroleum and natural gas production on Federal lands..- Petroleum and natural gas have become very important for preparation of fertilizers, operation of farm equipment, processing of agricultural products and transportation of farm products. The Bureau of Land Management has responsibility for leasing of potential petroleum producing areas on Federal lands, and the Geological Survey is responsible for technical consultation with the Bureau of Land Management prior to leasing and supervision of the leases through the development and production phases. Geologic mapping on land and marine geologic investigations conducted by the Geological Survey serve as the basis for most of the more detailed exploration programs conducted by the petroleum industry.

Management of wildlife resources. —The Fish and Wildlife Service is responsible for the conservation of many types of wildlife and their habitats. The natural resources of wildlife contribute directly to food supplies and are also important for the balance of nature that is essential for future food availability.

Preparation and distribution of topographic maps of the United States.— These maps are prepared by the Geological Survey and form the basis for most planning and engineering development in the country.

Complicatiom and distribution of land use maps and information-- The Geological Survey is conducting a hind use mapping program that will be completed for the conterminous states within a few years. Times data will be essential to the quantitative evaluation of relationships between land use for agriculture and other competing uses.

Remote sensing can contribute to information gathering and analysis, in terms of efficiency, timeliness and accuracy for all of these activities. In some cases, remote sensing is the only way to collect the necessary data and perform an analysis in a timely manner.

REMOTE SENSING APPLICATIONS

A number of specific research projects, demonstration projects and cooperative programs are in progress within the EROS Program at the present time. Others have progressed to the point that the participating organizations are continuing the work initiated by the EROS Program. These activities are all conducted with the direct participation of the responsible agencies. The participating agencies include Federal, state, local, and foreign governments, and domestic and foreign organizations. The following discussion will be restricted to uses of remote sensing technology and related uses of data collection platforms.

Water Availability

The efficient and practical use of water is the key to successful agricultural production, both of plant crops and meat products. The use of remote sensing technology, including the use of images from the Landsat Earth orbital satellites, is proving to be an aid in the agricultural field in three ways: (1) in determining the volume and availability of water for agriculture, (2) in aiding in the distribution and management of the agricultural water supply, and (3) in assisting in the determination of the quality of water for agricultural purposes.

In many areas of the United States, ground water is "mined" (extracted at a greater rate than replenished), and information relating to the rates of extraction, the means of replenishment, and the availability of temporary sources of water, such as playa (temporary) lakes, is currently limited. Promptly delivered and analyzed satellite images can assist in the inventory af available water and determining and protecting the most effective points of aquifer recharge.

The volume and availability of water is determined in different ways for different purposes. Mapping of the extent of surface water in lakes, rivers, and other inland water bodies and in the measurement of the changes in the amount of water in storage is readily facilitated by periodic analysis of Landsat images. Recent work by the U.S. Army Corps of Engineers and the National Aeronautics and Space Administration has shown that water bodies as small as 1.6 hectares (4 acres) can be identified and mapped, and changes in area covered by surface water can be readily discerned over periods of time.

Because irrigated agriculture is primarily supplied from surface water sources, the assessment of the distribution of such water is of vital importance in determining the areas that can be irrigated during a given year, assessing the amount of water available at the beginning of an irrigation season, and in determining the source areas for water which may not now be used for irrigation but which could possibly be used in the future.

Much of the water available for irrigation and other uses in the western United States occurs as snow and is released when the snow is melted during the spring and early summer. Monitoring of the mountain snow pack during the winter and the melting of that snow during the spring thaw period can aid in the forecasting of water supplies and in determining their allocation during the irrigation season. The U.S. Geological Survey participates in the monitoring of the mountain snow packs. At present a cooperative project between the USGS, NASA, and other agencies is being undertaken to demonstrate the feasibility of using such snow cover mapping and water runoff forecasting in California, Colorado, Oregon, and Arizona.

Use of ground water for irrigation is on the increase in the western United "States. Exploration for ground water is aided by the analysis of Landsat images to locate aquifers, or water bearing formations, that occur just below the surface of the land. Such aquifers may be indicated by the pattern of the rocks and sediments, the vegetative indicators, and by land-use clues, While much of the exploration for ground water must inevitably rely on drilling and definite proof of the availability of adequate supplies of water, initial indications of the presence of ground-water bearing formations may be obtained from the analysis of Landsat images and may guide efficient programs of exploration and drilling.

The distribution and management of water systems for irrigated agriculture requires real time decisions, on the present and continual availability of water, and the means which will distribute water to the users at the appropriate time. Remote sensing technology allows the water manager access to an up-to-date inventory of the amount and distribution to irrigated lands as well as availability of water for irrigation. Measurement of amounts of wateflow in rivers, canals and distribution systems is monitored by telemetering the data into the water manager's office.

Water data is used in two prime ways. The first is in exploration for water. Knowledge of the amount of water available at a given time and its quality is an essential factor in planning for the construction for large water distribution and diversion works and for the decisions on the allocation of financial and other resources for the production and management of such water. Landsat image analysis can significantly aid in determining such characteristics of the water and the terrain and can aid in the scientific and engineering planning for the development and in exploration of water resources.

The second, management and regulation of water resources, requires real time knowledge on the availability of water at various points and time and at various places. The continuing repetitive nature of Landsat images allows an assessment by the water manager of availability of water and the ability to have information on the availability and flow of water at various points telemetered directly to his office allowing him to make faster and more efficient decisions on the allocation of that resource.

The applications of remote sensing to the study of water resources have been summarized in a recent report of the Space Applications Boardd of the Academy of Engineering of the National Research Council. It provides detailed assessments of the types of data needed for management of inland water resources, of the benefits that may accrue from better management of inland water resources based on the use of remotely sensed data, and suggests several demonstration projects that could be undertaken to provide such proof. The Geolgical Survey has engaged in research on the applications of remote sensing technology to water resources problems for a number of years and has actively been involved in a number of water management groups within the United States in such projects. The benefits to be achieved from these applications are potentially large. Achieving the desired objectives and maximum benefits will require the continued involvement of management groups and a continuation of the research leading to the demonstration of feasibility of the specific application.

Weather Modification To Enhance Water Availability

Seven Landsat data collection platforms (DCP's) have been used by the Bureau of Reclamation in a major winter weather modification program designed to determine the feasibility of enhancing runoff into the Colorado River Basin. The platforms, located in the severe winter environment of the San Juan Mountains of southwestern Colorado, have been operated snee the spring of 1973. Temperature, precipitation, solar radiation, streamflow, humidity, and snowpack water equivalent observations are routinely relayed by Landsat to the Goddard Space Flight Center where they are transmitted to a Denver computer and are available via teletype terminals within 3 to 8 hours from on-site transmission.

During the 1973-1974 winter season, the platform system proved to be a valuable tool in providing additional and mare rapidly acquired data for weather forecasting, cloud seeding operations, streamflow foreca sting, and evaluation purposes. Data have been used for near real-time monitoring of meteorological and hydrological data for control of cloud seeding operations and verification of weather forecasts. Project experience has shown the Landsat field installations to be remarkably reliable, weather resistant and cost effective with the capability of relaying high-quality data in near real time. The availability of such data contributes to the decision making processes of the Bureau of Reclamation's research and development program in precipitation management.

Another study was initiated during the summer of 1975 near Miles City, Montana. This study involves testing the effectiveness of recording rainfall in the High Plains through use of Landsat. The satellite relays data from 64 rain gages and provides reliable, nearly instantaneous rainfall information. The project is part of the Bureau of Reclamation's High Plains Cooperative Program, a comprehensive research effort to refine the technology for seeding summer clouds to increase rainfall over the High Plains States. *

An automatic system for the collection of precipitation and other meteorlogical parameters from the Miles City cloud seeding site has been developed and tested. The design incorporates a network of digital precipitation gages operating within a 10-kilometre (12-mile) radius of a Landsat. DCP. The design also includes a concept for data collection by aircraft from a network of gages operating over an area of several thousand square miles. Two Landsat/Geostationary Operational Environmental Satellite (GOES) compatible DCP's will also be installed in the project area. A variety of meteorological data parameters including average wind speed and direction, temperature, and humidity will be relayed for project control and to evaluate the effect of cloud seeding research.

The use of satellite imagery from GOES is also being considered within the Bureau of Reclamation's Atmospheric Water Resources Management Program. The availability of near real-time imagery will provide valuable information on cloud growth and location for project management. The pictorial record of cloud events will also be of value for evaluating the results of cloud seeding.

The Bureau of Reclamation is currently providing technical support and laboratory facilities to the Soil Conservation Service (SCS) of the Department of

Agriculture for examination of the Upper Rio Grande drainage in the Sangre de Cristo-San Luis Valley area of Colorado. SCS is developing runoff forecasts based on snowpack information derived from satellite imagery.

Irrigated Land Inventoried

Inventories of irrigated lands are important for estimating agricultural pro duction. They are also important in planning of water management. Water management involves both surface water and ground water. Surface water management must include recreation, wildlife habitat, flood control and power generation as well as irrigation requirements, The use of ground water for irrigation is increasing rapidly in a number of western states. Continued increases in and widespread use of this resource must consider the impact on the water table and on the ability of the aquifer to recharge at a rate comparable to rate of water withdrawal.

Center-pivot irrigation systems we readily observed on Landsat imagery, particularly band ***5 (600-700*** nanometres), the red band, and in false-color composite images where contrast between irrigated and nonirrigated areas is marked. In recent years deployment of center pivots has increased rapidly; Nebraska, for example, is currently adding about 2,000 per year. In some areas, the increased deployment could affect the local ground water table. Both the University of Nebraska and the EROS Program have used Landsat imagery to count the num-number of center pivots for the entire state during the irrigation seasons of 1972, 1973, and 1$74. Analysis of such imagery shows that the number of center pivots in part of Holt County, Nebraska, increased from 508 in July 1972, to 552 in July 1973, and to 740 in August 1974.

An inventory of irrigated agricultural lands is being conducted in the Klamath River basin of Oregon in cooperation with the Oregon Department of Water Resources. This project is designed to demonstrate the utility of multidate Landsat data and manual analysis techniques for inventorying and monitoring irrigated land area. The Klamath River Basin Compact between the States of ***Oregon*** and California limits the acreage of land in each state that may be irrigated within the basin. Compliance with the terms of this compact requires annual inventories of the irrigated acreage so that regulation can be imposed as the limit is approached. The EROS Program, through the Pacific Northwest Regional Commis-mission Project, is assisting in a demonstration of the use of 1:250,000 Landsat color composite prints acquired at two or three dates during the growing season, together with manual delineation of irrigated land and dot grid sampling procedures to estimate the acreage of irrigated land.

In the Bureau of Reclamation, satellites such as Landsat are revolutionizing data collection, and the application of remote sensing technology promises to become increasingly useful as the full range of its potential is explored and exploited. Consideration is being given to the future use of remote sensing to assist in obtaining information for the following types of Bureau activities:

(a) Periodic inventory of irrigated lands and cropping patterns to determine changes in area for improved water use projections; and land use inventories to identify environmental problems and growth patterns.

(b) Gathering of crop census data on projects more accurately and economically. The potential also exists for determining the state of plant vigor and associated yield estimates.

(c) Timely **and** rapid acquisition of basic water resources data to achieve better conservation. management, and use of existing supplies. A typical example would be the periodic monitoring of water surface areas at remote reservoir sites to assist in measurements of water lost to evaporation.

Impacts of Changing Land Use on Agriculture

The availability of Landsat imagery since July of 1972 has provided scientists, planners, environmentalists, cartographers, geographers, economists, and others with the data and the means to objectively monitor environmental impact caused by man's activities and the attendant changes in land surface cover. Not only is such monitoring of environmental impact and changes in land surface cover possible for the United States but for all the land areas of the world as well.

In the United States the land classified as agricultural is one of the most variable because it is subject to seasonal change, change in crop type, or conversion to industrial or residential land. The current Landsat technology, for instance, could provide each state and the nation as a whole with an annual inventory of total land under cultivation on a seasonal basis. This information could then serve as the basis for estimating the amount and distribution of agricultural land being converted to non-agricultural use.

The EROS Program is participating in a demonstration project to measure the conversion of cropland to urban land. Four specific areas are included in this project. The areas are: (1) the 10 largest urban areas in the State of South Dakota, (2) the Atlanta, Georgia, urban area, (3) the Puget Sound urbanized area, and (4) the Portland-Willamette Valley urban area. In each of these areas, the analysis is being conducted in cooperation with Federal, regional, state and/or local agencies to demonstrate the applicability of satellite and aircraft data to urban land use planning. One of the principal concerns of land use planners is determining "highest and best use" of a given parcel of land. It follows that, as property values rise in urban or near-urban areas, the competition between conflicting land uses becomes of major interest to land use planners. Thus, timely, economical and reliable estimates of the rate of conversion of prime, high-value, agricultural land to urban uses, is a primary information requirement. Within each of the study areas, the utility of multitemporal Landsat data and interactive digital image analysis techniques for meeting this information requirement is being demonstrated.

Rangeland Management

The purpose of rangeland management as conducted by private enterprise or by Federal or state governments is to ensure the highest production of cattle and sheep commensurate with conservation and maintenance of good condition of' the rangelands. This is an example of the sustained yield concept or the maximization of production over a long period of years rather than maximization for only a short term with consequent degradation of the range conditions which could lessen production in later years. The rangeland manager has two basic tasks that can be facilitated by remote sensing technology and particularly by the use of Landsat images. The first is basic assessment of rangeland condition and determination of the grazing capacity of the range. The second is monitoring of the range conditions for day-to-day and year-to-year management.

Basic assessment of the range involves mapping and describing grazing lands so that the soils and water conditions are well known and the type, distribution, and density of vegetation is well known. From that, the capacity or number of grazing animals per unit area can be determined. Research, using Landsat images, in both the United States and Australia is demonstrating that the land can be subdivided into areas of varying grazing capacity based on the vegetation, soils, and nature of the land surface. The Landsat images are satisfactory for such an evaluation at small scale over large areas.

Monitoring of range conditions will provide the range manager with information to determine what the grazing capacity of the range should be for a given year, whether it is wet or dry, whether there has been natural or manmade degradation of the land, and whether or not rangelands have been improved by management practices. Degradation of rangelands can take place by overgrazing or erosion. These features can be seen on Landsat images and can be quantified by digital processing of the images.

It is necessary for the rangeland manager of public lands to set the grazing capacity of these lands in any given year in such a manner that the land will not be required to carry too many grazing animals, and thus be degraded, and yet not carry too few grazing animals so that production may be optimized. The qualities of the Landsat images are such that these decisions can be made. The major deficiency at the present time is in obtaining data and analyses rapidly enough to get that information to the manager at the time that he needs to make his decision.

The Bureau of Land Management and EROS have sponsored a pilot study in rangeland monitoring in the Susanville district of California. The study, conducted by the University of California, Berkeley, was directed at a large variety of problems that are of concern to the bureau, and the results are to be made widely available within the bureau, so that applicable portions can be utilized operationally in the various regions. Specific demonstrations from this study include the ability to make rapid regional assessments of range class conditions to guide release or withdrawal of grazing leases. The capability to monitor change in water areas of large stock ponds and range reservoirs can be used to guide decisions concerning grazing leases. Rapid changes in range conditions can occur as a result of floods, hail, wind, temperature, drought, and disease. The effect of all of these factors on range conditions can be monitored by use of Landsat data, but rapid processing and analysis of the derived information is necessary in order to make timely management decisions.

This study determined and demonstrated the feasibility of utilizing Landsat data to monitor the seasonal change of range conditions within the annual grassland type of California. The seasonal condition of the forage Is directly related to the quality and quantity of available forage. Monitoring these changes provides inputs for determining the relative amount of forage produced, the location of high-quality forage, the timing of livestock movement to and from rangelands, and the fire hazard associated with dry forage.

This study and related investigations have been important considerations by the Bureau of Land Management in the preparation of a comprehensive, strategic long-range plan. This plan will adapt the latest in automatic data processing and remote sensing technologies into a Bureau of Land Management information system. The strategic plan is designed to point the direction in which the Bureau of Land Management might go in these areas and to provide a basis for ***more*** informed decisions about (1) the acquisition of information system hardware and software, (2) the automation of system data, and (3) the use of remote sensing technology.

The integrated approach to using automatic data processing and remote sensing technology will include the following areas: domestic livestock grazing, fish and wildlife ecology and habitat development, outdoor recreation, timber production, watershed protection, wilderness preservation, minerals development, environmental protection and enhancement, river basin planning, and general land use classification under the concept of multiple use. Resource management and development activities are supported by a construction and maintenance program which provides and maintains roads, trails, and physical improvements such as recreation facilities and watershed control structures; and by an active program to protect the public lands and their resources from wildfires and from all other forms of public and private misuse.

The EROS program has been cooperating with most of the Latin American countries in the use of Landsat and other remote sensing methods. Many South American countries realize that Landsat data can provide them with much of the information that is needed for natural resource inventory, planning, and development. Bolivia, for example, has vigorously pursued a multidisciplinary approach in which geologists, hydrologists, agronomists, and foresters worked together to produce maps ***in*** their respective disciplines and then combine these into what are called "land capability maps." These maps show where farming, grazing, irrigation, and other types of development are feasible. State planning organizations have seen the value of these initial maps and have urgently requested that other areas be done as soon as possible.

Repetitive observations from satellite images have shown that some of the savannah areas of southeastern Bolivia, being planned for colonization and agricultural development, are periodically inundated by floods and, as a result, safer areas have been chosen.

In southeastern Colombia Landsat images have shown the extent of slash and burn development for cattle grazing in the tropical jungle near San Jose de Guaviare in the western headwaters of the Orinoco River basin. Repetitive images from Landsat will enable monitoring of the growth and changes in range conditions.

New colonization on the Caribbean side of the volcanic mountain range of Costa Rica has been partially mapped from Landsat images. Cloud cover has hampered completion of conventional aerial cadastral surveys. Development has gone on in this area for more than 15 years but has never been adequately recorded. Consequently, the Costa Rican government has been unable to determine the extent of this growth, nor estimate its impact on its national economy.

The U.S. Geological Survey participated in a cooperative program ***between*** NASA and Brazil for uses of remote sensing that was initiated in 1968. Brazil now has its own technical expertise and is able to conduct its own remote sensing programs. A specific example is the use of airborne side-looking radar (SLAR) under Project Radam that has completed the mapping over 4.6 million km^2 (1.7 million square miles) of the Amazon Basin. Analyses of the SLAR mosaics have resulted in geologic, hydrologic, forest and soils maps that have demonstrated the vast resources that are available for development. Brazil is now in a better position to plan orderly development of mineral resources, communities, forest and farming regions, highways and power sources of the vast Amazon Basin. Satellite images are now available to monitor such growth. The Government of Brazil has recently extended SLAR coverage to the entire nation. Neighboring countries. such as Colombia, Venezuela, Ecuador, and Peru, all aware of the Brazilian experience, have adopted the method for other parts of the Amazon and Orinoco Basins.

In Iceland, animal husbandry, particularly sheep and cattle, is an important element of the economy. Grass, therefore, is an important agricultural resource.

Although Iceland was forested at the time of initial settlement in 874 A.D., the excessive harvesting of timber, the irrtroduction of large, free ranging flocks of sheep, and the apparent slight deterioration of the climate have resulted in almost total denudation of forested land. Birch, dwarf birch, and willow trees and various bushes exist in favorable locations, but only two sizeable areas of true forest still exist, Hallormsstadur in eastern Iceland, and Vaglaskogur near Akureyri. A cooperative investigation between U.S. and Icelandic scientists has used Landsat false-color composites to demonstrate that accurate inventories of areas covered by trees and bushes can be made that will assist in planning future reforestation work. Of greater importance, however, will be the ability to provide accurate inventoried of grasslands with such imagery. A preliminary study of MSS false-color composites of various parts of Iceland has shown that at least five' vegetation types can be mapped on Landsat imagery. These are: (1) bushes, dwarf trees, and shrubs; (2) natural grasslands; (3) reclaimed land; (4) cultivated homefields; and (5) lichen-covered lava fields. In addition, barren lands can be delineated by their absence of vegetation.

The agricultural industry of Iceland is heavily dependent on the areal extent, health, and growth rate of the grasslands. The grasslands are usually divided into lowlands and highlands. The highlands are used for grazing by sheep during the summer months. The lowlands are used for cattle and Icelandic ponies during the late spring, summer and early fall.

The highland grasslands are used in their natural state, while some of the lowland grasslands have been subjected to extensive ditching to lower the water table, thus improving the soil properties and increasing the grass yield. On the homeflelds, the application of fertilizer, ditching, and seeding have markedly increased the yield. The harvesting of hay from the homefields provides the feed for the animals kept through the winter months.

Considerable effort is being expended to reclaim the overgrazed lands through reseeding and fertilizing of barren areas. Many areas are also being reforested to reverse the post-settlement trend of soil erosion. The reclamation program is directed at an increase in the area of grazing lands to meet the future resource needs of a rapidly growing Icelandic population. In 1974, on the occasion of the 1100th anniversary of the settlement of Iceland, the Icelandic Parliament passed a bill to restore the land to its pre-settlement condition. a costly project which will encompass decades of effort Landsat imagery could provide an effective way of monitoring the progress of this land reclamation project, if acquisition of coverage over Iceland can be assured.

Flood Mapping

A collaborative study of 1920 river kilometres (1200 river miles of the Mississippi flood that occurred during the spring of 1973 was conducted by the U.S. Geological Survey, NOAA, NASA and the U.S. Army Corps of Engineers, Several investigators developed methods during this study to apply optical and digital data processing to delineation of the flooded area. The results of these investigations demonstrated important engineering, economic, disaster relief, and planning applications. Landsat data obtained before, during, and after the flood were essential in conducting these studies.

As a follow on to these earlier research efforts in flood mapping, Landsat-2 imagery was ***used*** by the State of Louisiana and the Geological Survey to map the extent of flooding of the lower Mississippi River, and the Red, Ouachita, Black, and Atchafalaya Rivers during mid and late April 1975. Through special arrangement with NASA, Landsat imagery was received from Goddard Space Flight Center 2 days after the satellite had made its orbital pass. Analysis of the imagery was performed jointly by personnel of the Louisiana Office of State Planning; the EROS Program Applications Assistance Facility at Bay St. Louis, Mississippi, and the Geological Survey Geography Program. By comparing unpublished Land Use Data and Analysis (LUDA) maps with flood-time Landsat imagery, State officials delineated flooded areas and determined that flood waters covered approximately 3,200 hectares (8,000 acres) of urban and other highly developed regions, 120,000 hectares (300,000 acres) of farmland, 43,600 hectares (109,000 acres) of upland forest, 279,200 hectares (698.000 acres) of wetland forest, and 1,120 hectares (2,800 acres) of sand land silt areas. These totals were then broken down in ‘accordance with areas in each parish (county) that had been flooded. Both the maps and statistics were used by the State for rapid analysis of flood damage and to document immediately the need for allocation of Federal disaster relief funds. According to the Louisiana State Planning Office, the results of the study indicate that Landsat data provide a fast, accurate, and a relatively inexpensive method of compiling flood data for disaster planning and post-flood analysis.

In July, 1975, flooding occurred in the Red River Valley of Minnesota and North Dakota. The EROS Program, in continuation of its on-going activities in develop ing remote-sensing technology for flood applications, conducted an investigation on the flood, which had a profound impact on the rich agricultural lands of this area.

The Red River flood posed a particularly difficult challenge in that the soils of the Red River Valley tend to be very dark and hence provide low contrast with wet soils and standing water, which also are poor reflectors of incident solar infrared radiation. Previous experimentation had demonstrated the capability of Landsat multispectral scanner data to detect, delineate, and classify not only the flooded from the non-flooded areas, but to distinguish types of flooding and various characteristics of the flood plain. Employing digital analysis techniques, Survey scientists used Landsat data of the Red River flood and successfully separated areas of overbank flooding from flooded agricultural fields resulting from impeded precipitation runoff. The processing techniques employed made it possible to increase the contrast between the low reflecting soils in areas affected by flooding and those not affected by flooding, and between areas of standing water and saturated soils. Analysis of the post-flood data revealed the extent of crop loss and damage.

Utilization of Landsat data and optical and digital processing techniques specifically developed for flood assessments makes it possible to automatically depict the exceedingly complex distribution of the flood waters in a matter of hours, whereas traditional procedures require many man months of effort employing manual photointerpretation and depiction of boundaries. Accuracy of mapping of overbank flooding based on Landsat data has compared favorably with results obtained by traditional techniques. It is unlikely that the complex distribution of flooded agricultural fields of North Dakota that were depicted automatically by digital analysis could have been accurately mapped by traditional practices employing black and white panchromatic aerial photography.

A serious constraint in the usefulness of flood assessments by any technique is the timeliness of data availability and analysis. Under the current experimental Landsat Program, film imagery or computer compatible tapes are not received routinely by investigators in the field until six weeks or more following imaging of the study area by the satellite. In terms of flood assessments, historical data obviously is of little or no value for guiding rescue operations, identifying disaster areas for governmental or insurance applications, or for monitoring the progress of the flood wave down the valley.

Flooding in the Susquehanna River Valley occurred following Hurricane Eloise in 1975. A request was made to the Canada Centre for Remote Sensing to employ their Prince Albert satellite data reception facility to collect the data transmitted by Landsat-2 on its first post-flood orbits over the Susquehanna River basin. Two scenes covering the flooded area between Williamsport and Harrisburg were imaged by Landsat-2, transmitted to Prince Albert, recorded on magnetic tape. converted to film and shipped to the United States within 24 hours of data acquisition. Two additional days were required for shipping and release from U.S. Customs. The data were in the hands of investigators within 72 hours from acquisition by the satellite. The extent of flooding and the areal extent of the surface water at the time of imaging and general surface conditions are clearly depicted on the processed imagery.

Indicators of Climatic Change

It is impossible to work in analysis programs using satellite remote sensing data without realizing that many of the parameters being measured could be of importance to understanding climatic change. The direct effects of climate on agriculture and food production are observed throughout the world.

As the world population increases and greater demands are made on the major areas of croplands, climatic fluctuations or trends will take on more and more significance. The recent drouth in the Sahelian region of Africa has caused the disruption of entire societies. Reduced crop yields in the U.S.S.R. have forced the Soviet Union to make large grain purchases on the world market. At higher latitudes, the reduction in length of the growing season impacts on the magnitude of crop yields and even what crops can be grown,

In the 1960's sea ice moved into the coastal areas of Iceland and the average annual temperature was lowered. This had a devastating effect on hay production in the northern and to a lesser extent in the southern part of Iceland.

68--877-76-19

Parameters, such as the extent of snow fields, retreat and advance of ice caps, behavior of glaciers, characters of the "green wave" of vegetation as it moves to higher latitudes in the spring and the "brown wave" as the vegetation dies or becomes dormant in the fall, and surface temperature characteristics of large bodies of water including the oceans, can be measured directly by remote sensing. Global surveys are needed for climatological research. Satellites provide many of these capabilities.

Documentation of parameters that are significant to climatic change should become a standard practice of all scientists who are working with remotely sensed data. These analyses can then be used by appropriate organizations in establishing climatic trends and hopefully as a basis for climatic prediction in the future.

Phosphate for Fertilizer

Sedimentary phosphate rock is an increasingly important raw material for production of agricultural fertilizer, A common problem in prospecting for this material, however, is that cursory field observation reveals few physical properties which distinguish phosphatic from non-phosphatic beds. Although small hand-carried ultraviolet lamps have been used to stimulate luminescing minerals and rocks, including phosphate rock, these methods of prospecting are limited because the lamps are low powered, effective range is limited to a metre or less, and the work must be conducted at night because the low intensity luminescence is obscured by bright sunlight.

The Fraunhofer line discriminator (FLD) is an airborne optical mechanical device which permits daylight detection of luminescence several orders of magnitude below the intensity detectable with the human eye. This instrument was developed through cooperative programs between NASA and the U.S. Geological Survey., Helicopter tests during 1974 and 1975 have shown that FLD response to gypsiferous and phosphatic beds of Miocene age northeast of Santa Barbara, California, exceeds nonphosphatic beds 'by a factor of two. Laboratory measurements of eight phosphate rock samples from the United States, Brazil, and Colombia show that all appear to luminesce within the sensitivity limits of the FLD.

Liquid effiuents from processing of phosphate rock commonly contain materials which can contaminate surface and ground water and be injurious to vegetation. Laboratory analysis of samples collected from central Florida show that these effuents are luminescent, exceeding the luminescence of background streams by more than a factor of five. These results are confirmed by airborne FLD measurement of the luminescence of effluents from several central Florida processing plants which was performed in early 1975 in collaboration with the Environmental Protection Agency.

Energy Resources

Central to the production of agricultural products is the availability of energy for field preparation, irrigation, harvesting, drying, transport, and refrigeration; this, in addition to the derivation of fertilizers from petrochemicals, focuses the Department of Interior's energies on the use of new techniques for the inventorying and finding of new sources of energy.

Space observations are becoming increasingly important in this search and in understanding the environmental impacts of energy development. These observations add to our current capabilities of discovery and environmental assessment by providing an overview that can add to our efficiency in exploration.

In terms of discovery and production, satellites now in orbit can help us in at least six ways. These are:

1. Detection of geologic structures that were previously unknown and may be significant with respect to the localization of hydrocarbons;
2. The possible detection of very subtle tonal anomalies, that may represent alteration of the soils resulting from mini-seeps of gas from hydrocarbon reservoirs;
3. The potential for detecting natural marine oil seeps with consequent improvement in efficiency of offshore exploration;
4. The monitoring of ice distributions and movement in Arctic areas, such as may affect transport of materials in and out of the Arctic; the cost of seismic exploration in Arctic sea ice areas, and the safety of exploration and production operations;
5. The monitoring of oil field development and transport facilities, such as the Alaska pipeline and an assessment of this development upon the environment;

6. The images are useful as base maps in poorly mapped parts of the world.

Landsat data is being used by international oil firms for exploration in poorly mapped regions in the headwaiters of the Amazon Basin. Bolivia has used Landsat data to plan a gasline from Sucre to Puerto Suarez, which will eventually connect with major industrial markets in Sao Paulo, Brazil.

Studies conducted by Chevron Overseas Petroleum, Inc., have demonstrated how Landsat data have assisted in petroleum exploration in Kenya. The imagery permitted company scientists to outline the boundaries of the sedimentary basin that is of interest. This led to more intelligent locations of boundaries to the concession that was negotiated with the Government of Kenya. Information on geologic structures in the basin, obtained from interpretation of the Landsat images *is* being used as a guide for planning and carrying out the detailed geological and geophysical field investigations.

In Alaska, landform analysis of Landsat images, substantiated by geophysical data, led Geological Survey scientists to propose a new area for petroleum exploration. The images show that lakes in the Arctic Coastal Plain are dominantly elongated with the long axes parallel and trending about N 9" W. Northwest of the Umiat oil field, an additional strong east-trending regional lineation, not previously recognized on aerial photographs or in field studies, is expressed by elongation of some lakes, alinement of others, and by linear interlake areas. The trend of this lineation is parallel to the trend of deflections in contours of the magnetic and gravity fields in the area and parallel to westerly deflections in the northwest ends of northwest-trending folds mapped to the south. In addition, the alinement of many small lakes forms a large ellipse superimposed on the regional lineation. Sparse seismic profiles show periodic reversals in dip and regional arching in shallow strata beneath the area. Collectively, these data suggest that heretofore unsuspected deep structures may be concealed beneath the younger Quaternary Gubik Formation that covers the area of the image. In addition, strata *in* shallow folds are younger than those tapped by the oil wells of the Umiat field to the south, and may contain favorable reservoir beds.

Mosaics of the conterminous United States, compiled by the Soil Conservation Service for NASA, have been analyzed by U.S. Geological Survey geologists interested in linear features that may be of tectonic significance. Mosaics at scales of 1 :5,000,000 and 1 :1,000,000 were used to evaluate and identify new and to reevaluate previously known geologic features. Studies of smaller regions have shown that the occurrence of major mineral deposits is closely related to the intersection of linear features that are major fracture systems. Similar studies of gas-producing areas in the Appalachians show that the most productive gas wells are near or within areas of highly fractured bedrock.

Recent petroleum discoveries in the Mobile Bay region of Alabama prompted Halbouty Oil Company to conduct an independent experiment to determine whether or not *use* of Landsat data can provide insight into possible ***extensions*** of petroleum producing areas in a region of active exploration, if these data can aid in re-evaluation of existing subsurface information, and the importance of these interpretations for planning subsequent seismic and other geophysical surveys.

Landsat images of the area were interpreted for linear and curvilinear features. These were compared with a map published by the Geological Survey of Alabama depicting the general trends of exploration potential extending from Mississippi into the State of Alabama. The location of producing fields was superimposed on this information. Significant results of this investigation are:

Landsat interpretations reveal some associations where producing fields are alined along linear features or are on the flanks of large curvilinear features.

Several major discrepancies between the subsurface maps and features interpreted from Landsat data were noted. For example, the Citronella field, one of the largest fields producing by artificial lift from depths greater than 10,000 feet is shown on the crest of a dome at depth while the Landsat imagery suggests that it is in an interdomal area. Also the structural interpretation of the Mobile graben differs significantly from the interpretation derived from subsurface data. Landsat interpretations suggest that the structure is much more complex in the northeastern quadrant of the area than is reflected by the subsurface contours.

Landsat imagery shows promise as a tool to monitor energy-related development in Alaska. Examination of the vegetative cover, on a false-color composite Landsat image of the Umiat oilfield, revealed only one indication of scarring of the delicate tundra as a result of the intense oil exploration in this area in the late 1940's and early 1950's. This suggested that the environmental effects of oil exploration were not spreading but rather were healing. This conclusion was largely substantiated by low-level helicopter surveys undertaken by Geological Survey scientists in the summer of 1973. One short, clear-dozed, and repeatedly used trail near Umiat still formed a marked scar.

In response to the increase in coal mining activity in the Appalachians, the U.S. Geological Survey, in cooperation with other Federal and state agencies, is assessing the effect of coal mining on water quality, sedimentation, and streamflow of eastern Tennessee. Aerial thermal infrared imagery is used to delineate ground water outflow, pending on strip mining benches, storm runoff, surface water flow, and indications of acid mine drainage. Digitally processed Landsat imagery is used to delineate land cover categories including forest groups, agricultural land, and bare earth caused by strip mining. The Landsat analyses are useful for updating geologic maps showing strip mining activity, and for direct comparison with the status of strip mining in the late 1960's when the field mapping was done. An analysis has been completed for the dates of February 19, 1973, March 23, 1974, October 10, 1974, and March 26, 1975, for the Duncan Flats Quadrangle at a scale of 1:24,000. The resulting maps show both active and inactive strip mines, the extensions of bare earth areas, regrowth of vegetation and the effects of strip mining on sedimentation in streams.

The Canadian Centre for Remote Sensing has recently completed a study showing the importance of meteorological satellite and Landsat data to sea ice monitoring in the Canadian Arctic. The study projects large benefits for inbound and outbound shipping in this area. It also considers reduction in damage to ships by identifying navigation hazards in ice-infested waters, increased productivity for marine seismic crews, and the types of data needed for operational decisions to continue drilling or to cease drilling for petroleum in this region. The benefits for the Canadian Arctic are large. The United States may well anticipate comparable. if not larger, benefits in the next few years in the Beaufort and Chukchi Seas off northern Alaska as exploration increases in the search for domestic sources of petroleum. It is imperative that timely Landsat data be provided to U.S. shipping in the Arctic.

One indication of the importance of Landsat images to energy related industries can be found by examining the types of organizations that purchase data from the EROS Data Center. This evaluation indicates that from a Forbes list of the top 500 U.S. industries, 113 are energy related, and 81 of these have purchased data from the EROS Data Center. Thirty-four of the 81 energy-related industries show a highly repetitive ordering pattern, either initiating new orders on approximately a monthly basis, or retaining standing orders for data as they become available.

EROS DATA CENTER

A major portion of the EROS Program activities are conducted at the EROS Data Center at Sioux Falls, South Dakota. This Center serves as a central archive for most Department of the Interior aerial photography, NASA aerial photography and space imagery acquired by NASA. The data base is automated to allow rapid inquiry for any of the data that are available. This data base is generated and maintained through a cooperative effort with the National Cartographic Information Center. Plans call for adding aerial photography and other remotely sensed data to the data base as it is acquired by the Geological Survey and NASA and to enter into agreements with other agencies to either archive their data or to reference it in the data base.

The Data Center has excellent photographic laboratories suitable for large volume photographic reproduction and special photographic processing. These photographic capabilities are used to reproduce imagery contained in the data archives to satisfy individual requests. The data are sold for a price that includes the cost of materials and labor to make the appropriate copies.

At present the major deficiency in the Data Center is in the inability to process the large amounts of electronic (high density digital tape) data that are planned for the near future. This capability is needed to improve the throughput time between acquisition of Landsat data and the time when users can receive their copies and to upgrade the quality of the data that is delivered to customers.

The Data Center building was designed with facilities for training. Training is conducted as a part of an applications assistance and technology transfer function. The Data Analysis Laboratory at the Center serves as a research, technique development and training facility. This laboratory has state-of-the-art equipment for analysis of electronic imagery.

Data Available

An important activity of the EROS Data Center is archiving, retrieving, reproducing and distributing remotely sensed data. Data currently archived at the Center exceeds 6,000,000 images, including over 600,000 frames of Landsat imagery ; Landsat electronic data in the form of computer compatible tapes; over 40,000 frames of Skylab, Apollo, and Gemini data; more than 1,800,000 frames of data from the NASA Research Aircraft Program; and almost 4,000,000 frames of Department of the Interior aerial mapping photography.

The demand for reproduction of these archived data has continued to increase both in number of frames and dollar value. In FY 73, 165,000 frames of data were suplied to the user community, data volume grew to almost 300,000 frames in FY 74, and has exceeded 400,000 frames in FY 75. At the same time, dollar income at the Center increased by 91 percent from FY 74 to FY 75, with total dollar income from the sale of data exceeding $1.6 million in FY 75 (table 1).

TABLE 1.–INCOME FROM VARIOUS DATA PRODUCTS PRODUCED BY THE EROS DATA CENTER DURING FISCAL YEARS 1973-75

	LANDSAT	Other satellite[1]	Aircraft	Total
Fiscal year—				
1973	$153, 000	$12, 000	$84, 000	$249, 000
1974	593, 000	44, 000	248, 000	885, 000
1975	930, 000	113, 000	567, 000	1, 610, 000
1976 estimate	1, 720, 000	140, 000	920, 000	2, 780, 000

[1] Gemini, Apollo, and Skylab imagery and photography.

Approximately 58 percent of the dollar value for products at the Center is for Landsat data. The customer profile for purchase of all data shows that private industry is the largest single purchaser, with 30 percent of the total dollar value, and agencies of the Federal Government coming next with 24 percent. Academic and educational institutions account for 16 percent of data sales, while foreign customers comprise 12 percent. Individuals, state, and local government agencies comprise the remainder.

Agricultural Related Training

A primary function of the EROS Data Center is to offer formal training on the utility of remote sensing techniques. Normally these training sessions are up to one week in length and stress the use of remotely sensed data in a practical application. For example, workshops given during 1974 and 1975 included:

(a) Digital analysis of Landsat data to assess spruce budworm defoliation for the Animal and Plant Health Inspection Service, USDA.

(b) Deterioration of rangeland and cropland conversion to rangeland for the Soil Conservation Service, USDA.

(c) Sampling frame construction using Landsat data for the Statistic Reporting Services, USDA.

(d) Renewable resource assessment for the Forest Service, USDA.

(e) Irrigated lands inventory for the Bureau of Reclamation. USDI.

(f) Rangeland Productivity estimation for the Bureau of Land Management, USDI.

Two or three times a year a three to four week course is offered to foreign nationals, stressing the fundamentals of remote sensing with enphasis on specific applications such as agricultural and soils inventory. To date there have been 132 attendees from 49 countries. Twelve African countries. 19 Asian countries, 9 European countries, 8 South American countries, and Australia have been represented. The five courses that have been conducted were in June 1973. June 1974, September 1974, May 1975, and September 1975. Also, training in foreign countries consisting of lectures. workshops. and seminars has been conducted by EROS Program personnel. Countries visited during Fiscal Year 1975 which involved agricultural related training included Australia, Algeria. Thailand, Mali, Mexico. and Ghana.

Data Analysis Laboratory

The Data Analysis Laboratory at the EROS Data Center provides specialized equipment and qualified personnel to aid users in the analysis of remotely sensed data, particularly Landsat images, for a variety of purposes. The sophistication and cost of image analysis equipment has made it desirable to centralize such facilities, so that they may be used at their maximum efficiency. Work at the Data. Analysis Laboratory is not restricted to scientists within the EROS Program. It is also available to all interested users from Federal, state and local government agencies. The philosophy under which the laboratory operates is that it accommodates users on reasonable schedules for demonstrations, experiments, and training in the computerized analysis of remotely sensed data in order to work out solutions to resource problems and to train users in the methods of data analysis.

Facilities of the Data Analysis Laboratory include the General Electric Image 100 Multispectral Analysis System, which is used for classification, analysis, and mapping, of resource environmental features from Landsat digital images and images from aircraft multispectral scanners; an Interpretation Systems Incorporated Analysis System, which allows the overlay of up to 73 repetitive images of a given area for analysis of time changes in natural and manmade features and a terminal to the computer facilities at the Laboratory for Applications and Remote Sensing at Purdue University for large area classification and mapping of land features using the LARS multispectral analysis system. Users experiment with the various facilities to find methods of solving particular resource problems of interest and importance to them, to determine the feasibility of various automated interpretation approaches, and when their experiments prove successful, they determine the means by which they would use such methods operationally in their resource management responsibilities. Technical assistance by experienced machine operators and resource scientists familiar with automated analysis is available to assist the investigators. The facilities of the Data Analysis Laboratory are also extensively used in training courses conducted at the EROS Data Center both for domestic and foreign users.

Interest in and use of the Data Analysis Laboratory has been widespread and has required a two shift operation, five days a week. Personnel are available to assist in the operation of the equipment and in suggesting approaches to the solution of their problems. During the four month period from July 1, 1975, to October 30, 1975, seventy-nine percent of the available time of the Data Analysis Laboratory was spent in working with users and demonstrating the use of the system to groups of trainees.

The Data Analysis Laboratory is providing users with access to sophisticated data analysis facilities and basic help on their use. This is a great help in creating a large corps of knowledgeable users of remotely sensed data who can apply such data to their resource management problems in the future.

CONCLUSIONS

Remote sensing technology has many direct applications to food production. Examples are crop inventories, plant vigor estimates, range capability and readiness measurements, and adverse effects on agriculture such as floods and disease. Food production depends on more than directly observable parameters. Climatology, mesoscale meteorological conditions, weather modifications, surface and subsurface water management, availability of energy, products derived from petroleum and other minerals and land use information are also major considerations for a modern food production program. Remote sensing technology has direct contributions to solving the problems related to each of these additional information and material needs.

Many capabilities of remote sensing have been demonstrated. Others are in the research stage. Still more areas of applications have not been started. The entire potential for using remote sensing technology cannot be adequately measured at this time. The demonstrated capabilities do, however, represent a major contribution toward achieving many information needs. More emphasis needs to be placed on physical models to turn data into useful information, and still more attention needs to be placed on using this information for real management decisions.

Agencies with operational responsibilities express three basic reasons for caution in becoming dependent on Landsat data. These are:

(a) Landsat is experimental. There is no assurance of continuity beyond about 1980, or even earlier if a spacecraft or launch vehicle fails.

(b) Data are not available soon enough to be used in making time-critical decisions.

(c) Standard photographic products contain less than the complete data content of the original digital data, thus precluding their use in some unique applications.

The last two of these reasons are technical. The solutions are known, within the resources available, and NASA and the EROS Data Center are augmenting their data processing and distribution systems to make the necessary improvements. The first deficiency relates to policy and the intention of the United States to continue in a leadership role in global Earth resources satellite programs.

An important factor, that is often overlooked, is becoming more and more apparent from our experience with the Landsat program. This factor is the unifying influence of a global data base with uniform characteristics that serves scientists in many discipline. The results are threefold: (1) scientists in different disciplines are communicating better and understanding the relations of their discipline to other Earth sciences; (2) international scientific communication has been improved, because scientists from all nations can obtain data of uniform characteristics and compare their results of analysis and analysis methods. The number of international applications examples using Landsat data that are discussed in this report illustrates the significance of this international communication; and (3) the availability of repetitive data of dynamic phenomena permits the establishment of wholly new types of scientific studies, many of enormous potential value to our understanding of the global *environ*ment.

Great possibilities exist for international cooperation on a mutually productive basis. The history of science may well record that the development of the NOAA and Landsat series of satellites and the ready availability of their data to all rank as one of the great achievements of the 20th century. These satellites that provide repetitive environmental and resource data for the entire planet may rank in the same class as the invention of the telescope or the microscope in providing man with a completely different view of himself and his planetary environment. Very few people, scientists included. truly appreciate the revolutionary significance of these satellites. As with all other great steps forward in technology and exploration, many years will pass before the total significance is grasped. It is important, therefore, that this gestation time be shortened, so that we may make more effective use of the environmental information sooner.

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[The following questions were submitted by Senator Humphrey to Dr. DeNoyer and his answers thereto:]

Question 1. You indicate a number of agencies in the Department of Interior have found the LandSat information useful in their management programs. Has the Bureau of Land Management found this information more comprehensive and more accurate, than comparable information obtained from other sources ?

Answer 1. The Bureau of Land Management has reported that it could make extensive use of Landsat imagery for monitoring the condition of grazing grassland, therein permitting re-evaluation of grazing leases and limiting the time and number of animal-unit months for each lease. The information would permit the rangeland manager to make a decision of lease or no-lease. This information would be far more accurate and comprehensive than present estimates based on visits at intervals of three years or more to some of the more remote regions of the Federal rangelands.

The Bureau of Land Management is preparing a project plan for an Applications System Verification Test (ASVT). The intent of this ASVT is use of remote sensing data as one of the data sources for a comprehensive information system that is being developed by the Bureau of Land Management.

Question 2. Would Landsat information be used primarily to replace information obtained from other sources, or primarily to supplement information from other sources?

Answer 2. Landsat provides an additional data source for most applications. Other types of data are often needed to carry out complete investigations. In some cases. Landsat provides unique capabilities that make new types of assessments possible. In still more cases. the short time required for analysis of Landsat data make this approach attractive for measuring dynamic characteristic of surface features. In strip mine monitoring, for example, the Geological Survey of

Indiana has used Landsat to monitor change that has occurred in the areal extent of strip mines since the region was mapped by conventional methods *in* 1968. In the analysis of geologic structure, Landsat permits regional landscape features to be related to regional faults and fractures systems which have been verified by field and aerial photographic methods. Landsat also permits the delineation of regional alignments of topography, streams segments, and other features, some of which are hundreds of kilometers in length and cannot be recognized except on Landsat imagery. Landsat is being used operationally in Nebraska to monitor the annual increase in the number of center pivot irrigation systems, which cannot be practically and economically performed in any other way.

Question 3. What, if any, agencies in the Department of Interior, have indicated that they would like to participate in, and share in the cost of, an operational Landsat program?

Answer 3. We are concerned about funding the space segment of a program of this type from many sources. The whole program might fail if any one contribution of funding failed to succeed *in* the budgetary process.

The EROS Program of the Department of the Interior would like to participate by providing for the ground segment of an operational Landsat system. The ground segment would include archiving of data, reproduction of data, and distribution of data to users. This type of participation will require substantial budget increases and close coordination through the entire budgetary process to ensure that both the space and ground segments of the program are funded adequately and on consistent time schedules. Accordingly, the Department of the Interior presently is reviewing its position regarding the role it might play in the ground segment of an operational Landsat system. ,

The following Department of the Interior bureaus have indicated that they would use data from an operational version of Landsat and would underwrite the cost of data analysis for applications within their bureaus:

Bureau of Land Management; Fish and Wildlife Service; Bureau of Reclamation ; Bonneville Power Administration; and U.S. Geological Survey.

Question 4. Which agencies do you expect in the future to make sufficient use of Landsat information to justify their sharing in the underwriting costs?

Answer 4. As implied in the answer to question 3, it would be desirable for a single agency to have implementation and funding responsibility for the space segment of a Landsat system. Those agencies indicated above, plus the Corps of Engineers, Department of Defense; Statistical Reporting Service, and Forest Service, Department of Agriculture; Bureau of the Census, Department of Commerce; and the Agency for International Development of the Department of State, would be users of data and could be expected to fund their own data use programs.

Question 5. What, in your opinion, are the major bottlenecks in the current Landsat experimental program?

Answer 5. The greatest bottlenecks in terms of operational uses are assurance of continuity of follow-on satellites similar to Landsat, quality of data provided to risers, timeliness or currency of data when it reaches the user and transfer of technology to users.

Question 6. What actions would eliminate these bottlenecks?

Answer 6. The assurance of continuity would require a commitment by the United States and appropriate funding levels to support an operational program. Steps are being taken by NASA and the Department of the Interior to solve the data quality problem. These steps involve implementing complementary digital data proressing systems which will permit production of higher quality products for specific applications, and digital data that retain all the information acquired by the satellite. Technical solutions to the timeliness problem are known but actions are progressing slowly because of insufficient fiscal and personnel resources. Limited efforts to transfer the technology to users have been very successful. Additional efforts could be undertaken to the extent that resources become available.

Question 7. What plans does the Geological Survey have for continued cooperation with other countries in the use of Landsat information?

Answer 7. Two or three times a year, a 3- to 4-week course is offered at the EROS Data Center to foreign nationals, stressing the fundamentals Of remote sensing with emphasis on specific applications. To date there have been 132 attendees from 43 countries. Training in foreign countries consisting of lectures, workshops. and seminars have also been conducted by EROS Program personnel at no travel cost to the Department. This is indicative of the international need and interest in remote-sensing training. Countries visited during FY 75 included