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1973 SIGNIFICANT ACCOMPLISHMENTS

EARTH OBSERVATIONS DIVISION
SCIENCE AND APPLICATIONS DIRECTORATE

National Aeronautics and Space Administration

LYNDON B. JOHNSON SPACE CENTER

Houston, Texas

NOVEMBER 1974

NR-09-03357

Preface

In 1972 the Earth Observations Division reported significant advances in remote sensing techniques for earth resources applications. The momentum carried strongly into 1973 when these techniques were used for evaluating multispectral scanner data from NASA satellites for applications in several earth resources disciplines. The effective cooperation between the division and supporting university research centers was directed this year toward achieving an accurate evaluation of the automated data processing programs designed to analyze remotely sensed data. Progress in 1973 established a level of competence in remote sensing applications procedures that allowed confident planning of very-large-scale, quasi-operational earth resources activities in cooperation with other governmental agencies.

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Introduction

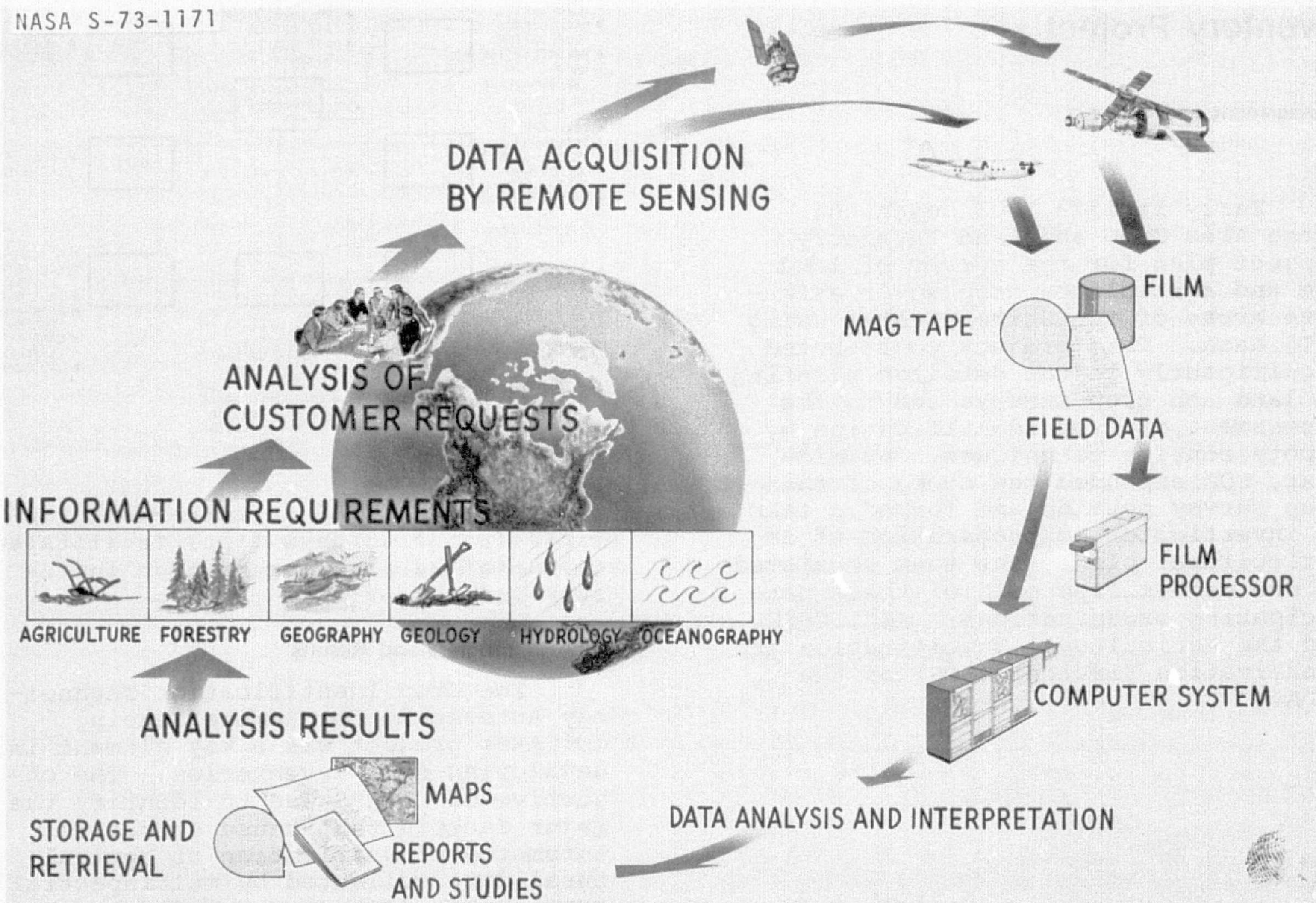
In 1973 the Earth Observations Division (EOD) of the Lyndon B. Johnson Space Center (JSC) contributed significantly to the utilization of data collected by the new remote sensing satellites by developing new applications techniques and by combining automatic data classification with statistical clustering methods. Continuing research was concentrated in the correlation and registration of data products and in the definition of the atmospheric effects on remote sensing.

Generally, EOD maintained a balanced program of the basic elements of remote sensing: data acquisition, data correction, data analysis, data management, and earth resources applications. The primary data center for receiving and distributing remotely sensed data from Skylab was JSC. Goddard Space Flight Center (GSFC) was similarly responsible for the first Earth Resources Technology Satellite (ERTS-1) data, and EOD was responsible for analyzing and describing the accuracy of the Skylab Earth Resources Experiment Package (EREP) operating sensors. In addition, EOD personnel handled requests from, and delivery of data to, authorized Skylab EREP principal investigators. Some EOD personnel directly investigated the utility of EREP data for earth resources applications.

Working with cooperating university centers and the U.S. Department of Agriculture (USDA), EOD also contributed significantly to identifying the causes of errors encountered in the automated classification of agricultural data. The U.S. Forest Service, too, cooperated closely with EOD in developing forest management techniques. The federal legislation requiring mapping of all water impoundments in the United States gave EOD and the State of Texas an opportunity to demonstrate the utility of automated classification of multispectral data acquired from satellites.

This close cooperation with universities, federal agencies, and GSFC enabled EOD to contribute significant accomplishments, not only in agriculture, forestry, and geography, but also in environmental geology, land use, and other earth resources disciplines. These 1973 EOD accomplishments indicate that with the cooperation of varied groups, flight program support, and adequate program planning, remote sensing technology can make a significant contribution to better management of earth resources.

Applications Development

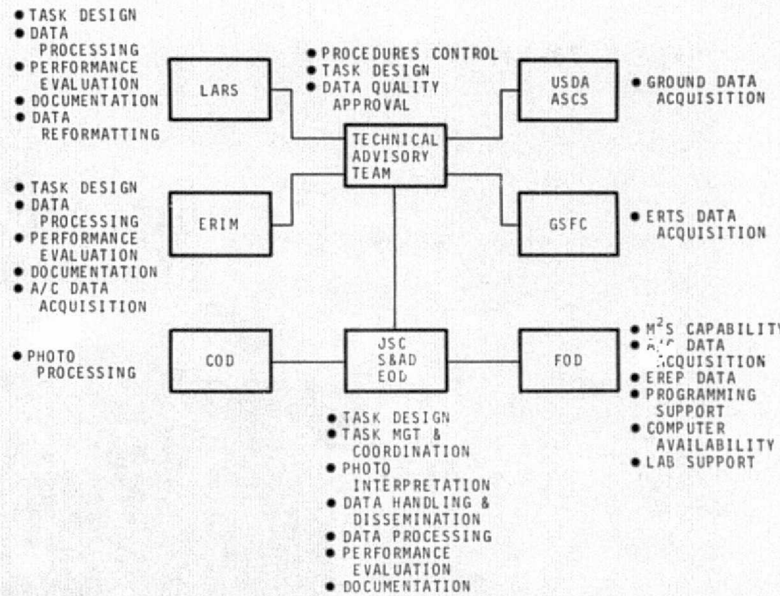


An operational remote sensing applications system. During 1973 NASA/JSC evaluated the utility of remotely sensed data from aircraft and satellites for this system.

Large Area Crop and Land Inventory Project

Management and Support

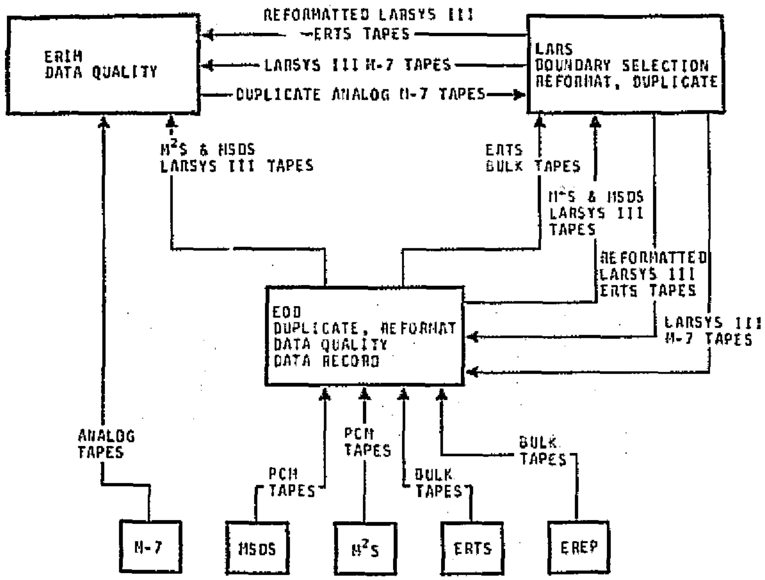
Early in 1973, EOD began the Large Area Crop and Land Inventory Project plan for the survey of land use and agriculture crops over extensive areas of the United States using ERTS data. This project contributed significantly to the detailed planning of land and crop surveys and to the assessment of crop identification by remote sensing techniques. At midyear, EOD expanded the scope of the crop survey portion and formed a team to investigate the preparation of an agricultural plan. The team consisted of one member from each of these participating organizations: JSC, GSFC, and the Agricultural Stabilization and Conservation Service (ASCS) of the USDA.



The various CITARS organizations (defined in the acronym list) facilitated the detailed planning of crop inventory investigations.

CITARS Progress and Results

The Crop Identification Technology Assessment for Remote Sensing (CITARS) project was a key element in developing crop inventories. The objective of CITARS was to identify the major factors that cause errors in automated classification of agricultural data collected by multispectral scanners (MSS's).



Scanner data flow diagram. Installation of the Purdue terminal at JSC and other improvements brought better communication between EOD and supporting universities.

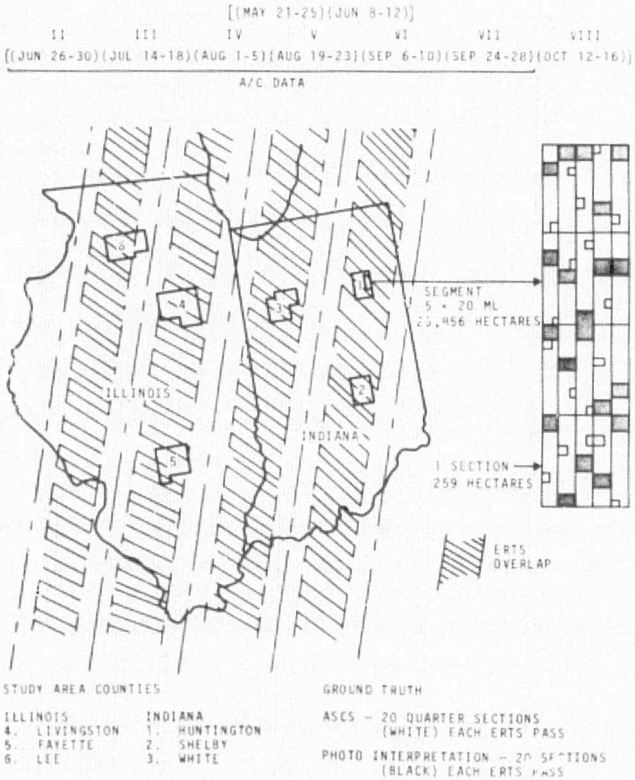
Once these problems were isolated, their effect could be minimized by the designers of the statistical clustering and classification programs at JSC, Purdue's Laboratory for Applications of Remote Sensing (LARS), and the Environmental Research Institute of Michigan (ERIM). Also, the ASCS could design more effective sampling plans to maximize the ability of automatic data processing to accurately extrapolate known data over large areas.

The specific CITARS project objectives were to (1) extend ground truth with the use of aerial photography, (2) extend spatial and temporal signatures by automated data processing techniques, (3) build a temporal model for wheat, corn, soybeans, and "other" crops, and (4) develop and refine data processing and analysis techniques. The CITARS team used an "analysis of variance" comparison to identify the most accurate analysis techniques.

The CITARS project has been well documented on weekly and monthly bases. A final report on the image analysis phase of CITARS has been published and is summarized in the following paragraphs.

The Mapping Sciences Branch of EOD supported CITARS in site selection, data acquisition, and crop identification extension through photointerpretative methods.

Working under general guidelines established by CITARS, personnel assembled topographic coverage of selected areas in Indiana and Illinois, randomly positioned the six test-area segments within selected counties, and randomly selected 20 quarter-section tracts in each segment for periodic investigation by field personnel of the ASCS county offices.



Study area for CITARS showing ERTS flightpath and sampling plan. Researchers chose sample segments and sections by rigorous statistical procedures so that various remote sensing techniques could be evaluated accurately.

The Mapping Sciences Branch served as the interface between the EOD Project Support Office and the CITARS project in evaluating and ordering ERTS-1 data coverage and as the contact between the project teams and the ground investigators.

The branch conducted training sessions at ASCS facilities in Indiana and Illinois to introduce field observers to the objectives of the project and to explain operation of the NASA solar spectrophotometer.

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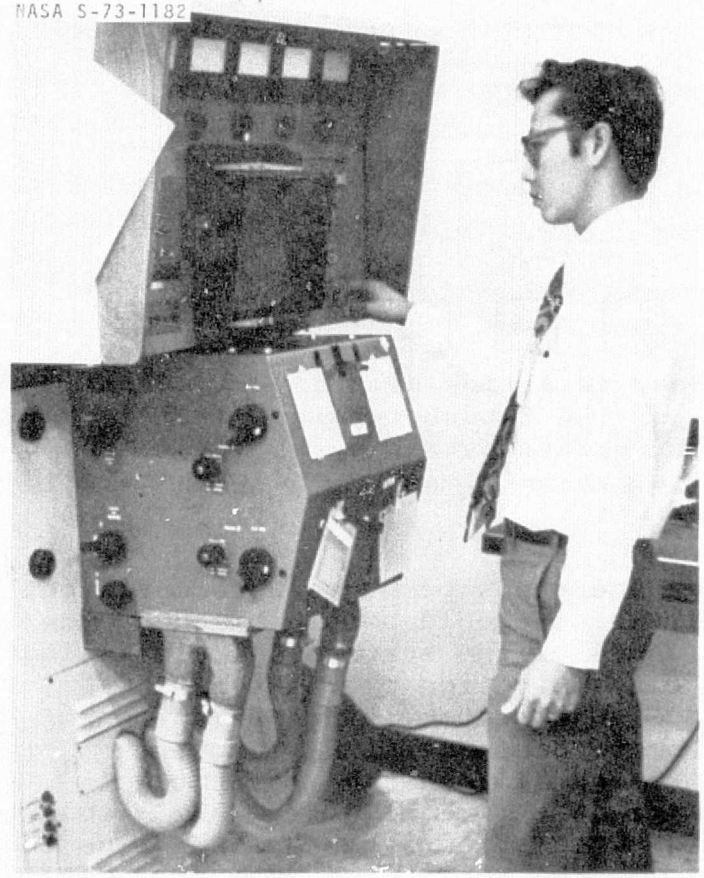


Image interpreters at JSC use this additive color viewer printer to analyze multispectral photographs of CITARS test sites.

Radiation measurements on the day of each ERTS overpass and detailed observations of crops in the 20 quarter-section tracts were mailed to JSC at 18-day intervals from June through September. Branch personnel accumulated the data, supervised the compilation of crop data by fields, and distributed crop identification data for the quarter-section tracts to LARS, ERIM, and JSC automatic data processing personnel.

After each aircraft data collection mission, the photographs were evaluated for coverage and image quality. Three image interpreters extended the identification of corn, wheat, and soybean fields from ground truth tracts to 20 one-section tracts in each segment through color infrared (IR) photographs (taken from an altitude of 30 to 46 km). They calculated crop proportions for each of the 20 sections from areas measured on metric photography, prepared controlled photomosaics of each site at a scale of 1:24,000 for compatibility with printer output from computer-aided analysis, and transmitted overlays keyed to the photomosaic and tabular data to automatic data processing personnel.

MISSION/ GROUND TRUTH	DATES	CORN	SOYBEANS	WHEAT
83-B	6/29/73	Bare Soil to Thin Red	Bare Soil or Very Thin Pink	Green, or Red With Green
ASCS	6/9/73	• Pretassel • Height 15-30 cm • Canopy 5-20%	• Newly seeded to prebloom • Height 5-10 cm • Canopy 0-5%	• Headed • Height 70-91 cm • Canopy 80-100%
83-H	7/5/73	Bare Soil to Light Red	Bare Soil to Thin Red	Green, Red W/Green or Brown W/Green
ASCS	6/26/73	• Pretassel • Height 61-122 cm • Canopy 5-20%	• Prebloom • Height 8-30 cm • Canopy 0-5%	• Mature • Height 91 cm • Canopy 80-100%
83-D	7/16/73	Light Red to Red	Thin Red	Bare Soil or Gray
ASCS	7/14-16/73	• Pretassel to Tassel • Height 61-213 cm • Canopy 50-100%	• Prebloom to Bloom • Height 5-51 cm • Canopy 5-80%	• Harvested (Stubble) or Other Crops
83-D	8/2-16/73	Green or Green W/Red	Red to Bright Red	Bare Soil or Gray
ASCS	[illegible],2/73	• Tasseled • Height 91-274 cm • Canopy 50-100%	• Prebloom to Early Pod Set • Height 15-91 cm • Canopy 5-100%	Bare Soil, Stubble, or Other Crop
83-H	8/20/73	Dull Red to Red	Very Bright Red	Bare Soil or Gray
ASCS	8/20,21/73	• Tasseled • Height 91-274 cm • Canopy 50-100%	• Prebloom to Late Pod Set • Height 20-91 cm • Canopy 5-100%	Bare Soil, Stubble or Other Crops
249	8/27/73	Dull Red to Gray	Bright Red	Mostly Gray
ASCS	None	Tasseled or Mature	Pod Set to Late Pod Set	Stubble, Bare Soil or Other Crops
83-D	9/12/73	Dull Red to Gray	Bare Soil to Bright Red	Gray
ASCS	9/6,7/73	• Tasseled • Height 122-274 cm • Canopy 80-100%	• Pod Set to Mature • Height 46-91 cm • Canopy 60-100%	Stubble, Bare Soil or Other Crops

Example of a report from JSC image interpreters comparing color infrared photographs with ground truth data.

Regional Applications Project

Transfer of Technology to the State of Texas

For the past 2 years, EOD has been working with agencies of the State of Texas to effect the transfer of the remote sensing technology being developed by NASA to the state for use by the various state agencies concerned with land use planning and related environmental considerations. During the past year, various significant accomplishments served to consolidate program activities and to enhance the initial phase of the technology transfer.

The governor's Interagency Council on Natural Resources and the Environment established the Remote Sensing Task Force to develop a statewide plan for the use of remote sensing technology and to effect the transfer of technology. A subgroup of the task force was established to determine objectives and requirements of the various agencies and to define the overall program implementation plan. The EOD then conducted a series of seminars to give the task force an in-depth exposure to remote sensing technology and computer-aided analysis and information systems.

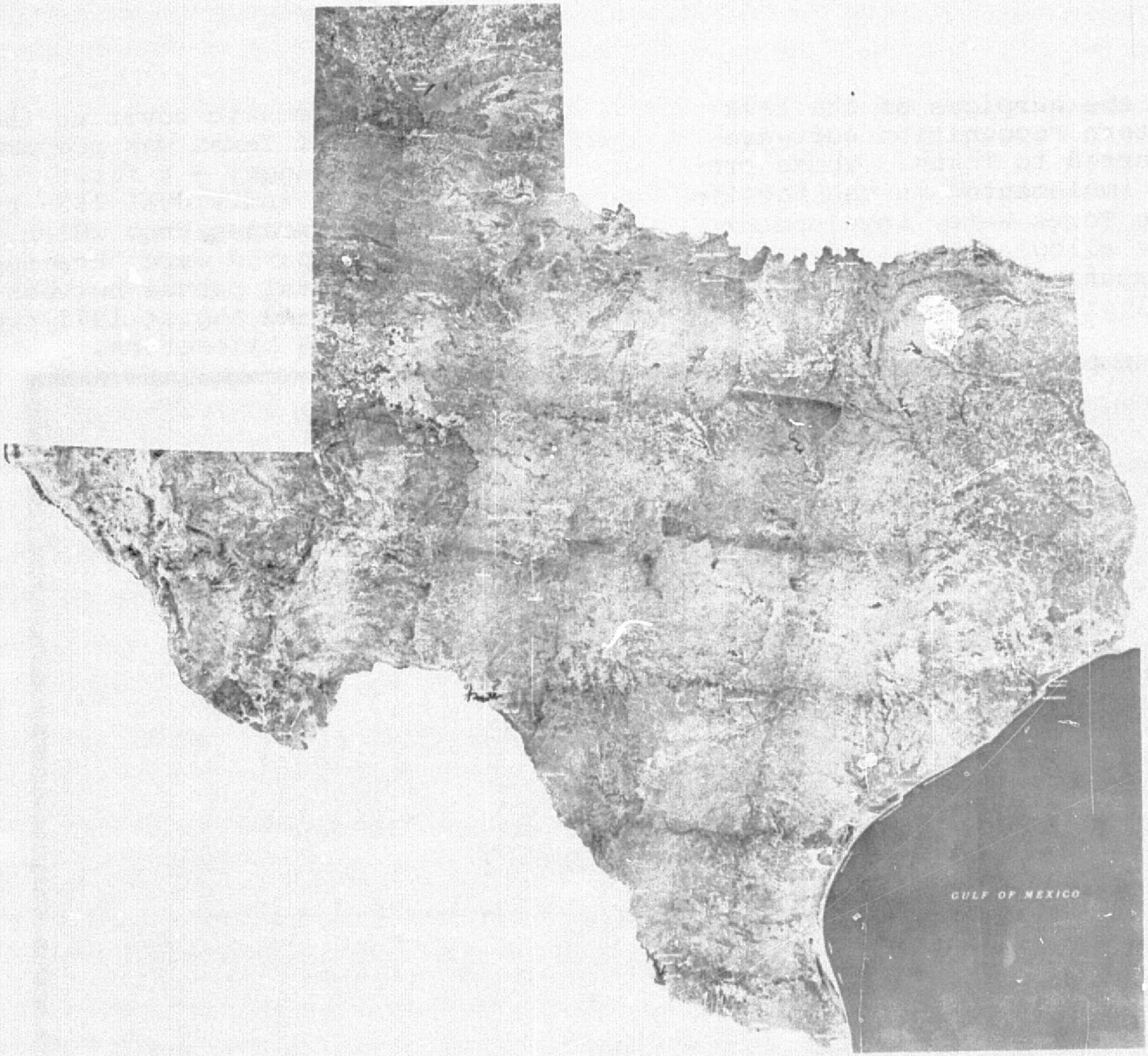
The Texas Office of Information Services contracted with LARS to train state personnel on the use of the LARS program for computer-aided analyses of multispectral data. A remote terminal connected to the LARS facilities at Purdue was installed in Austin to provide a training facility, and an intensive training program funded in part by the U.S. Civil Service Commission under the 1970 Intergovernmental Personnel Act was begun.

Employees from Texas state agencies at a seminar on remote sensing and multispectral data analysis.

Under the auspices of the task force, pattern recognition software was transferred to Texas. These programs were implemented in the facilities of the Texas Water Development Board, thus allowing Texas to utilize current computer processing techniques in its analysis of remotely sensed data.

A single mosaic covering the entire State of Texas was prepared from ERTS-1 imagery - a first for this state. The 44 individual 185- by 185-kilometer scenes from which the mosaic was prepared were obtained on different orbital passes between November 1972 and August 1973 from an altitude of 926 kilometers.

Photomosaic of the Houston area prepared from high-altitude aircraft photography. Personnel of EOD have mapped part of Texas using similar aircraft imagery. A photomosaic of Texas has also been made from ERTS imagery.



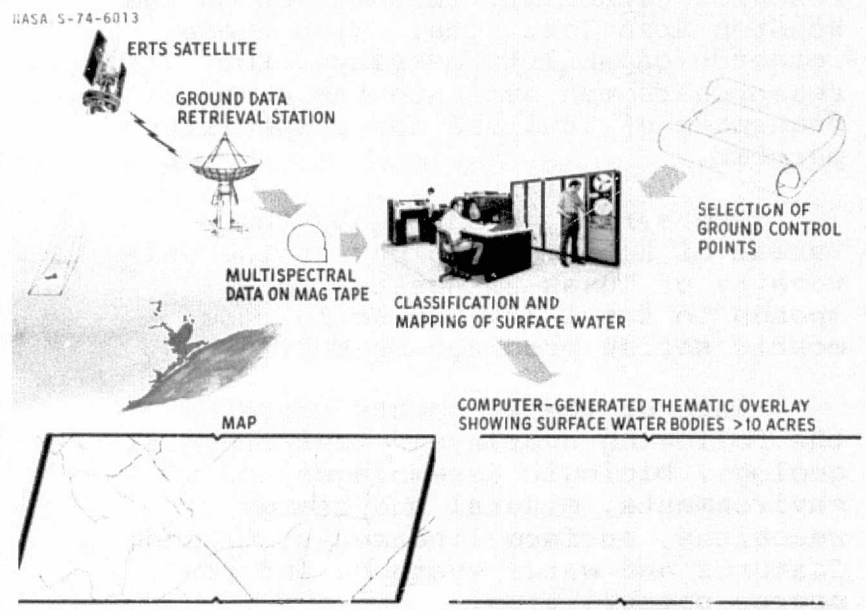
Photomosaic of Texas prepared from ERTS-1 photographs. Products such as this are significant in providing federal, state, and local planners a current base for compiling more detailed information over large geographic areas.

Evaluation of Water Impoundments

For the National Program of Inspection of Dams (NPID), the EOD developed a computer-aided procedure that uses ERTS-1 data for detecting surface water and locating it in registration to topographic and highway maps. The EOD has published this procedure in a five-volume manual to transfer the technology to potential users. The investigators developed the procedure for surface water inventory by quantitative analyses of ERTS-1 data of an east Texas study area.

Researchers at EOD transferred the procedure to the U.S. Army Corps of Engineers and to the Texas Water Development Board for an inventory of Texas water impoundments. The law establishing NPID requires the Secretary of the Army, through the Corps, to inspect all U.S. dams for safety to human life and property and to report the results to all state governors and the U.S. Congress.

Investigators at EOD also developed for the NPID a manual image interpretation technique using ERTS-1 black-and-white imagery from band 7, a zoom transferscope, and state highway maps and transferred this technique to the Texas Water Rights Commission.



Researchers at EOD use ERTS data and these techniques to find and record surface water.

Environmental Geologic Maps for the Houston Area Test Site

The Regional Applications Project Office obtained a series of 21 map overlays containing environmental and resource capability information on the Houston Area Test Site. With these resource capability overlays, EOD researchers can evaluate the consequences of land use for a specific purpose.

The series, produced by the Bureau of Economic Geology at the University of Texas at Austin, corresponds to the 1:125,000-scale base mosaic series produced by EOD.

Each of the 21 sheets contains the following overlays: environmental geology, biologic assemblages and environments, mineral and energy resources, surface lineaments, manmade features and water systems, and resource capabilities.

Forest Applications Project

Timber, Soil, Landform, and Wildlife Investigations

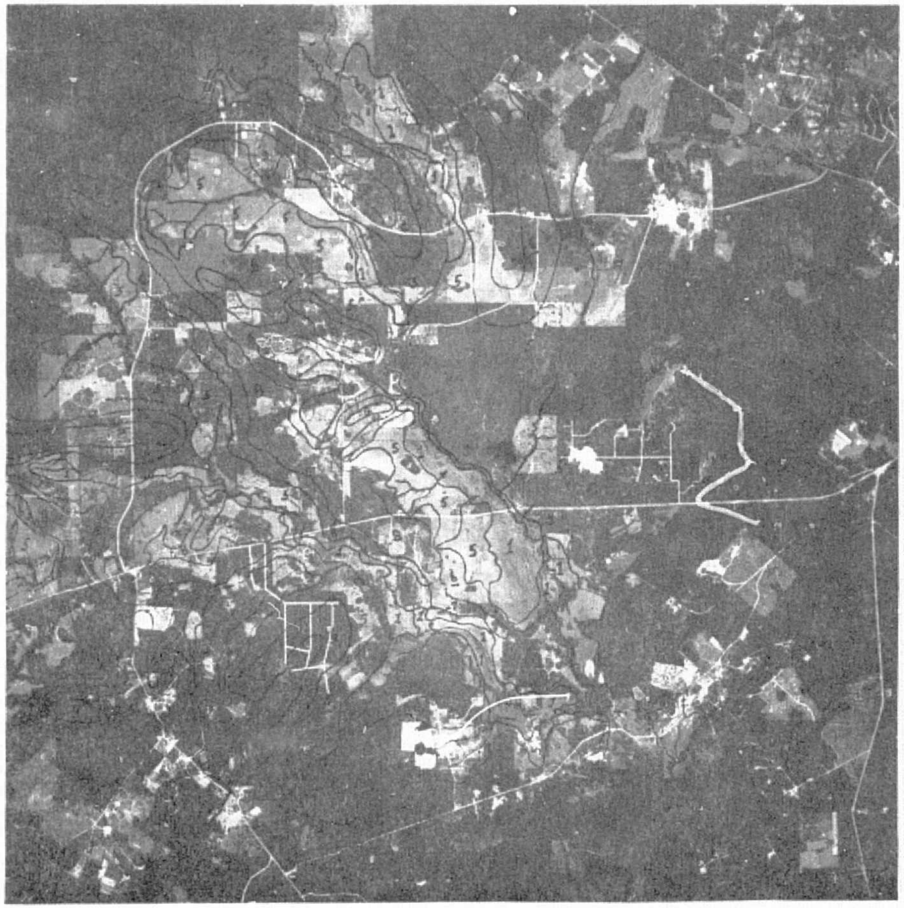
The EOD Forestry Applications Project (FAP) is an investigation of the potential of remote sensors to supply timber, soil, landform, and wildlife information. As a result of this investigation, the FAP team conducted a timber inventory of the Sam Houston National Forest (SHNF), Texas, from the C-130 aircraft 24-channel MSS. The investigators classified timber types and timber conditions into 30 classes with a table look-up classification scheme and developed signatures for 90 subclasses.

Using Skylab's S-190B Earth terrain camera imagery, the team mapped the transportation systems of the Yellow Pine Ranger District in the Sabine National Forest, Texas. The investigators concluded that the imagery would help update present forestry maps to include changes in major transportation routes.

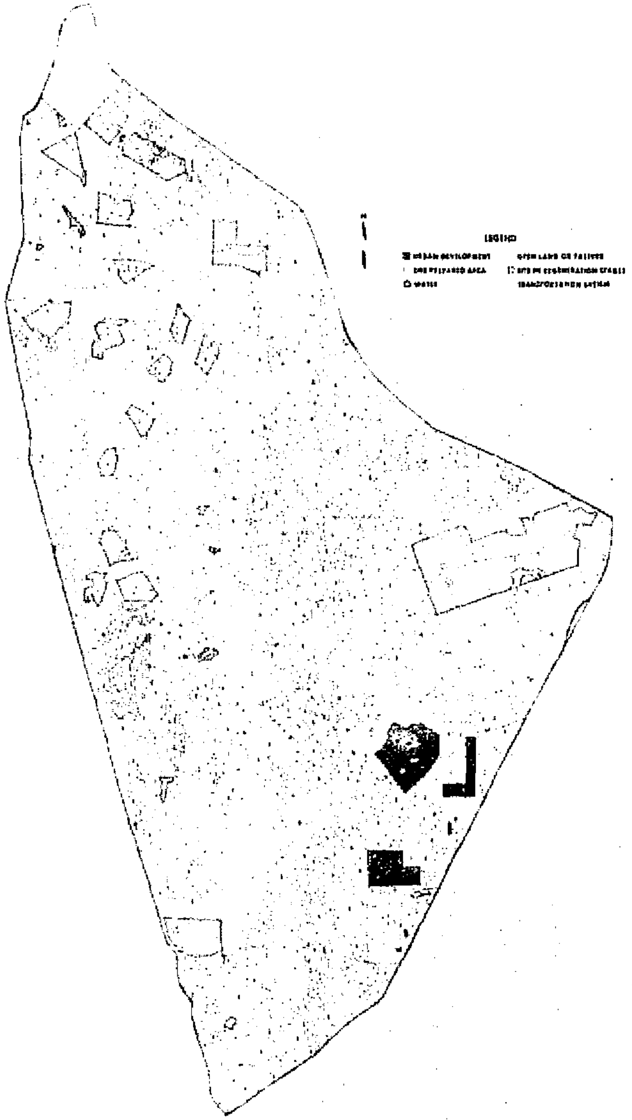
The FAP team also studied the use of small-scale color IR imagery from aircraft for identifying and locating soil erosion caused by groundline log skidding on clearcuts in Mount Baker National Forest, Washington. From the imagery analyzed, the team identified areas of excessive gullying. Identification of these areas allowed field personnel to go to affected areas, determine the rate of erosion, and suggest preventive measures against further degradation.

As part of a regional forest soils resource inventory, the FAP team mapped landforms in the Raven District of the SHNF. Using aircraft color IR photography, the team identified landforms with more than 97-percent accuracy.

In other work on the SHNF, the FAP team used aerial photography to establish the relationship between canopy density and understory forage production.



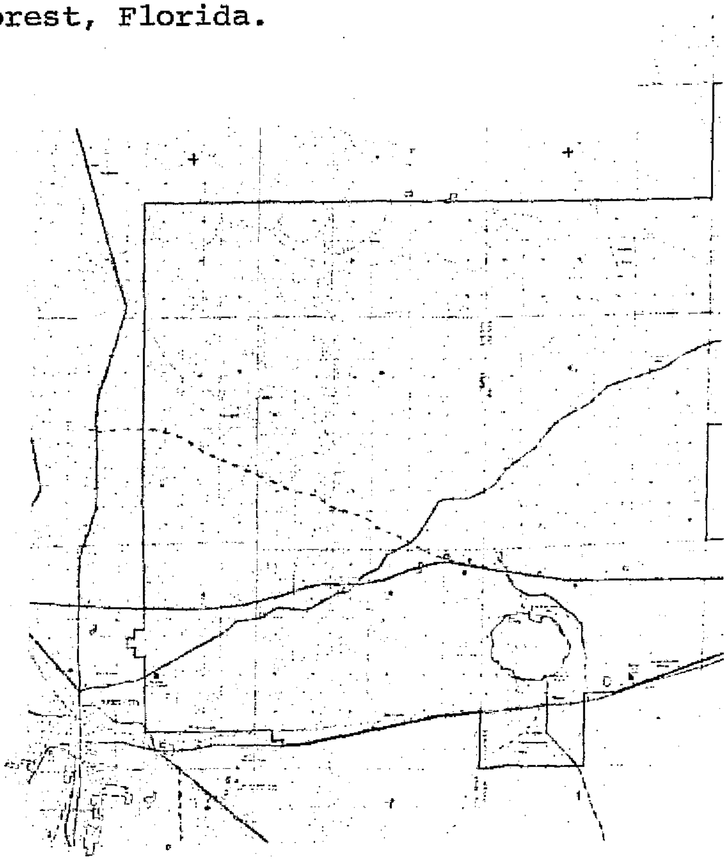
Landforms delineated on color infrared photograph of the Raven District, Sam Houston National Forest. (The handwritten numbers were made by the photointerpreter.)



Canopy density map of the Tarkington Unit, Sam Houston National Forest. Researchers use this map to determine timber volume, ability of the forest to support wildlife, and other information needed for forest management.

Osceola National Forest Water Body Analysis

Using ERTS-1 data, the two-channel linear discriminator developed under the NPID, and computer-aided techniques, the EOD mapped all open surface water areas 4 hectares or larger in the Osceola National Forest, Florida.



Map of Osceola National Forest, Florida, with overlay showing surface water.

Unit Planning Assistance Process

In 1973 the EOD developed the pilot system of Unit Planning Assistance Process (UPAP), a forestry-oriented, computerized information system. The UPAP system helped forest land use planners evaluate the effects of various management alternatives on resource availability and land capability.

The EOD defined all the required UPAP tables and entered and evaluated enough hypothetical and real data to enable optimization of the system. The available output options in tabular and map form include overall optimum and minimum alternatives and optimum solutions for each resource desired.

Color Mosaic of the SHNF

Personnel of the EOD constructed a color IR photomosaic of the SHNF to demonstrate to forest managers its utility for unit planning as opposed to the conventional line or planimetric maps now used. The mosaic is semicontrolled (partially corrected for lens distortion) and has been reproduced at three different scales: 1:24,000, 1:125,000, and 1:250,000.

Many advantages of the photomosaic have been demonstrated by its use. The mosaic allows an interpreter to study many individual photographs at once. It allows large regional patterns to be related to environmental factors that might not be evident in other maps or single photograph frames. It provides an up-to-date inventory of the transportation network of the area and a reasonable assessment of the area's economic potential, relative accessibility, and general vegetative cover. Most importantly, it is an economical way of constructing information maps for forest management.

Petroleum Industry Symposium

In November 1973 NASA/JSC invited petroleum-producing companies to an earth resources remote sensing symposium explaining new techniques that could apply to petroleum exploration, production, or transportation. The symposium was very well attended, with most companies represented by several key technical and management personnel.

A tour of EOD facilities in Building 17 and informative presentations by EOD remote sensing specialists highlighted the symposium. Petroleum industry representatives were shown the EOD facilities for image analysis, photogrammetry, rectification of metric photographs, production of photomosaics, camera calibration, and interactive computer-aided analysis of remotely sensed data. The EOD personnel explained the role of the division in the NASA earth resources program, described the techniques used in EOD/JSC remote sensing applications studies, and gave representative examples of data products.

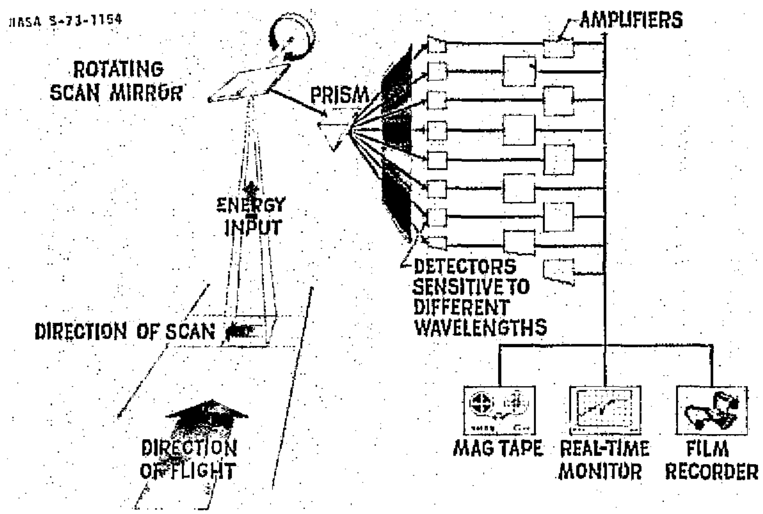
Petroleum industry symposium representatives touring Building 17. They saw the techniques used in the rectification of metric photographs, image analysis, and production of photomosaics.

ERTS-1 Data Applications

Introduction

When the GSFC received ERTS-1 telemetry from the satellite, the center converted the telemetry to digital tapes and multispectral images and then forwarded them to principal investigators for applications evaluation. The EOD at JSC evaluated the applications data from the standpoint of these disciplines: agriculture, coastal and estuarine hydrology, rangeland resources, forestry, urban land use, and regional land use.

From December 1972 through September 1973, EOD published significant findings reports for each of the 11 ERTS disciplinary applications as part of the final ERTS-1 reports. In March 1973, five EOD interim reports were presented at the GSFC ERTS Symposium on these topics: land use determination, agricultural analysis of MSS data, processing and interpretation of ERTS-1 data, classification and areal measurement of land and water coastal features, and forest and range mapping. At another symposium, held in December 1973, three EOD reports summarizing the final reports from the analysis teams were presented. Finally, reports detailing the team findings were compiled; the results of these ERTS-1 investigations are summarized in a compendium on the utility of ERTS-1 data analyzed through conventional image interpretation and computer-aided classification procedures.



The multispectral scanner records electromagnetic waves reflected or emitted from the Earth's surface in selected wavelength bands. Scanners may telemeter signals to ground stations, and the data collected can be computer analyzed.

ERTS-1 Data

The 11 significant findings reports on ERTS-1 data for each of the disciplinary applications presented the following findings:

1. The forest analysis team found that bodies of water 1 hectare in size can be detected.

2. The coastal analysis team determined that more spectral clusters identifying water can be separated when data from the coastal land areas are excluded from the data processed.

3. The agriculture analysis team achieved automatic pattern recognition classification accuracies on rice, barley, stubble, and safflower with digital MSS data comparable to accuracies obtained with low-altitude, airborne MSS data.

4. The ERTS-1 signature extension team analyzed the usefulness of MSS data in identifying water features and found that small bodies of water could be detected by searching for small values (from 0 to 15 on a scale of 0 to 63) in the IR data.

5. While investigating the characteristic reflectance properties of surface water as measured by the MSS, the coastal analysis team found that band 7 (800 to 1,100 nm) could detect

changes in water reflectance, such as those caused by turbidity.

6. The coastal analysis team was able to determine areal extent of wetlands with an 89- to 99-percent correlation agreement between aircraft photography and MSS data.

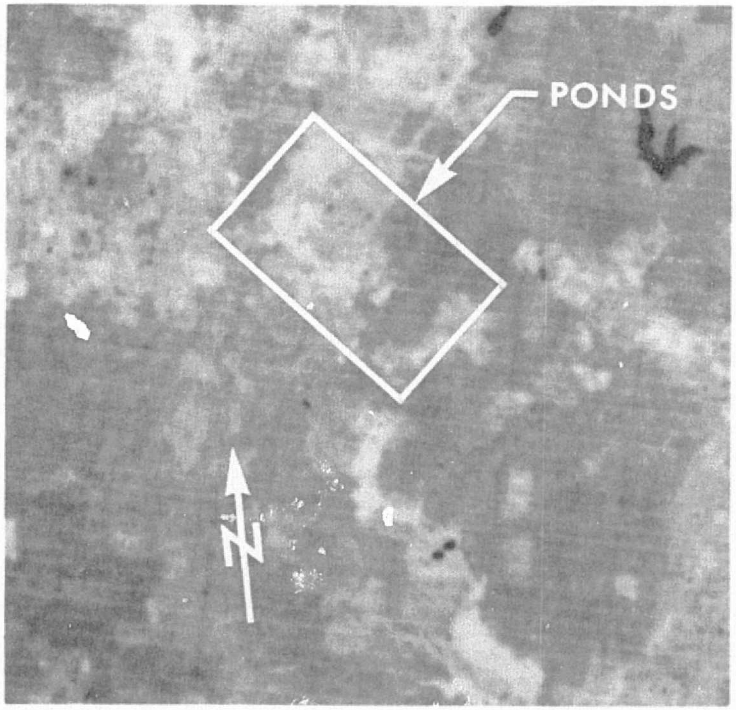
7. The forest analysis team detected the effects of a prescribed burn on vegetation by using ERTS-1 imagery.

8. The Mapping Sciences Branch achieved automated temporal registration of ERTS-1 data. The automated registration of these data will allow scientists to register MSS data acquired from satellites for the same area on two or more different dates.

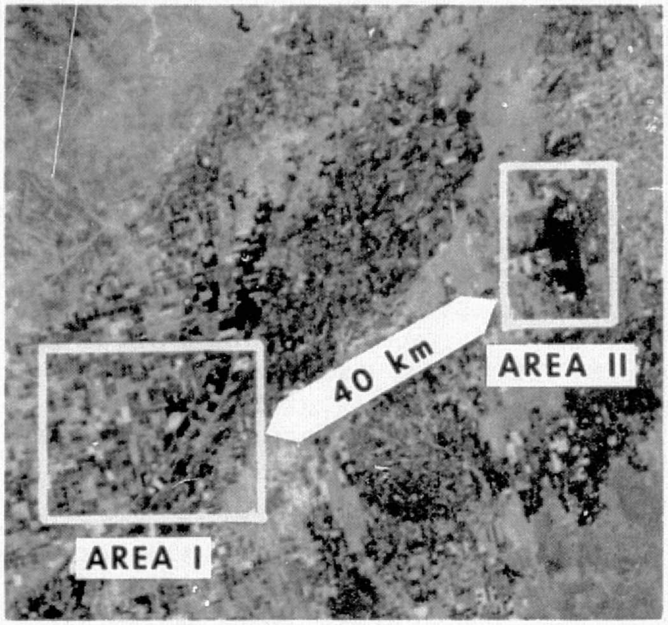
9. The coastal analysis team detected an extensive phytoplankton bloom in ERTS-1 imagery.

10. The coastal analysis team demonstrated that changes in water coverage due to rice farming practices, flooding, and tidal level changes can be detected from ERTS-1 data. Tracking water levels is vital to wetlands management and to mosquito control activities.

11. The EOD personnel found that coastal features could be separated more easily when the MSS data were corrected for effects of sun angle, sensor calibration, and atmosphere.



Rectangle locates pond in ERTS-1 image of site near Bath, Texas. The EOD Forest Analysis Team observed ponds as small as a hectare on this fifth-generation MSS image.



The ERTS-1 MSS data of San Joaquin Valley, California, show the two areas studied by an EOD analysis team. Field statistics from area I were used to classify crops in area II.

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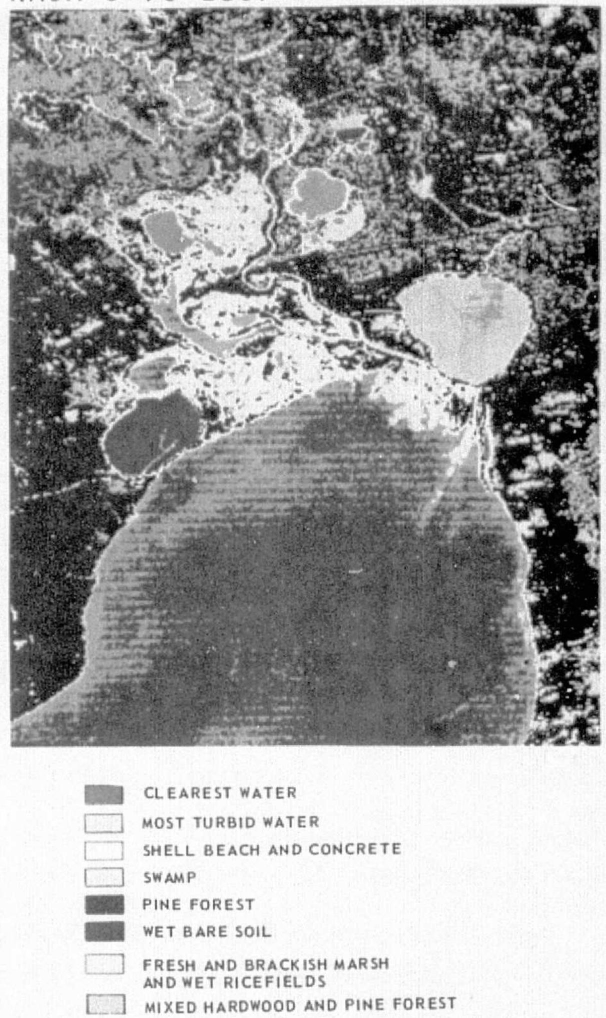
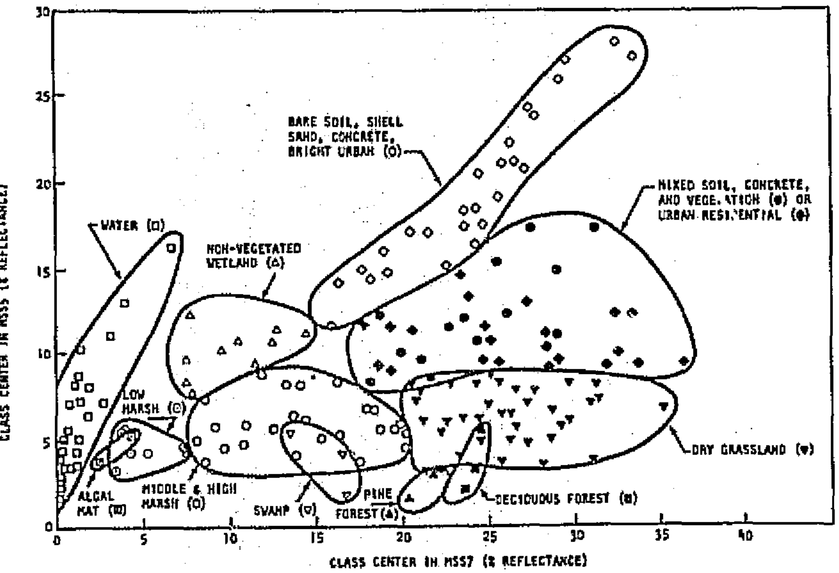


An ERTS-1 image of Trinity Bay, Texas. The Coastal Analysis Team observed changes in Trinity Bay wetlands.



Cluster analysis of ERTS-1 MSS bands 5 and 7 revealed the reflectance signatures of coastal features shown in this graph.

GSFC ERTS-1 Symposiums

The five EOD papers presented at GSFC during the March 1973 ERTS Symposium were interim reports describing (1) a comparison of land use determinations with data from ERTS-1 and high-altitude aircraft, (2) the results of an analysis of ERTS-1 MSS data for an agricultural area, (3) significant techniques of processing and interpreting ERTS-1 data, (4) unsupervised classification and areal measurement of land and water features on the Texas coast, and (5) forest and range mapping in the Houston area with ERTS-1 data.

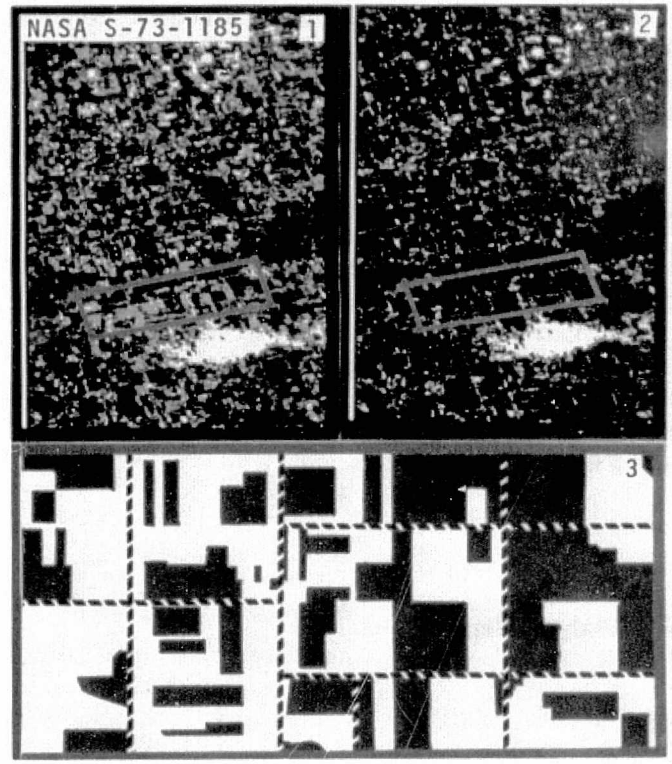
The ERTS-1 data were used successfully to classify land in the Houston area to Level I and in some cases to Level II for regional inventories.

An ERTS-1 scene over Monterey Bay, California, was analyzed to test the ability to discriminate among crop types and to provide accurate areal measurement using satellite-acquired MSS data. The results indicated that the ERTS-1 MSS data can provide the identification and areal extent of agricultural lands and field crop types. Later data sets of Hardin County, Iowa, and Holt County, Nebraska, have undergone preliminary analyses for evaluation of crop types and areal measurement.

JSC provided the framework for the systematic evaluation of the various elements comprising a prototype multispectral data processing and analysis system.

From the MSS digital data used to delineate coastal land, vegetation, and water features, 17 to 30 spectrally homogeneous classes were defined. With aircraft photography as a base, areal measurements were made on the salt marshes to an accuracy range of 89 to 99 percent.

Conventional imagery interpretation techniques of forest features indicated a classification accuracy of 63 percent. Computer-aided interpretations of the forest features with a clustering technique gave a 70-percent accuracy. Two species of coastal range salt marsh grasses were mapped. The separation of the two species (marsh-hay cordgrass and gulf cordgrass) has a natural boundary marked by a change in ground elevation as small as 7.6 centimeters above sea level.



[1]Cluster map of corn in Hardin County, Iowa.

[2]Cluster map of roads in Hardin County, Iowa.

[3]Ground truth map of corn in Hardin County, Iowa.

Cluster analysis can be used to identify different categories of features. Note the accuracy of cluster analysis compared to the ground truth map.

At the December 1973 ERTS-1 Symposium at GSFC, the EOD ERTS-1 analysis teams reported that through conventional image interpretation and computer-aided techniques, land use for Levels I and II, as described by U.S. Geological Survey (USGS) Circular 671, could be categorized for the Houston gulf coast area. They also reported investigation of conventional image interpretation and computer-aided techniques to determine to what extent ERTS-1 data could detect, identify, locate, and measure agriculture and forest features.

ERTS-1 Analysis Reports

The approach, results, and conclusions made by the ERTS-1 analysis teams in their particular applications are fully detailed in seven reports to be distributed in 1974. The major conclusions drawn from these reports are as follows:

1. Data of the type provided by the ERTS-1 MSS will be significantly valuable for conducting extensive regional inventories and surveys in land use, cropland, and range/forest resources and for determining certain coastal and estuarine resources and conditions (such as water, turbidity, marshland, forests, and phytoplankton blooms).

2. Classification performance for various features using ERTS-1 data both by conventional image interpretation and by computer-aided methods compared favorably with classification performance historically achieved with high-altitude aircraft data.

3. These investigations confirmed the assumptions that large area crop and land resources inventories, as stated in USGS Circular 671 for the Level I land use survey, can be conducted with ERTS-1 data using relatively little ground truth.

4. Field width, relative contrast, and orientation were important characteristics in the accurate detection of individual field boundaries.

- Narrow fields oriented east-west (parallel to the scan lines) were more difficult to detect and measure than fields oriented north-south.

- Fields less than 50 meters wide were not consistently detectable.

5. Low computer-aided classification accuracies occurred when a spectrally complex urban scene was classified with extensive nonurban

areas containing spectrally homogeneous features. To increase classification accuracies of certain urban land use categories, it was necessary to develop separate computer inputs and to regroup some spectrally similar clusters. Even so, classification accuracies of urban landscapes did not approach the accuracies achieved in classifying the land use categories containing more homogeneous features (e.g., agriculture, forest, and water).

6. Some categories of land use appeared to be best arrived at by classifying at a detailed level and aggregating to more general levels.

7. Sun-angle effects were significant in measuring an absolute reflectance and in discriminating class. Temporal analysis of ERTS-1 data sets demonstrated a high degree of signature overlap in various spectral classes. Removal of sun-angle effects resulted in good discrimination of the same classes. Atmospheric effects may not have a pronounced impact on spectral discrimination of classes in a relative sense but must be removed to determine absolute reflectance.

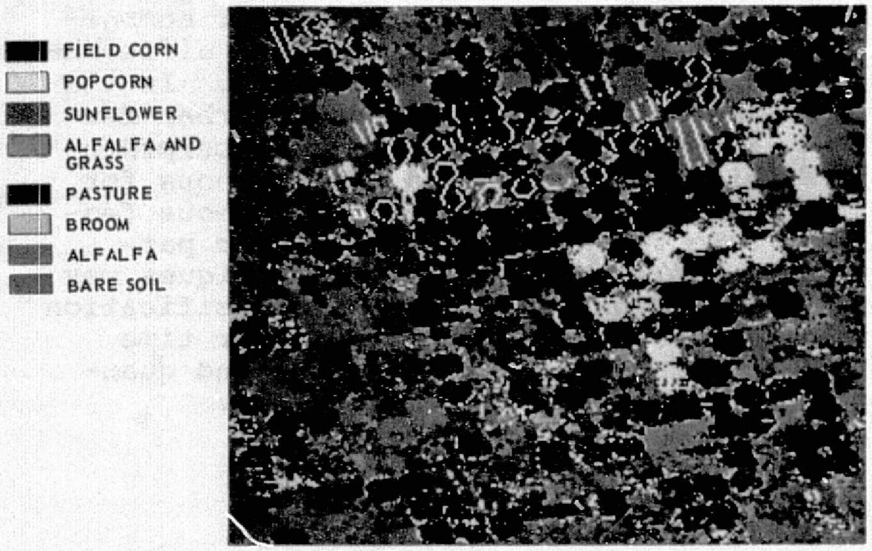
8. Temporal analysis provided better discrimination between certain features.

9. The computer-aided classification techniques were generally more accurate than conventional image interpretation techniques for homogeneous features that could be differentiated by spectral contrasts. In the separation of urban and nonurban features, conventional image interpretation methods proved advantageous for delineating small, heterogeneous features (e.g., urban and linear patterns). The choice of techniques may depend on the degree of classification accuracy acceptable, computer time available, analyst skills, and quantity of data to be processed.

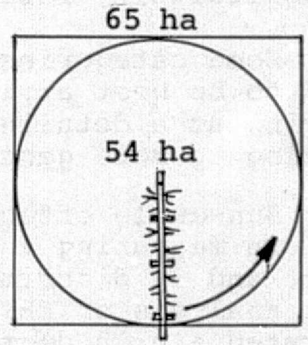
Agriculture

The agriculture team had excellent results with ERTS-1 data on large homogeneous, spectrally similar fields. Holt County best exemplifies the team's success with a single data set and with temporal analysis. The cluster analysis of the data set from a single ERTS-1 pass did not separate corn into classes, but with the two-pass data set cluster analysis separated the popcorn from the field corn. Grain sorghum was also separated with good results.

NASA S-73-2855



Circularly irrigated fields in Holt County, Nebraska (left). Automated data classification of these fields used JSC clustering techniques to separate spectral information. Surprisingly, field corn shown by gray circles differs from popcorn shown by white circles. Circular crop patterns result from center pivot irrigation systems. The table below shows the accuracy of this automated classification.



	TRAINING FIELDS				TEST FIELDS			
	TOTAL SAMPLES	MISCLAS-SIFIED	THRESH-OLD OUT	PERCENT CORRECT	TOTAL SAMPLES	MISCLAS-SIFIED	THRESH-OLD OUT	PERCENT CORRECT
Red and dark red field corn or popcorn	979	4	1	99.3	504	3	0	99.4
Red field corn	745	13	1	98.2	456	13	0	97.0
Yellow popcorn	234	9	2	[a]95.3	48	1	0	[a]97.9
Orange sunflowers	50	2	0	96.0				
Dark violet alfalfa	34	1	0	97.1				
Light violet alfalfa and grass	18	0	0	100.0				
Light green grass	109	3	0	97.3	54	0	0	100.0
Dark green pasture	219	4	2	97.3				
Gray-brown fallow (bare soil)	50	0	0	100.0				
Blue grain sorghum	14	1	0	92.9				
Black threshold								
White test and training								

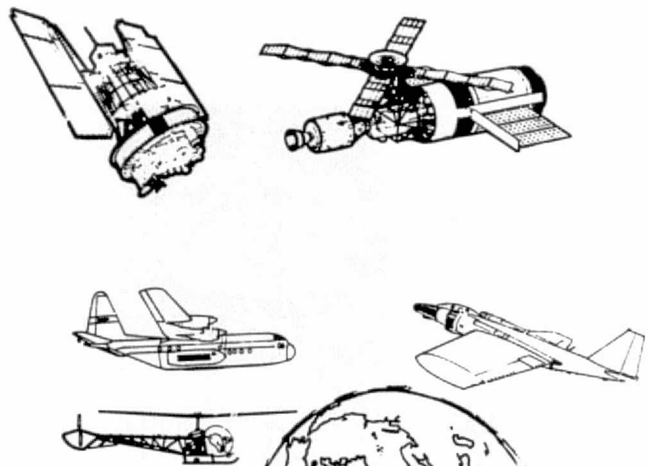
[a]This number does not reflect that one out of the seven known popcorn fields was misclassified as field corn.

Land Use

Relatively high classification accuracies for Level I land use categories were achieved by conventional image interpretation and computer-aided classification techniques, except the urban and built-up category which was derived from computer classification of the entire study area. When only the preselected urban area was classified in Level II categories, considerably better computer classification accuracies were attained. This apparent discrepancy in accuracies was probably due to the spectral heterogeneity of the urban scene in which vegetated urban features were spectrally similar to the vegetated agriculture-rangeland features.

To determine the accuracy of the land use map generated by the nonsupervised classification, the land use team generated a misclassification error matrix for the categories developed from the 32 clusters by comparing the nonsupervised classification with a base developed from 1:120,000-scale high-altitude aircraft photography (ground truth) of the same area. Some of the differences in the areal extent of certain categories can be attributed to the manner in which a specific spectral cluster was assigned to a particular land use category.

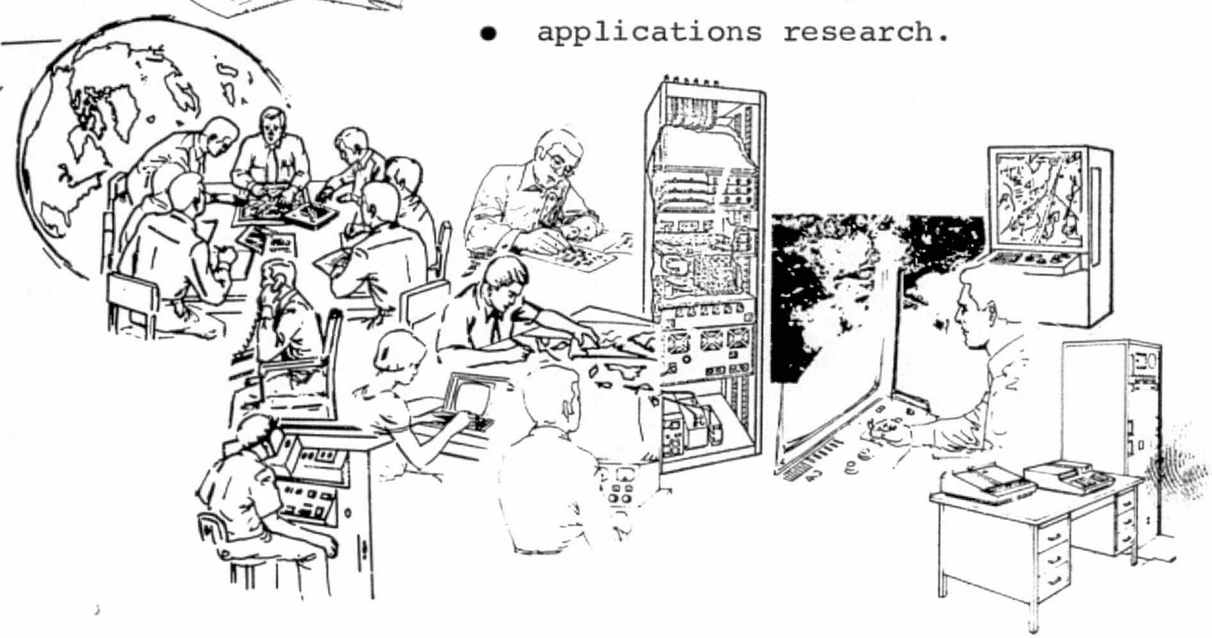
Research and Technology



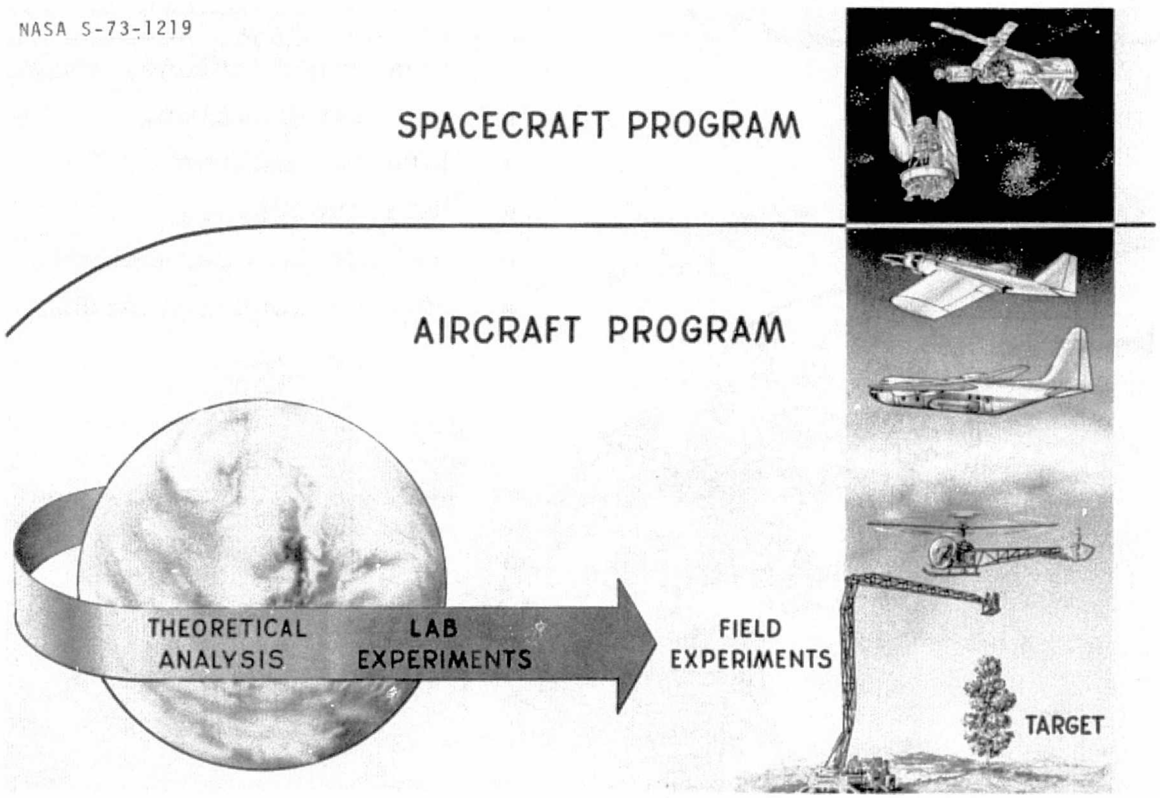
Introduction

The scientific research and technology projects of EOD and supporting universities conformed to the basic elements of remote sensing for earth resources applications, which are

- data acquisition,
- data correction,
- data analysis,
- information management, and
- applications research.



NASA S-73-1219



Theoretical analysis, field experiments, and sensor development are elements in the JSC research and technology to develop remote sensing techniques for earth resources applications.

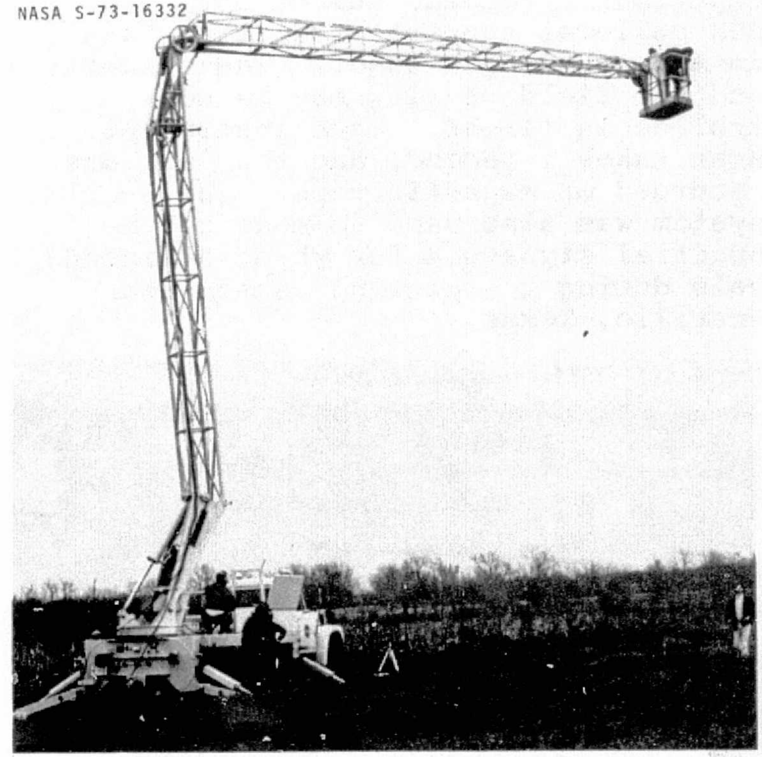
Data Acquisition

Specific data from aircraft and field observations aid in interpreting the broader data remotely sensed from spacecraft and satellites. The extensive data are acquired primarily as electronically recorded spectral signatures. Various sensor systems are used to record the electromagnetic energy reflected from scenes or objects, but the majority of these are passive systems recording only naturally occurring energy.

The EOD studied spectral signatures of wheat varieties, wheat affected by virus disease, oats, and barley by using the Field Signature Acquisition System (FSAS). The FSAS is a heavy-duty truck equipped with an extendable platform and two sensors. The instrument platform and sensors are positioned over a field of plants or soil to collect spectral data. The EOD used the FSAS on field trips to Texas A&M University and to the SHNF.

One of the FSAS sensors is the Block Engineering Visible-Infrared Spectrometer System, an interferometer spectrometer with control and data processing electronics in two wavelength ranges. The other sensor is the Microwave Signature Acquisition System (MSAS), a passive radiometer operating in the X- and L-bands. The MSAS was used to collect data on microwave emission from moist soil in a cooperative program to determine the feasibility for remote sensing of soil moisture.

NASA S-73-16332



Truck and instrument platform of the field signature acquisition system. The sensors on the platform acquire data from field observations.

S-191H Field Spectrometer System

During Skylab 2, 3, and 4 missions, EOD used the helicopter-borne S-191H Field Spectrometer System (FSS) to support NASA atmospheric effects experiment proposal number 584. The FSS collects spectral radiation data in two wavelength bands. These bands and the field of view may be controlled in flight. Each instrument scan takes 1 second, and the data are recorded on magnetic tape. The S-191H system was also used to measure the spectral signature for wheat at intervals during the growing season near Amarillo, Texas.

Helicopters such as this carried remote sensing equipment for experiments on atmospheric effects during Skylab missions.

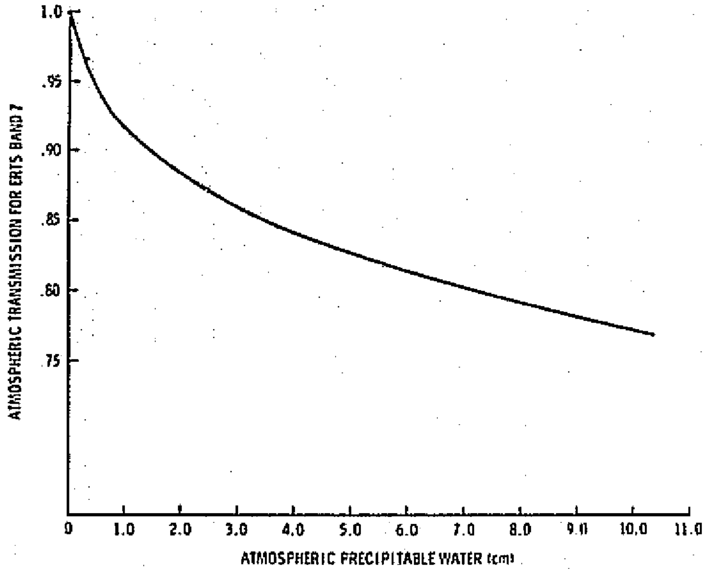
Data Correction

The EOD identified the effects of atmosphere on automatic classification of ERTS MSS crop data. To determine the effects of atmospheric water on an ERTS MSS band, researchers related water vapor lines made with a 10-layer atmospheric transmission model to the filter function response of an ERTS channel obtained from preflight calibrations. The investigators obtained transmission in the ERTS channel from preflight calibration and calculated the transmission in the band as a function of atmospheric precipitable water.

The investigators used ERTS data from three Illinois counties to assess the effect of gradients in humidity on signature extension classification. The investigators tested cases by choosing an atmospheric water amount and multiplying the ERTS channel by the proper factor. The results showed that water vapor deleteriously affects automatic classification of corn. A similar study showed that water vapor has a more adverse effect on crop classification of soybeans than on corn.

These studies suggest that future satellite sensing should use bands bypassing the effect of water vapor or use ground training fields with the least precipitable atmospheric water.

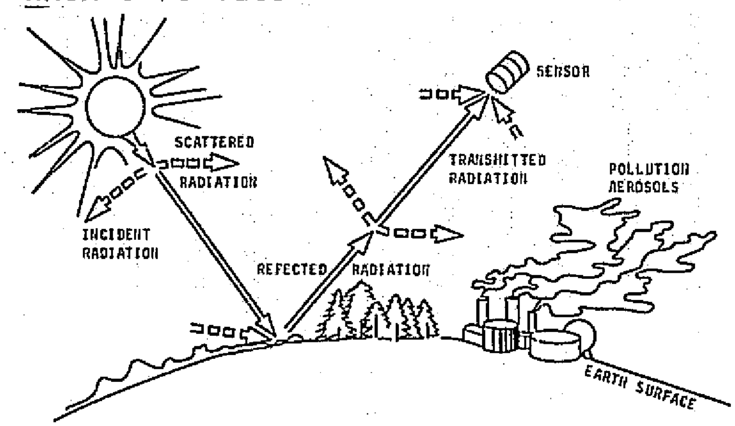
NASA S-73-1606



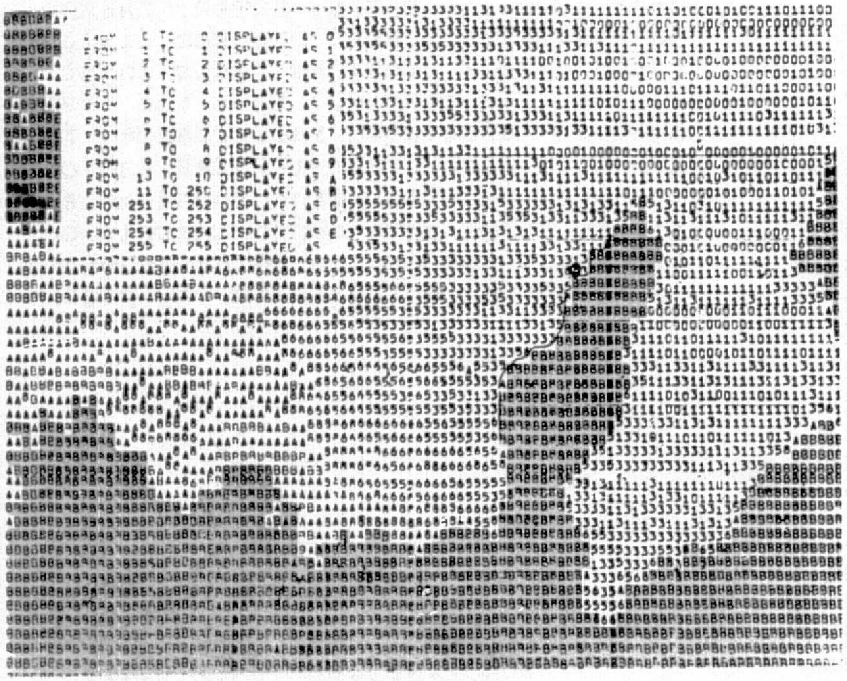
Calculation of water vapor amounts in the atmosphere. Investigators assessed the effect of gradients in humidity on signature extension classification by using ERTS data.

In similar work, the EOD studied the effects of sun angle and haze level on the accuracy of automatic classification. Researchers classified ERTS imagery with haze level and sun angle changes simulated by computer programs PREPS, ROTAR, HAZADD, and SANG. The PREPS program (illustrated below) provided basic input data for the others. When the investigators calculated reflectances from ERTS data with program ROTAR and compared the results with ground-measured values, ROTAR gave approximately correct reflectances. A ROTAR-generated map is shown on the following page.

NASA S-73-1209



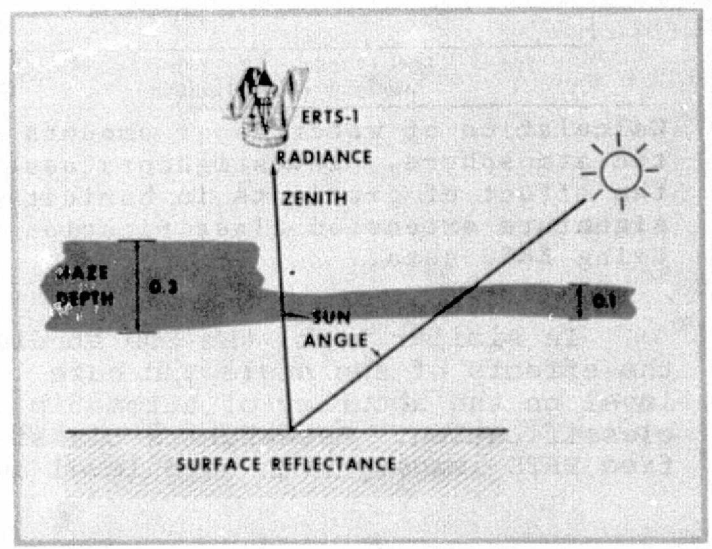
The PREPS program. This computer program provided basic input data for the classification of ERTS imagery.



Reflectance map of Lake Somerville, Texas, area produced from ERTS data with ROTAR (numbers represent percent reflectances). The lighter area is the lake. Compared with ground-measured values, the ROTAR reflectances were approximately correct.

The EOD used programs HAZADD and SANG to evaluate haze and sun angle effects on automatic data classification of three Illinois counties. The investigators assessed the effects of a uniform haze level and variation in haze level between training fields and the area being classified. A uniform haze level has little effect, but a difference of haze levels between training and test fields produced large errors. Sun angle differences between training and test fields also produced large effects.

NASA S-73-1209



Relative effects of haze addition and sun angle on radiance. Computer programs HAZADD and SANG were used to study automatic data classification and haze levels.

The EOD developed computer programs using combinations of algorithms to register aircraft and satellite digital MSS data in its continuing program to achieve spatial congruence between remotely sensed data and baseline maps. The registration programs use various computer output devices to produce hard-copy overlays of maps and photobase products. Examples of output products include:

1. An ERTS digital data output on a film transparency corrected to fit the mosaic data base.

2. An ERTS digital data output in geometrically corrected form on a line printer to overlay topographic maps and photomosaics.

3. An ERTS digital data output on a line printer to fit 1:125,000-scale maps.

4. Aircraft scanner and ERTS-1 digital data geometrically corrected and registered to photographic data bases and topographic maps at a 1:24,000 scale.

NASA S-74-32872

An ERTS-1 land use map of the Houston area and JSC with a 10-square-kilometer Universal Transverse Mercator grid automatically superimposed.

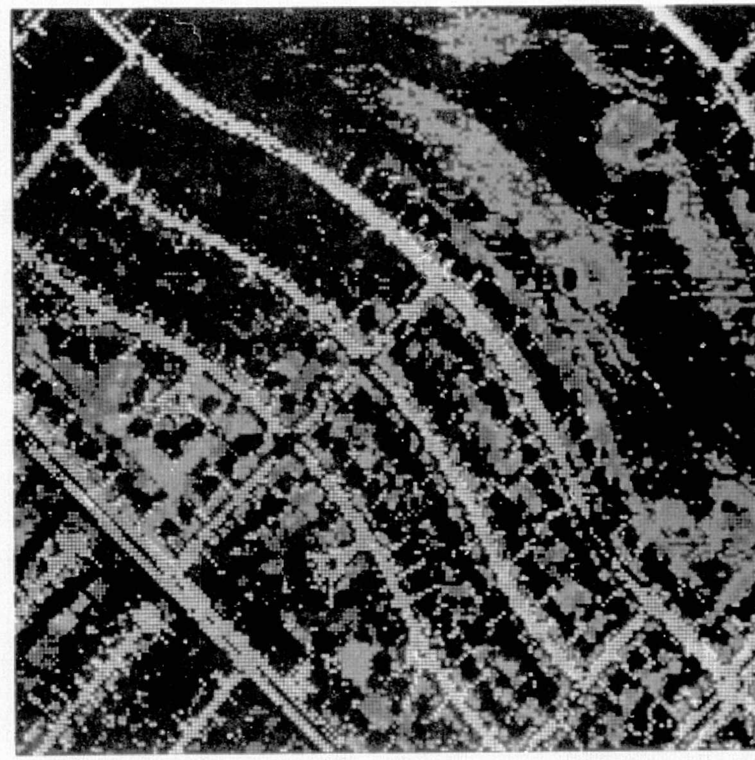
Data Analysis

CLUSTD

A new program for the nonsupervised classification of multispectral data at EOD, CLUSTD, was developed by a visiting scientist from the School of Engineering at Oakland University, Rochester, Michigan. The CLUSTD program is an alternate to the ISOCLS program, an iterative procedure for grouping multispectral data into sets or clusters of similar data. The CLUSTD program is now used on the Univac 1108 computer by JSC and cooperating universities.

CLUSTD, a single-pass clustering program, can process an unlimited quantity of data. The program outputs a nine-track tape of a cluster map. The tape can contain up to 700 pixels per scan line and cluster data containing from 1 to 36 channels of information.

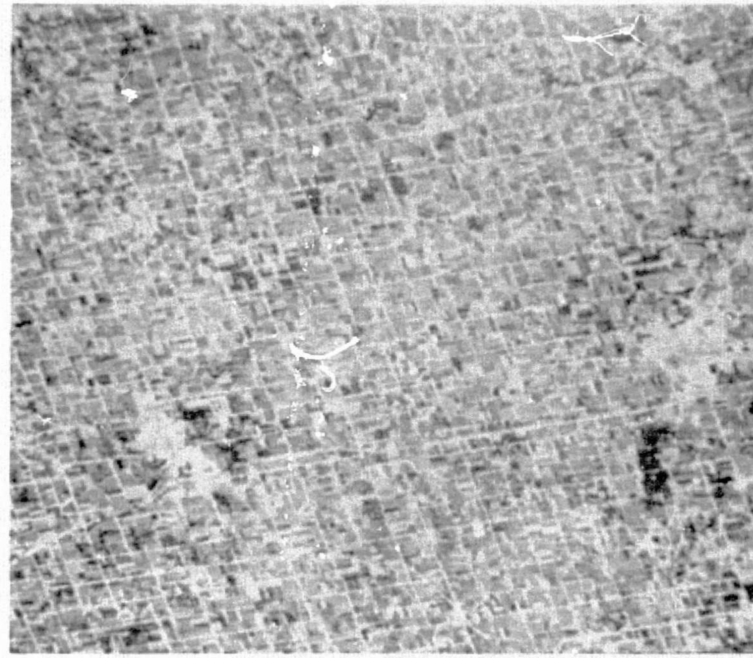
NASA S-74-32873



Output sample from the CLUSTD program. This photograph is the result of superimposing four figures with computer-generated microfilm plots directly in the additive color viewer printer. The pixels in these figures are classified into one of these groups: streets, houses, fairways, or greens.

LARS Agricultural Crop Classification and Mapping

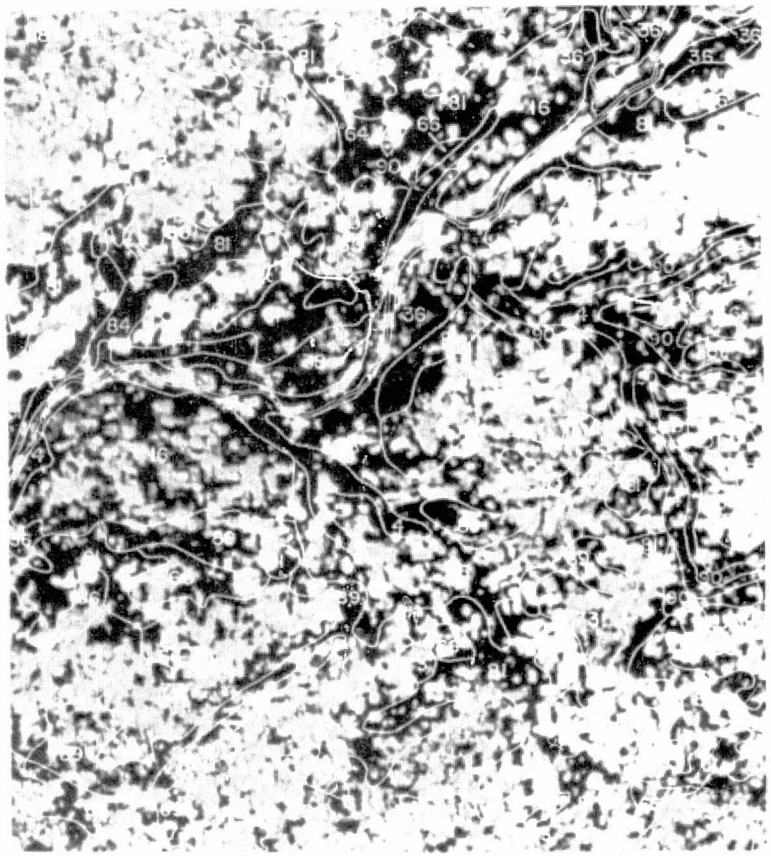
Research on identification of agricultural crop species from ERTS data resulted in the accurate identification of such crops or land uses as corn, soybeans, wheat, and rangeland. Classification performance was about the same as predicted from aircraft scanner data. This is particularly significant in light of the much larger areas classified with ERTS data. Acreage estimates made from classifications of ERTS data compare well to those made by the USDA. These results strongly suggest the potential of this technology for obtaining crop production information over large areas. One of the capabilities expected to contribute to further improvement of crop identification performance is registration of multitemporally acquired data. With this capability, the characteristics and use of temporal information for classification of crops and other cover types can now be fully evaluated.



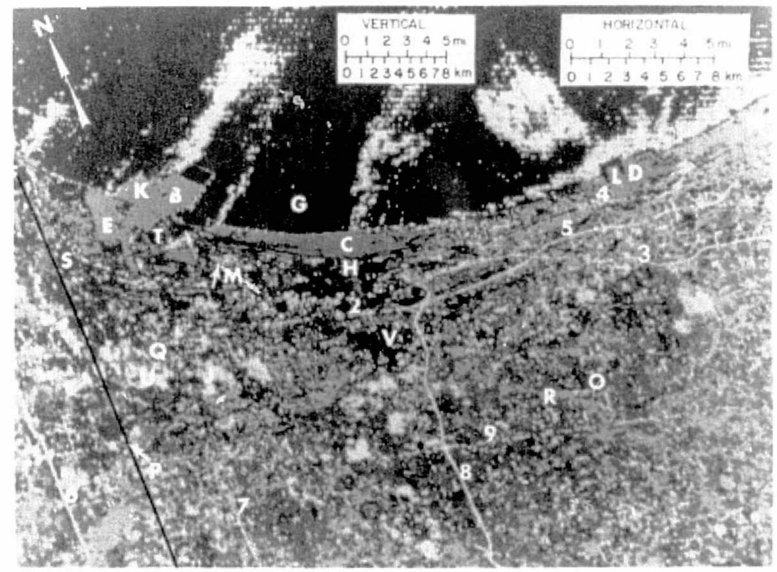
Computer classification of ERTS data identifying corn (black), soybeans (gray), and all others (white) in DeKalb County, Illinois.

LARS Soil Mapping

The potential value of remotely sensed data in soil inventories was advanced by studies relating soil properties to computer-processed ERTS images. These images provided more correct information on the location of soil associations for several counties than was available in previously existing maps.



An unsupervised classification of geometrically corrected ERTS-1 Tippecanoe County, Indiana, data with a standard generalized soil map overlaid for comparison.



Photograph from digital display of computer implemented land use classification of the Gary-Hammond, Indiana, area. Gray levels used for the display of the spectral classes are as follows:

Industrial/ commercial	Medium gray
Older housing	Black
Newer housing	White
Trees	Light gray
Grassy (open agricultural)	Dark gray
Water	Black
Smoke	White

The letters and numbers indicate discrete features of the area.

LARS Land Use Classification and Mapping

The ERTS MSS data obtained over urban areas were analyzed to assess the utility of computer-implemented classification of urban land uses. Several urban land use classes such as inner city, commerce/industry, low density housing, high density housing, trees, and water exhibited spectrally separable characteristics. Conclusions drawn from these studies suggest that computer analysis of ERTS MSS data can be a valuable input to the urban regional planner. Not only can ERTS data be a source of land use information, but it can also be used to update and/or supplement existing land use data banks.

LARS Forest Resources

Use of MSS data and computer-aided analysis techniques indicated that deciduous and coniferous cover types could be reliably mapped, not only in areas having little topographic relief, but also in mountainous regions. In some cases, spectral differences between species within each of these major groups were measured. Spectral variability within forest canopies caused by variations in stand density and textural characteristics of the forest canopy could be successfully overcome through use of a per field classification algorithm. A major study involving spectral band selection indicated the value of utilizing at least one wavelength band from each of the four major regions of the optical portion of the spectrum – visible (0.4 to 0.7 μm), near IR (0.7 to 1.3 μm), middle IR (1.3 to 3 μm), and thermal IR (3 to 14 μm). However, use of more than five wavelength bands in the classification did not cause significant increases in the classification accuracy.

LARS Water Resources

Water resources research involved two primary areas of activity: calibration of MSS data to enable accurate remote measurements of the surface temperature of water bodies and analysis of the spectral characteristics of scanner data in relation to water quality parameters. Use of the 9.3- to 11.7-micrometer portion of the thermal IR atmospheric window, accurate calibration of the hot and cold plates, and appropriate data processing techniques will allow the absolute temperature of the surface of water features to be mapped to an accuracy of better than 0.4° C for altitudes of at least 1.5 kilometers. Water pollutants could sometimes be delineated with MSS data even though they could not be detected on aerial photographs.

LARS Field and Laboratory Spectroradiometer System

The Exotech Model 20-C field spectroradiometer (0.4 to 14 μm) was implemented as part of a system to produce in situ spectra to aid researchers in interpreting the effects of crop and soil conditions on MSS measurements. Field techniques were developed to produce calibrated data for the reflectance factor, the reflection-distribution function, radiance, and irradiance. The system featured digital data output and programs for processing the data. One of the first experiments utilizing the field spectroradiometer studied the emissive properties of a stressed corn canopy as a function of the degree of stress present. Radiation modeling techniques applied to the field spectroradiometer measurement showed that geometric effects dominate the emissive characteristics of the plant canopy. Such results help explain why the thermal channel was so frequently chosen in the analysis of the corn blight watch scanner data. An artificial light source was constructed for this system, making possible even more carefully controlled experimentation under laboratory conditions.

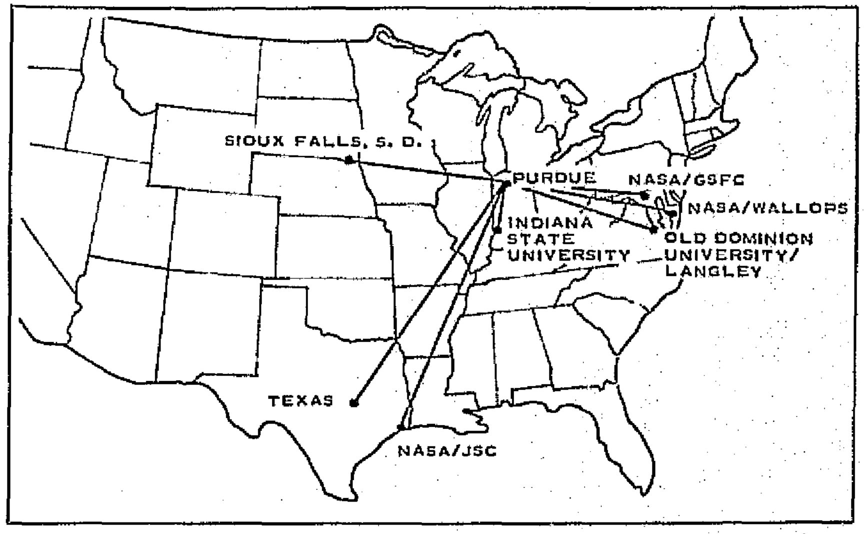
LARS Software System

The most important product developed for NASA by LARS is the LARSYS III automated classification program. This software system, involving more than 20,000 lines of program code, together with its more than 3,000 pages of documentation, easily represents the largest, most tested, and most user-ready remote sensing data analysis system in existence today. It incorporates into a single system the algorithms developed and evaluated over the last several years in a unique user scientist environment. Factors important in algorithm selection for this system (in addition to performance) were flexibility, robustness, cost-effectiveness, and simplicity of application for the user. It appears desirable to provide the widest possible availability of the capability which this system represents. Thus, in addition to delivering this system to NASA, Purdue has established a simple procedure by which any domestic organization can obtain directly the most current version of this system at no cost to NASA.

LARS Remote Terminal Experiment

The remote terminal experiment was proposed to address the questions of transferring the LARSYS technology to another site and to study a possible approach to operational data processing systems of the future. The LARSYS software was appropriately modified, and remote terminals were installed.

An important part of the remote terminal system was the development of training materials. The materials presently consist of six minicourses designed for individualized instruction and employ a variety of media. The terminal system so far has proven highly effective as a technology transfer method. More than 200 people have been trained on the system at various NASA centers. To test the system in a true user environment, a self-funded terminal was recently established in the offices of the State of Texas. Though the experiment is not complete, it is clear at this time that the system functions very effectively in a technology transfer mode and has made possible a very significant amount of analysis of ERTS data.



Locations of existing remote terminals.

University of Texas at Dallas

The University of Texas at Dallas developed a procedure for making an unbiased estimate of the proportion of a data set that belongs to each class known to be included in the data. The procedure requires a knowledge of the proportion of the data set assigned to each class by a supervised classifier and the pairwise probabilities of misclassification for this classifier on the data set. This procedure, developed for use in making crop acreage estimates from MSS data, is currently being tested on data from ERTS-1. An estimate of the variance of such an acreage estimate including the effects of both classification and sampling errors was also developed.

University of Houston

The University of Houston and EOD developed a linear feature selection program to improve the classification of MSS data and to yield greater accuracy and speed of computation. Numerical optimization procedures are used to find the linear combinations and the extrema for any one of several class separability criteria such as the average divergence, the average transformed divergence, or the average Bhattacharyya distance. The use of k features for the classification of an MSS data set allows improvements in classification performance compared with using k of the n available measurements or the same performance that required more than k channels, which saves computation time. During the summer of 1973, this approach was extended at Texas A&M University to feature selection to the case where the criterion of most interest, the probability of misclassification, is minimized.

Rice University

Rice University performed an analysis of several software systems available for use as applications development systems in the analysis of MSS data. An applications development system is a system that serves two kinds of users: (1) techniques development users who need the capability to modify existing algorithms easily or to add new algorithms under development and (2) production users who are trying out new applications of remote sensing and require the ability to efficiently process data with state-of-the-art techniques in amounts large enough to provide meaningful information about the application. The software systems tested were the LARSYS III developed at Purdue University; the Earth Resources Interactive Processing System developed at JSC; the Algorithm Simulation, Test, and Evaluation Program developed at JSC; and a batch version of LARSYS that is maintained at JSC. After a comparison of these systems, it was recommended that the best approach to an applications development system would be to convert LARSYS III to run under the IBM time-sharing option on an IBM 370/158 or 370/168, to add a more extensive imaging capability for remote terminal users, and to improve the modifiability of the system.

Applications Research

Soil Moisture and Modeling

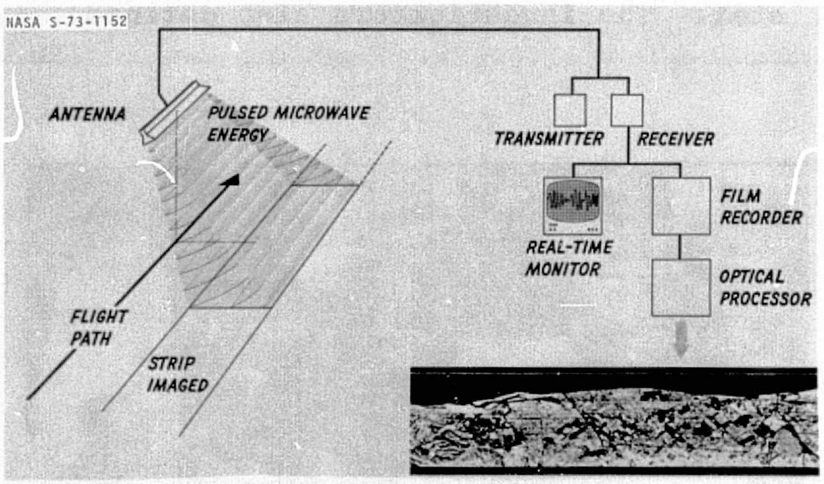
The EOD, Texas A&M University, the University of Arkansas, the University of Kansas, ERIM, USDA, and NASA/GSFC conducted the Joint Soil Moisture Experiment to evaluate microwave techniques for the remote sensing of soil moisture. Successful development of this technique would aid in predicting crop yields.

In one phase of the experiment, the microwave properties of bare and vegetated soils were measured simultaneously with the passive microwave X- and L-band radiometer and with the University of Kansas radar spectrometer. The investigators worked at field sites near Texas A&M University. An extensive series of data was obtained from fields having varying degrees of moisture. These data will be analyzed to determine the relative merits of active and passive methods for soil moisture measurements.

In planning meetings for the soil moisture flight experiment, the investigators chose Phoenix, Arizona, as the site. The experiment combined active and passive airborne microwave systems. The active system is the ERIM X- and L-band, dual-polarized, side-looking airborne radar. The passive systems, aboard the NASA/JSC P-3 remote sensing aircraft, include the Passive Microwave Imaging System and the multifrequency microwave radiometer. The investigators also defined

The Passive Microwave Imaging Data Analysis System to be used in analyzing data taken in the soil moisture flight experiments over Phoenix, Arizona.

how much ground truth was to be collected and designed new instruments for use in collecting the ground truth. The flight experiment was conducted during the month of April and met with excellent success. The investigators at ERIM are now beginning to analyze the flight data.



Side-looking airborne radar system for the soil moisture flight experiment over Phoenix, Arizona.

Environmental Research Institute of Michigan

To support NASA work, ERIM continued its comprehensive research into earth resources information systems using remote multispectral sensing of the environment from satellites. The long-range purpose of ERIM's research in remote sensing is directed toward developing two broad capabilities: scientific (discipline-oriented) studies, in which multiple types of information are extracted from regions of moderate size to study various natural processes (such as distribution of forage types), and operational surveys, in which specific types of information are extracted on a large scale (such as the spread of a crop infestation or the amount of planted acres in a particular crop). The development of models that give insight into the causes and variability in the signals received by the remote sensing system has been an adjunct to both of these major applications areas.

The CITARS project was developed for the purpose of generating and testing operational survey algorithms and procedures. Personnel from ERIM, EOD, and LARS jointly planned the CITARS project to assess the crop identification capabilities of specific ERTS multispectral data processing techniques. Researchers at ERIM analyzed test data collected from six counties in Indiana and Illinois and developed preprocessing techniques for the extension of signatures in CITARS.

Fayette County, Illinois
ERTS Data, 11 Jun 73
(Processed in Sept. 1973)

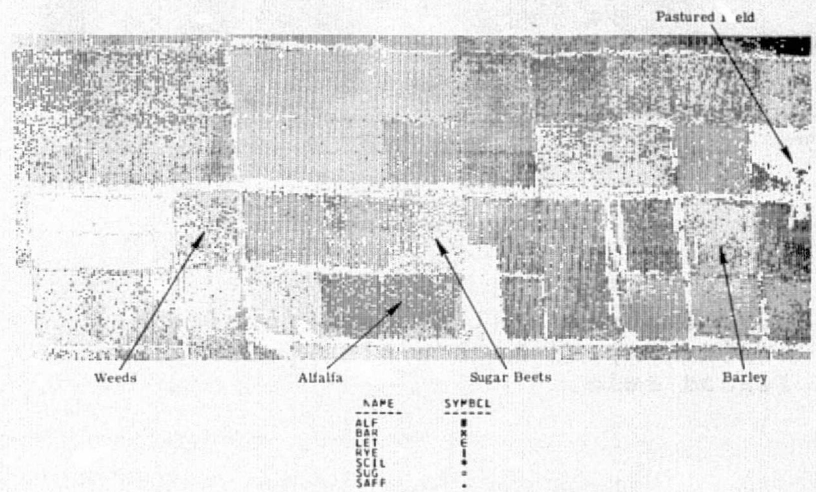
	Wheat Classification Results
Wheat Training	85% (Correct)*
Wheat Test	90% (Correct)*
Other Classes	
Corn	0% (False Detection)
Soybeans	4% (False Detection)
Trees	0% (False Detection)
Clover	6% (False Detection)
Pasture	0% (False Detection)

*On Confirmed Maturing Wheat Fields.

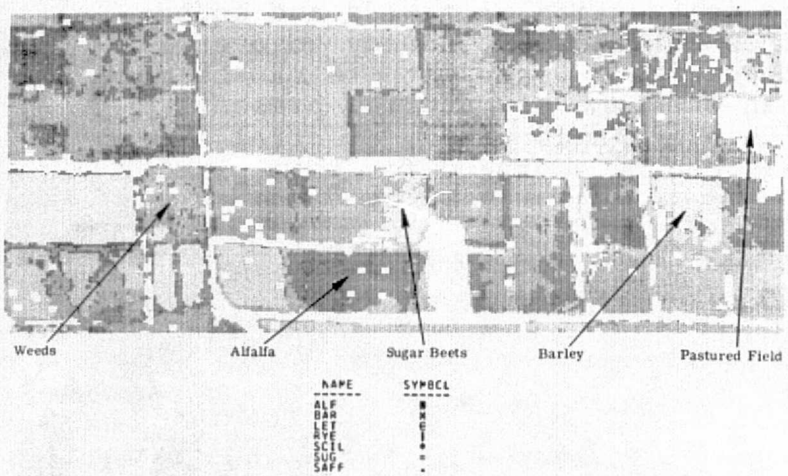
Wheat classification in Illinois from ERTS data. This work helps researchers assess the crop identification capabilities of specific multispectral data processing techniques for conducting large area crop inventories.

MSS data processing in the past has centered primarily on the spectral content of the signals. In recent years, in an effort to prepare the way for operational survey applications, ERIM researchers have utilized (or attempted to overcome) spatial, angle-dependent, and time-dependent characteristics of the multispectral data. In the last year, nearly every specific task touched on this area.

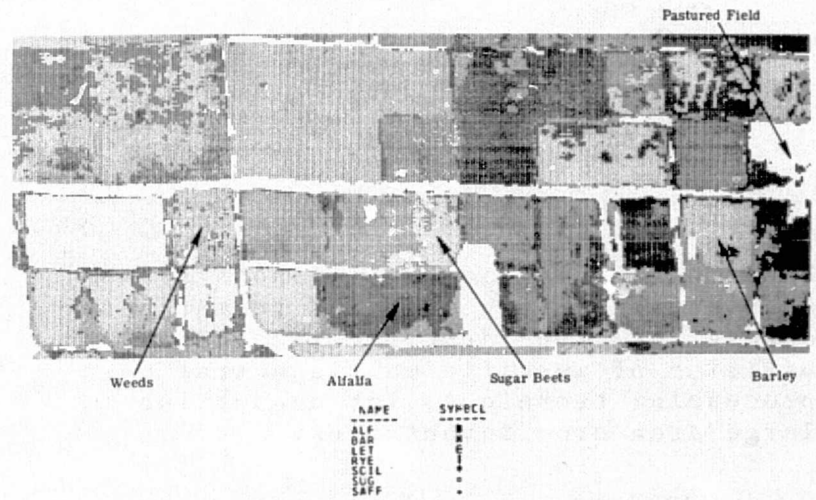
Nine-point processing is a method by which the pixels neighboring a particular pixel are used to assist in the classification of MSS data. The purpose is to produce more homogeneous classification results for large fields. The basic machinery to carry out this type of processing was programmed, and tests were performed with several nine-point rules. The rules used so far help in the delineation of fields and boundaries but show a tendency to overfill boundaries. Because there can be more than one type of material present within a single pixel, spectral signals can be confused for that pixel.



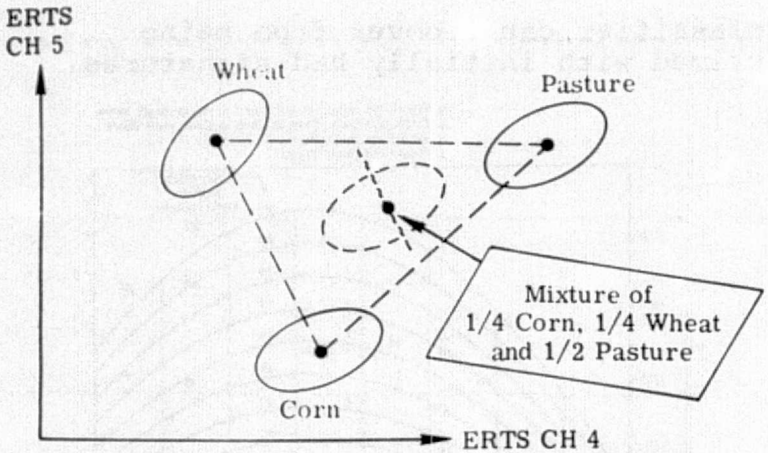
Some Imperial Valley, California, fields mapped by the one-point rule (the decision rule generally used).



Some Imperial Valley, California, fields mapped by the nine-point likelihood rule.



Some Imperial Valley, California, fields mapped by the best-seven-of-nine likelihood rule.



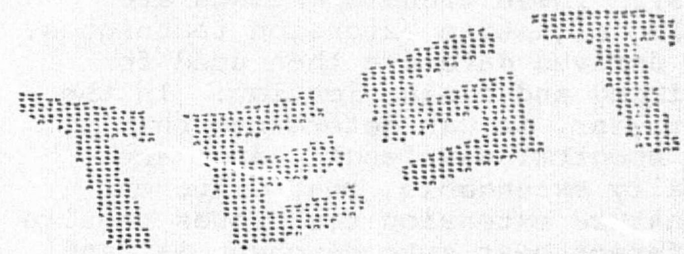
Signatures of four ground materials plotted on the quadrant formed by two ERTS channel gray scales. Given these plots, ERIM investigators used mathematical processes to estimate the composition of the mixed signature and thus increase the accuracy of large area acreage estimates.

Proportion Estimation

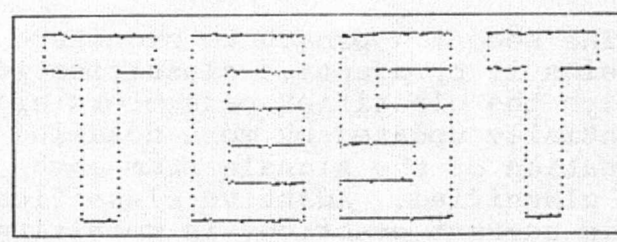
The ERIM researchers developed an algorithm for estimating the proportions of materials in a single pixel and tested the algorithm on CITARS and other data. Modifications to the algorithm limiting the number of candidate materials are now being developed as a result of these tests.

Scanner Geometry

In accurate estimation of areas and in scanner cartography, scanner data must be geometrically corrected with great precision. Simulated aircraft scanner data were successfully unscrambled to produce a rectified classification boundary map, and the acreage within boundaries was accurately estimated.



Simulated video.

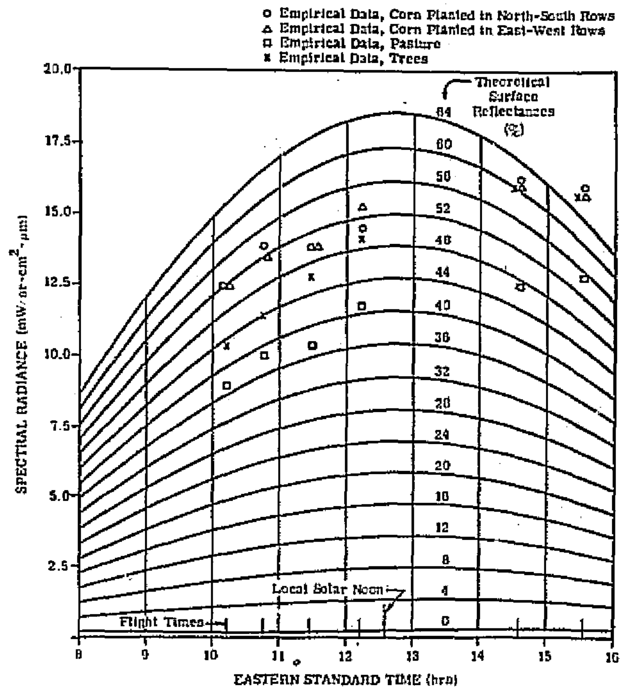


Corrected image.

Signature Extension Techniques

One of the major difficulties in classifying large areas is the space/time variability of the statistics which characterize the classes. The ERIM researchers have pursued three basic approaches to this problem. First, invariants in the data structure are assumed and then exploited by preprocessing transformations (such as additive or multiplicative corrections to the data or the ratioing of channels). These transformations are called signature extension techniques. The derived data are then used for training and classification. In the last year, it was determined that not all spectral wavelength bands are equally extendable, that different signature extension techniques require different best sets of channels, and that the use of additional data channels can at times be detrimental to classification accuracy.

The second approach to signature extension is by adaptive classification in which the classifier parameters are sequentially updated by more detailed examination of the signals from each pixel classified. Adaptive classification in current practices is resulting in elimination of approximately 30 percent of the errors of classification incurred without adaptation. Further, it has been found that line-by-line updating works as well as pixel-by-pixel updating and that the adaptive classifier can recover from being primed with initially bad signatures.



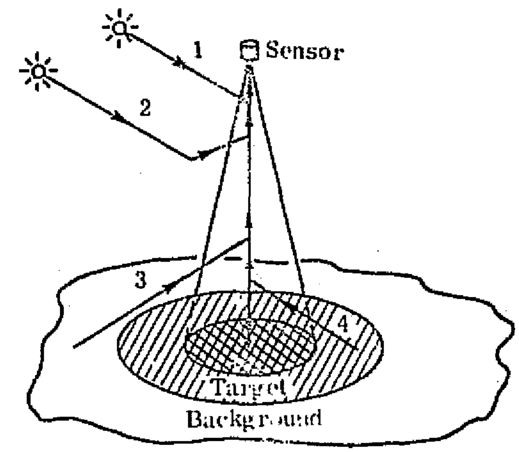
(c) Scan Angle 24° Eastward)

Radiance as a function of time, channel 8 (0.72 to 0.92 μm). Empirical data for four crops and theoretical data for various Lambertian surface reflectances. August 6, 1971: altitude, 1.5 kilometers; visibility, 23 kilometers.

A third approach to signature extension is to attempt through the use of models to find algorithms to correct the data for variability in viewing and illumination geometry and in atmospheric conditions. In one effort ERIM researchers (1) showed empirically the significant magnitude of the errors in classification caused by these variations, (2) showed the correspondence between theoretical model predictions and observed signal variability, and (3) showed a significant increase in classification accuracy when these effects were taken into account and corrected using the theoretical model. In a related effort, ERIM researchers exploited changes in viewing geometry to assist in classification.

A further example of elucidation of a process through the use of models is found in the phenomenon known as green haze, in which the radiation from a background (neighboring pixel) is scattered into the light beam from a target pixel. An atmospheric model utilizing empirically determined haze distributions was used to quantify this effect. Even for target pixels of moderately large reflectance, the effects of neighboring pixels were found to be significant in degrading the ability to classify target pixels.

Finally, the problems of calibration and of the system noise and identification of its effects on scanner data have constituted continuing effort. Current efforts have shown the long-term drifts and changes in noise and calibration and have applied the calibration trends so derived to improve the capability of extracting information from the scanner data.



CONTRIBUTIONS TO PATH RADIANCE

1. Singly-Scattered solar radiation
2. Doubly-Scattered solar radiation
3. Singly-Scattered background surface radiation
4. Singly-Scattered target surface radiation

Scattered radiation from the sun, background, and target reflected into a remote sensor. Researchers at ERIM found that the background significantly affects target radiance; therefore, this effect must be corrected to obtain accurate ground data from a remote sensing system.

From the projects described and from others, the ERIM multidisciplinary researchers plan to develop remote sensing information systems as practical tools to provide planners and decisionmakers extensive, accurate information quickly and economically.

Watershed Modeling

By using the Colorado State University version of the Kentucky Watershed Model, the EOD successfully simulated the runoff for both wet- and dry-year data for Alamosa Creek, Colorado. The investigators prepared data, determined model parameters, initialized and optimized parameters, selected control options, and interpreted results.

The simulation used a self-calibrating version of the Kentucky Watershed Model with a steepest descent optimizing routine and a straight version with a Calcomp plotting routine for the JSC CDC 6600 computer.

The Kentucky Watershed Model evolved from the Stanford Watershed Model written in BALGOL computer language for the Burroughs computer at Stanford Research Institute. Because BALGOL is not used extensively, FORTRAN translations of the model were published.

Remote Sensing of Virus-Stressed Wheat

The EOD and Texas A&M University conducted a field measurement program to assess the potential for remote sensing of stress in wheat caused by the wheat streak mosaic virus. The experimental wheat plots were located at the Texas A&M Agricultural Experimental Station. The EOD and the Texas A&M station showed that near-IR remote sensing can detect virus stress in the early stages.

The objectives of the work were to determine whether visible/near-IR remote sensing can detect wheat virus stress before observers in the field can see the symptoms and to correlate the spectral characteristics of the virus stress with time during the wheat season. The results showed that virus stress could be detected in the presence of healthy wheat.

Because environmental and disease stresses affect crop yield, this work may lead to a better understanding of how remote sensing can be used to predict yield.

Flight Program Support

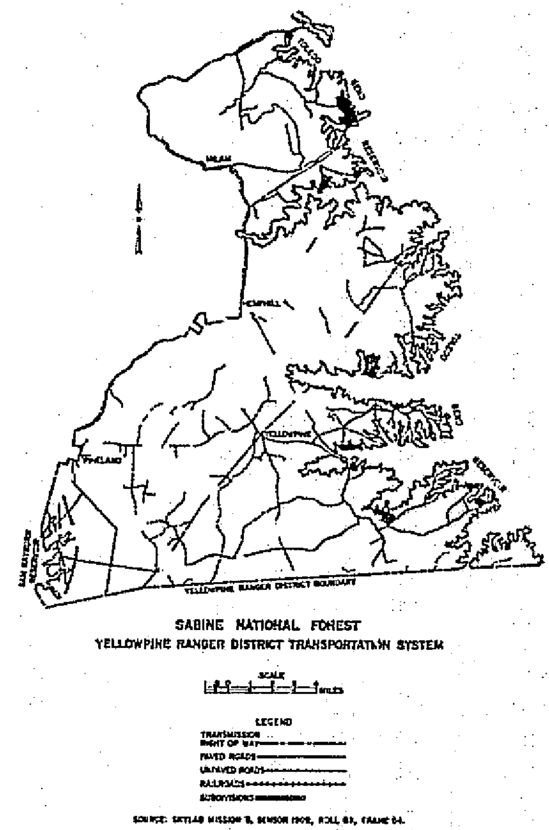
Skylab Investigations

The three manned Skylab missions were completed during 1973 and the first 2 montns of 1974. The EOD Principal Investigations Management Office (PIMO) was responsible for the scientific support to the Skylab mission operations and for the management of 141 principal investigators who will analyze the data acquired by the EREP on the three manned missions.

In addition to negotiating contracts and agreements with all these investigators, the EOD PIMO personnel performed the Skylab mission functions outlined in the following paragraphs.

Skylab 4 Visual Observations Project

A visual observations project conducted by the Skylab 4 crew was established as part of the Skylab experimental program. The purpose of this project was to determine the contributions that man can make by observing and documenting selected dynamic and static features of the Earth from the vantage point of near-Earth orbit. Ground-based operations were conducted by two groups specializing in mission operations, the Visual Observations Science Team (composed of scientists from 16 disciplines) and the Visual Observations Project Team (composed of members from the Science and Applications Directorate, Flight Operations Directorate, and Flight Crew Operations Directorate at JSC).



Transportation system of the Sabine National Forest prepared from a Skylab 3 S-190B image. Researchers find that the low-cost maps made from satellite images are surprisingly accurate.

The Visual Observations Book and a general map package were prepared to provide Skylab astronauts in-depth background for the phenomena and features which were identified as worthy of scientific study. In addition to these preflight-selected sites, the crewmen were free (within a limited timeline) to observe significant features. Because of the crewmen's initiative, many unanticipated findings were made, such as the extent of icebergs in the South Atlantic, the visibility of the Falkland Current, the ability to study ocean surface phenomena in sunglint, and the ability to monitor snow-melting patterns.

Binoculars and cameras were the primary visual observations instruments used on Skylab 4. Available camera and lens combinations included wide, medium, and narrow fields of view. The Skylab 4 crew completed more than 850 observations and acquired 2,000 handheld photographs of features representing 83 different categories of terrain, ocean, and atmosphere phenomena. The Visual Observations Science Team will use these data to determine the utility of space data in scientific investigations and the role of man in such studies. Results so far indicate that the crew can accomplish discrete and important scientific observations on future Earth orbital missions.

Skylab Concentrated Atmospheric Radiation Project

The Skylab Concentrated Atmospheric Radiation Project (SCARP) is a Skylab experiment involving the National Oceanic and Atmospheric Administration (NOAA), ERIM, the Earth Resources Laboratory at the Mississippi Test Facility, the Department of Earth Resources at Colorado State University, and EOD. The objective of this experiment was to test several radiation transfer models against observed radiation transfer for various atmospheric conditions. This test requires observation of the state of the atmosphere, radiation properties of the surface, and intensity and flux of solar and terrestrial radiation.

Data were acquired for three periods during the observation phase of the project. During the first period, warm, moist conditions prevailed over the rangeland west of Houston and offshore in the Gulf of Mexico. Skylab observation was not acquired for this case, but airborne data will be usable as a partial replacement. During the other two periods, hot, dry, polluted and unpolluted atmospheric conditions prevailed around Phoenix and warm, dry, unpolluted atmospheric conditions over White Sands Missile Base. Data collection throughout the series of Skylab missions went very well.

Simultaneous Skylab S-191/192 data and helicopter S-191H data were acquired under clear skies three times over White Sands Missile Base, twice over Padre Island, twice over Sabine National Forest, and once over Rosenberg, Texas.

More than 10 models of atmospheric scattering have been acquired and from these several will be selected for testing against observation. Three models of thermal radiation transfer have been acquired for similar tests. Analysis of the surface and airborne data is in progress. Analysis of the Skylab data is awaiting delivery of calibrated data.

Comprehensive Study of Atmospheric Attenuation Effects

The objectives of this comprehensive study were threefold: to collect data simultaneously from the S-191 spectrometer aboard Skylab, the S-191 field spectrometer aboard a NASA helicopter, and ground truth over selected sites; to test the applicability and accuracy of various techniques for remotely sensing atmospheric effects; and to develop techniques that would permit a future earth resources satellite system to gather much of its own information on atmospheric effects.

The following approaches were investigated:

- mathematical inversion of thermal radiances in carbon dioxide and water vapor bands to give vertical profiles from which corrections for the thermal window can be calculated;
- measurement of "black" targets (possible candidates are vegetation at 0.4 μm and water beyond 0.75 μm) to measure scattered solar radiation directly;
- measurements of the same target from two angles to give an estimate of the path transmission and path radiance;
- measurement of aerosol scattering effects from spectral scan across near-IR carbon dioxide band with water target; and
- evaluation of natural cloud shadows for estimating ground reflectivity.

EREP Experiments — Severe Storm Environments

The objective of one of the EREP experiments was to study severe storm environments and the role that they have on severe storm growth. Although most of the necessary conditions producing severe storms over an area are known, the conditions producing smaller scale phenomena are less well known, making severe storm watch and warning areas much too large (e.g., 1,766 by 7,062 km). In this experiment, EREP data were used to investigate storm genesis relative to land use in the Oklahoma area, storm genesis due to small-scale atmospheric moisture gradients, cloud top temperature versus altitude, and storm energy budgets relative to environmental conditions. So far, EREP passes have been collected in these areas:

Area	Track	Condition	Date
Oklahoma	48	Preincipient storm	June 11, 1973
Beaumont, Texas	34	Storm (15-km tops)	August 8, 1973
South America	19	Storms	November 30, 1973
Brazil	34	Storms	December 1, 1973
Caribbean	48	Cloud street convergence	December 7, 1973
Indonesia	70	Storms	December 8, 1973
Indonesia	—	Storms	December 15, 1973

Only a small portion of the data was received; it was confined to the June 11 and August 8, 1973, cases. The ground-truth data for the June 11, 1973, case obtained from the National Severe Storms Laboratory mesosynoptic and subsynoptic networks were analyzed and will be published soon. The June 11 case was studied for atmospheric and surface triggers since a squall line passed through the networks a few hours after the EREP pass. The S-192 data were analyzed in terms of a precipitable water map below the spacecraft, and a surface heating versus land use model is being developed. The storm tops on the December 15 case were contoured, and the S-192 data will be used to make thermal maps of the cloud top temperatures.

EREP Science Support

Most EREP investigations depended on weather, ground conditions, and readiness of the ground truth collection team. The EOD EREP Science Support Team (SST) was responsible for integrating these factors into the EREP ground track selection process, sensor operating timelines, film selections, sensor operating modes, and postpass evaluation of the data acquisitions. The SST maintained telephone communications with the investigators near the test sites when required and with the investigators made the judgments necessary to decide the adequacy of the conditions under which the EREP data would be gathered. The SST also maintained surveillance of required aircraft support, postpass verification of weather and site conditions, and support of the Public Affairs Office to the Flight Operations Team. All the investigative areas of the EREP program were represented in the SST.

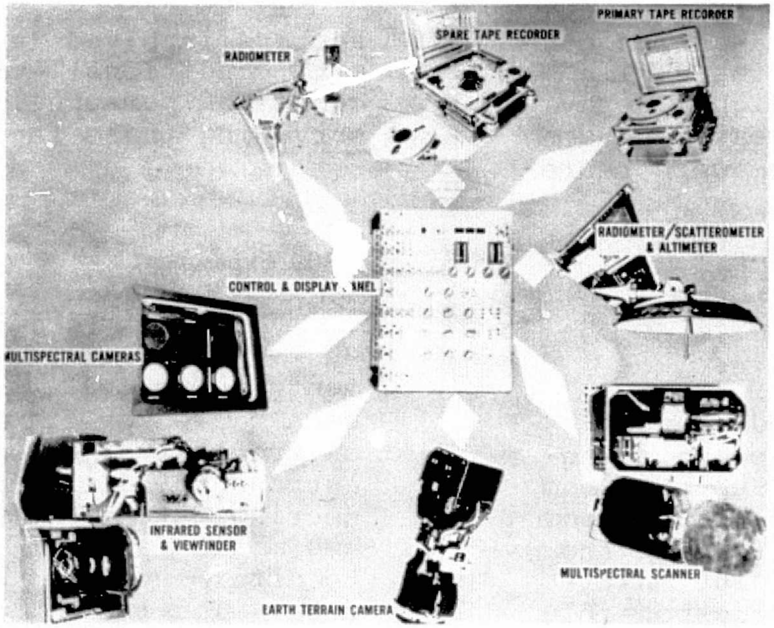
Multidiscipline Scientist

The EOD provided individuals designated as multidiscipline scientists to the EREP Staff Support Room (SSR). The SSR personnel comprised the EREP Flight Control Team in the Mission Control Center. The multidiscipline scientist was responsible for assimilating the varied inputs from the SST into a unified input to be used in establishing the Skylab and EREP flight plans, EREP groundtrack selections and timelines, realtime monitoring of the EREP data acquisitions and answering EREP questions asked by the crew, and postpass science evaluations. These tasks required constant effort because the factors involved (e.g., weather and site conditions) were dynamic and because SSR personnel were constantly surveying these factors.

M-509 Experiment

The purpose of the M-509 Experiment was to collect engineering data as a basis for future design of strap-on free-flight maneuvering units for astronauts. To complement the engineering data transmitted to the ground, two motion picture cameras were used to determine attitude and to position data. The task assigned to EOD personnel was to accomplish film mensuration and to correct the measurements for geometric distortions. Procedures to accomplish the task have been developed, and the Skylab 2 data are being processed. In addition, calibration film was collected and calibrated geometrically to provide focal length, principal point coordinates, and distortion coefficients.

NASA S-74-1071



The sensors and the control panel comprise the Skylab EREP.

Sensor Performance Evaluation of EREP

The EREP, consisting of four optical and two microwave instruments, was launched aboard Skylab 1 on May 14, 1973, and operated during each of the manned missions (Skylabs 2, 3, and 4). A considerable amount of test and calibration data was taken with the system during the development and checkout phases of the program. However, because of operational constraints on some of the sensors when operated in the ambient ground environment rather than in the space environment, some aspects of the performance could not be properly assessed before launch. In addition, the prolonged time during which the system was in space led to some changes in the performance characteristics. Because of these circumstances, NASA initiated a program to assess the performance characteristics of each sensor based on the actual flight data brought back from each mission.

Performance Evaluation Methods

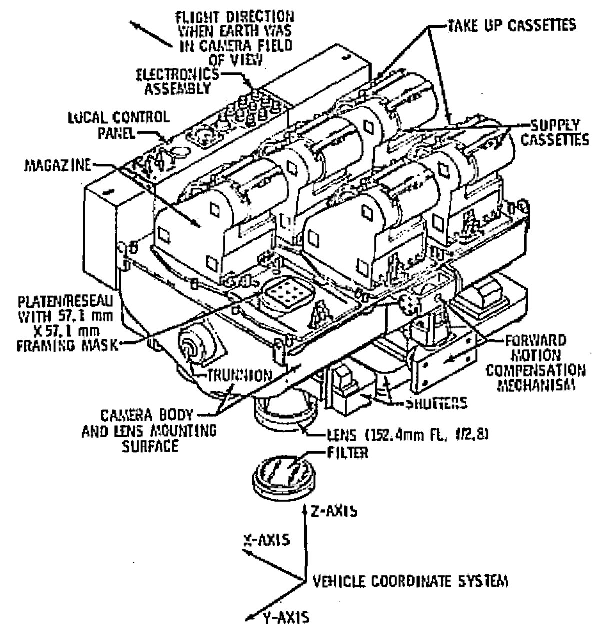
Natural targets were selected for evaluating specific aspects of sensor performance. To use the EREP sensors as efficiently as possible, every effort was made to select test sites already specified by the approved EREP scientific investigations. About 90 percent of the sensor test sites coincided with scientific investigation test sites, and duplicates of data obtained for the principal investigators were used to evaluate the sensor performance.

The sensors were evaluated in three general areas: radiometric performance (e.g., sensitivity to optical or microwave radiation and noise level), geometric performance (e.g., image distortion and resolution), and functional performance (e.g., shutter speed and gimbaling).

The radiometric response of the optical instruments in the visible/reflective IR region has been calculated from data taken of selected target areas in the southwest continental United States and from the lunar calibration data taken on each mission. Required data were taken at the ground sites at the time of EREP overpass to define solar radiation, atmospheric scattering, and ground reflectivity. The resulting calculated values for radiance at the spacecraft and the values of lunar radiance from the literature were then compared with the

NASA-S-74-4078

S190A
CAMERA



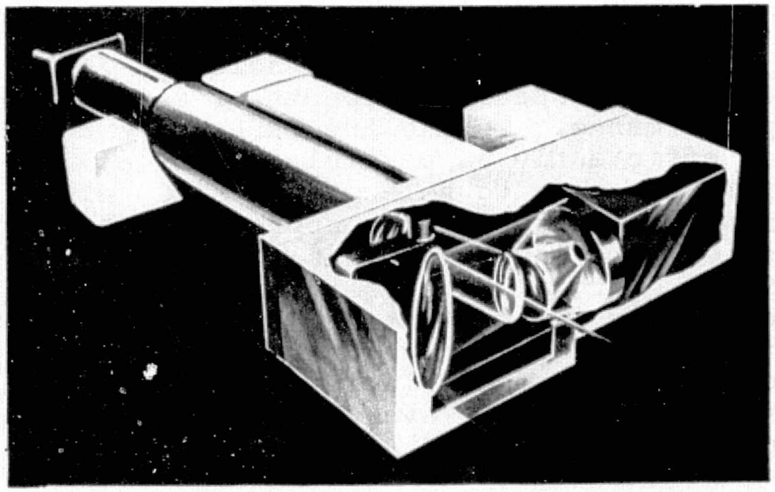
corresponding data provided by S-190A cameras, the S-191 spectrometer, and the S-192 MSS in the visible/reflective IR region. Calibration of the S-191 spectrometer in the thermal IR region was performed with data from deep space and from selected target lakes within the United States. The S-192 MSS was calibrated with data from the lakes only. Ground data taken at the time of overpass were used to correct atmospheric absorptions, and the calculated incident radiation at the spacecraft was compared with the EREP data. The variation of response within the S-192 scan line was assessed by determining the variation of radiance in an artificial scan line constructed by along-path averaging of uniform Earth scenes.

The geometric distortion of the imagery data from the S-190A and the S-192 instruments and band-to-band registration of the S-190A imagery were assessed by point-to-point measurements of images of accurately mapped cultural scenes. The spatial resolution of the six S-190A camera stations was assessed by visual edge matching and edge slope analysis techniques on agricultural scenes. The frequency response of the S-192 MSS and the optical off-axis rejection of both the S-191 spectrometer and the S-192 MSS were determined using the edge of the lunar disk.

Measurement of the noise in S-192 data was accomplished by determining the standard deviation from the mean value of a statistically large sample of data from a uniform scene, such as a cloud-free calm ocean.

The stability, precision, and antenna pattern of the S-193 transmitter/receiver operating in the active scatterometer mode were determined using an array of five spaced receivers located at a site beneath the Skylab ground track. The energy levels incident from the S-193 active transmission, as measured with this array, were used to calculate the antenna gain and to determine the antenna pattern and the pointing offset. The antenna pattern and pointing offset for the S-194 radiometer were determined from data of a relatively linear land/sea interface.

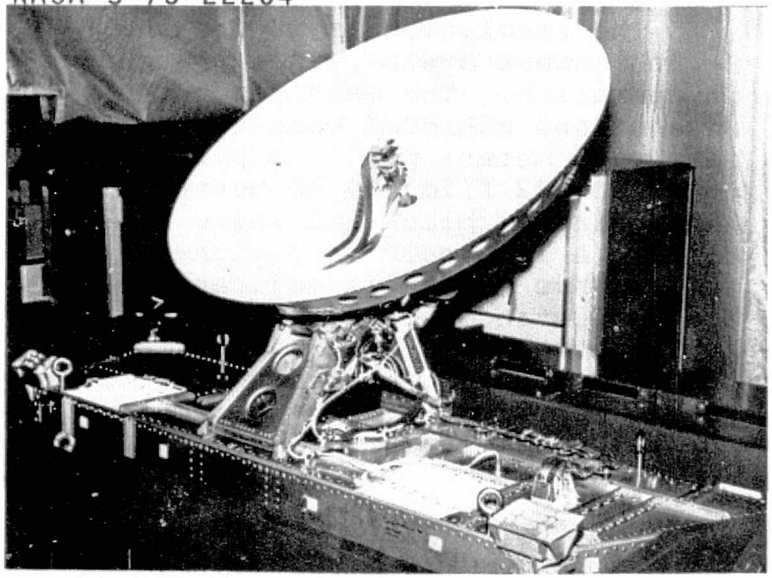
NASA S-74-22378



Sketch of the S-191 spectrometer.

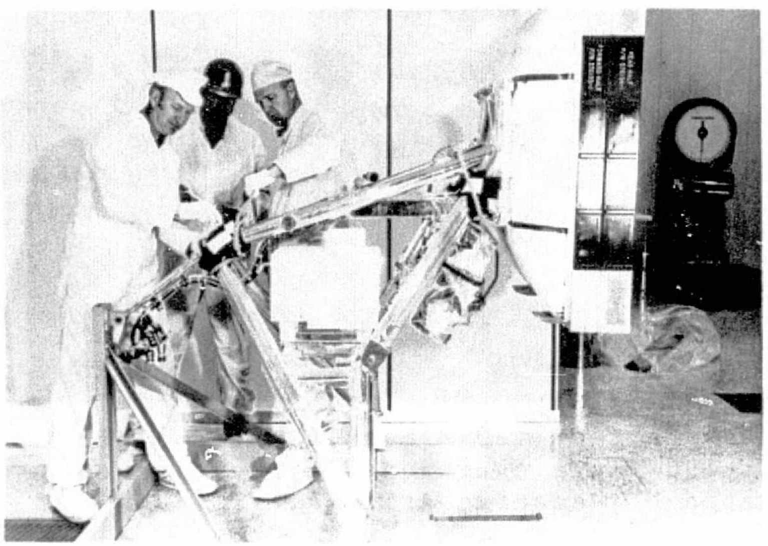
The pulse-shape characteristics and the altitude precision and accuracy of the S-193 band operating in the altimeter mode were determined. With the 29-meter-diameter steerable antenna at the NASA site on Wallops Island, the pulse-shape characteristics transmitted by the S-193 were measured in several altimeter submodes. The accuracy and precision of the altimeter were determined from data taken over accurately mapped regions of the geoid. In particular, data taken over the Atlantic Ocean along the United States coast were compared with the existing geoid data for that area.

NASA S-73-22264



The S-193 K-band microwave system antenna and panel assembly.

NASA S-71-3547-X



The S-194 L-band microwave radiometer.

Calibration of the S-193 (K-band) and S-194 (L-band) radiometers was based on the data from selected ocean targets having supporting ground-truth data of aircraft microwave radiometer coverage. These data, together with data of deep space, were used to define the dynamic range, noise level, and stability of the two radiometers.

Results of Performance Evaluation

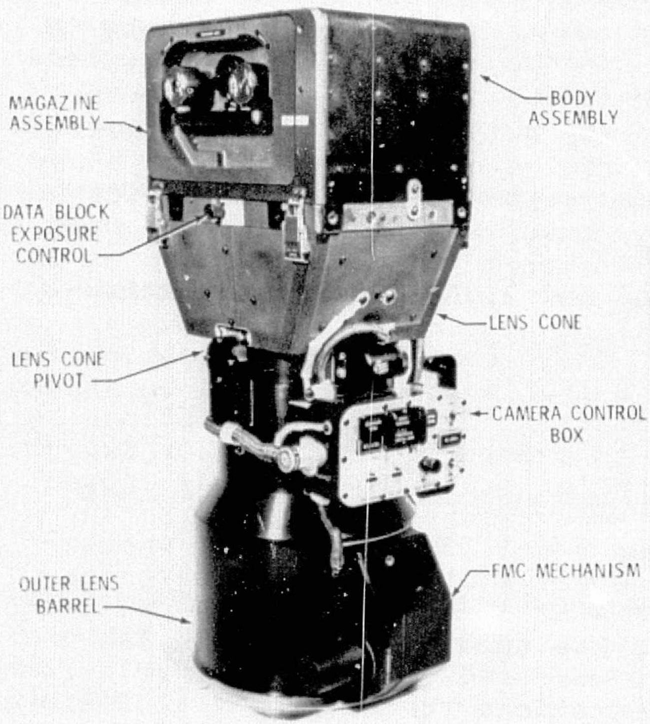
The frame verification for the S-190A photography for both missions consisted of tying in the frame numbers assigned to the photography to the computer-generated SKYBET ephemeris data.

The S-190A adjustments converged with root-mean-square photograph residual errors of 8.2 and 8.5 micrometers, resulting in differences from SKYBET ephemeris photocoordinates of 6,808 and 7,968 meters, respectively.

Image correlation evaluation for the S-190A was accomplished on second-generation film with all stations being fit to camera station 5. For Skylab 2 the color stations (3 and 4) showed root-mean-square residuals ranging between 9 and 17 micrometers, whereas the other station residuals ranged from 4 to 8 micrometers. A new procedure was applied when the Skylab 3 data were reduced, and residuals from all stations ranged from 4 to 8 micrometers. The new procedure should also reduce the residuals for the Skylab 3 color stations.

Timing correlation was required to generate the SKYBET ephemeris for the S-190B photography because no direct correlation existed between the exposure time and the spacecraft time. The clock in the camera was unreliable; therefore, a procedure was developed to accomplish the timing correlation within ±1.0 second of Greenwich mean time, and charts showing mission coverage with the S-190 cameras were prepared.

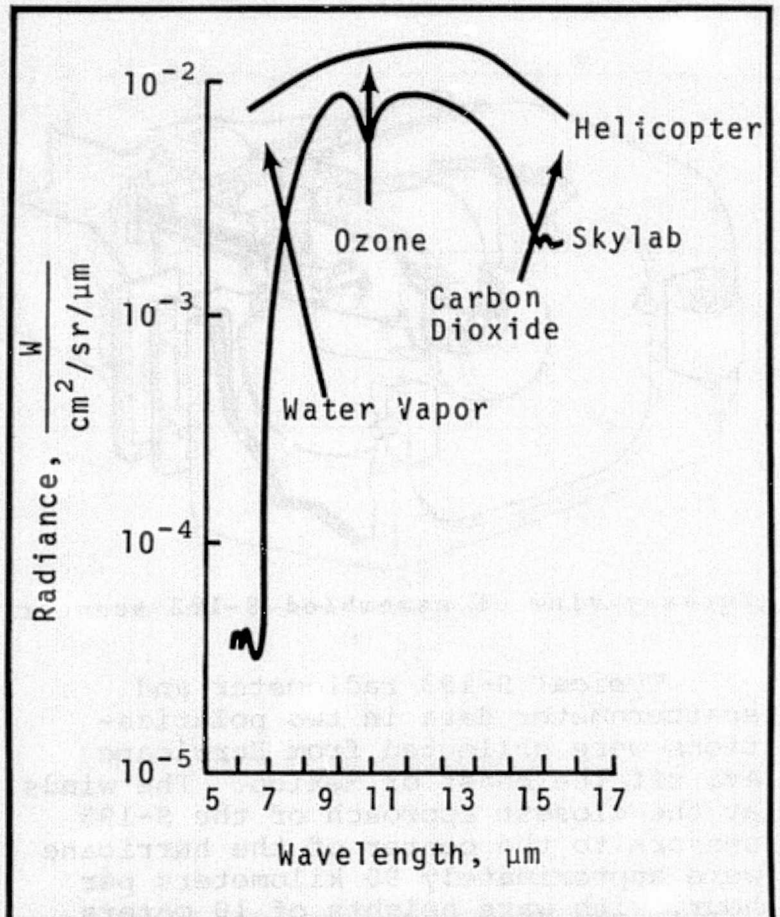
NASA S-74-3155



The S-190B Earth terrain camera.

The resolution limit for the S-190B camera system was approached in operation. The measured ground resolutions achieved were approximately 15 meters per line pair for color SO-242 film and 10 meters per line pair for black-and-white EK-3414 film. (A line pair is a high-reflectance rectangle adjacent to a low-reflectance rectangle, both having equal widths. See Military Standard 150A.) Performance of the camera was within expected limits for all parameters.

Enlargement (20 × magnification) of S-190 image over Sun City development area of Phoenix, Arizona.



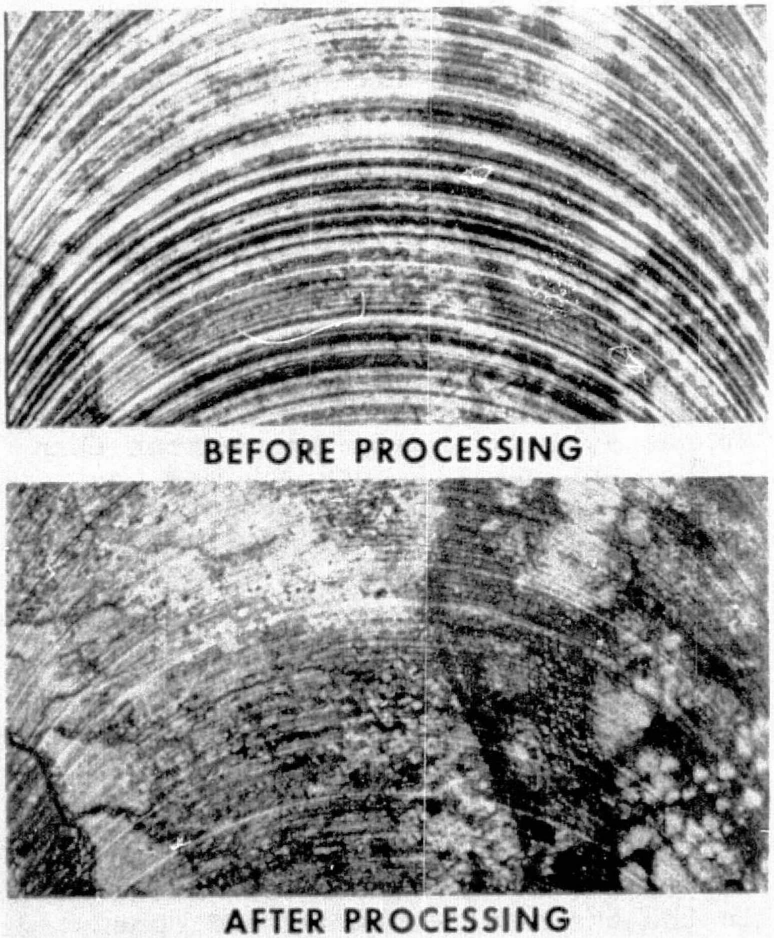
Typical S-191 spectral data obtained when the Skylab spacecraft was over White Sands, New Mexico. Only the thermal region of the spectrum is shown.

Spectral data were obtained with the S-191 spectrometer. The spectrum was also measured by a similar spectrometer mounted in a helicopter. The difference between the two spectra is produced by atmospheric absorption of carbon dioxide, ozone, and water vapor. The difference observed illustrates the use of S-191 data to determine atmospheric effects on data recorded from above the atmosphere. The spectrometer performed normally throughout the mission, and all its performance characteristics were within expected tolerances.

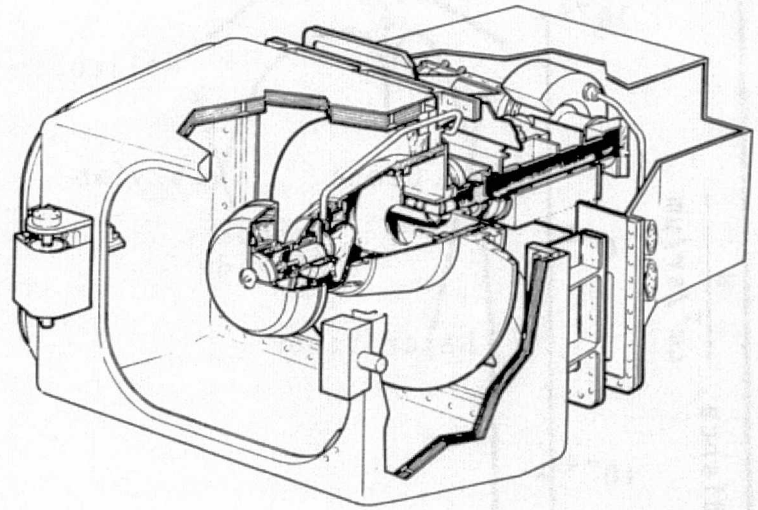
An evaluation of the suitability of S-192 data for classification and mapping of five crop classes in Holt County, Nebraska, was performed. Using raw (unprocessed) data from the four S-192 bands selected by the computer (bands 9, 11, 12, and 13), better than 90 percent overall accuracy was obtained, compared to 64 percent overall accuracy obtained using ERTS data from its four bands.

In several channels, high-frequency noise at discrete frequencies was observed. This noise produced herringbone patterns in the imagery. Because the noise occurred at sharp, well-defined frequencies, it was possible to remove the noise by computer analysis (mathematical filters). The low-frequency noise was most noticeable in the thermal IR channel and consisted of low-frequency noise that produced heavy banding (random noise) in the image. This imagery was not useful for photointerpretation because the banding obscured surface features. Consequently, mathematical filters and every-scan calibration data were used to minimize or remove the noise.

NASA S-74-3154



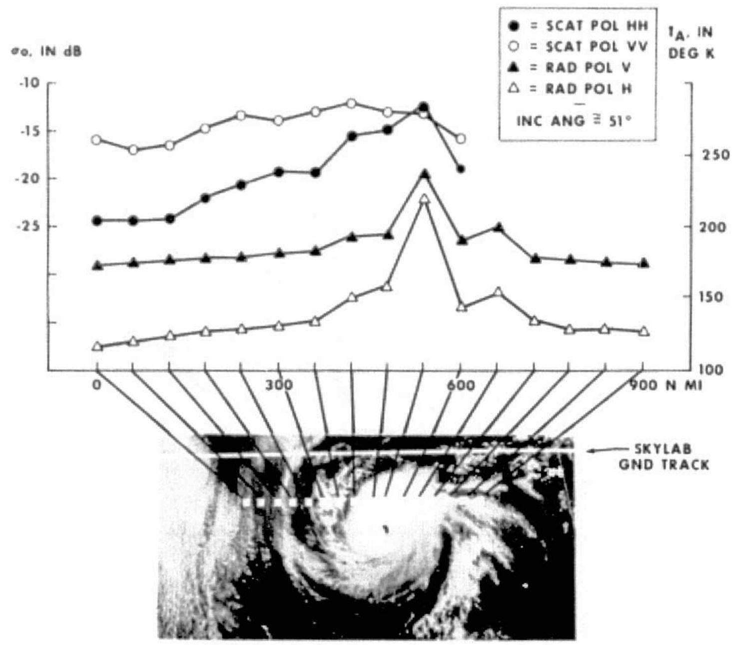
An example of S-192 thermal IR imagery. Low-frequency noise was present before data processing; after processing, the low-frequency noise had been filtered out.



Cutaway view of assembled S-192 scanner.

Typical S-193 radiometer and scatterometer data in two polarizations were collected from Hurricane Ava off the coast of Mexico. The winds at the closest approach of the S-193 sensors to the center of the hurricane were approximately 90 kilometers per hour, with wave heights of 10 meters. The changes of signal shown by both sensors as the spacecraft passed by the storm were caused primarily by changes in wave height, although rain clouds produced some effect. As wave height increased near the storm center, both the scattered signal intensity and the microwave brightness temperature increased by approximately the amounts expected. These data are being analyzed to determine the feasibility for mapping the waves of such storms.

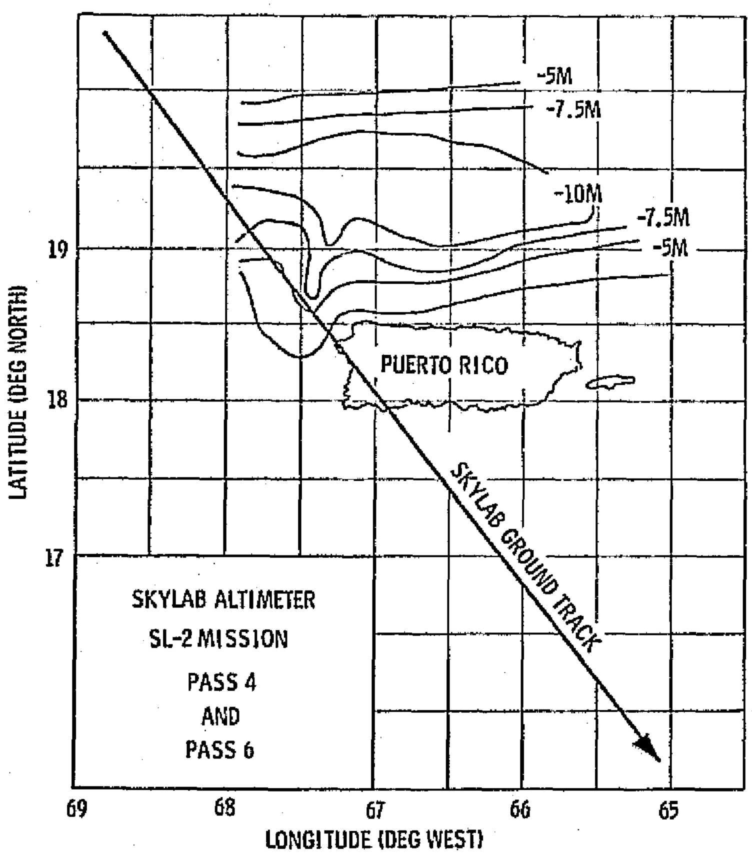
NASA-S-74-5120



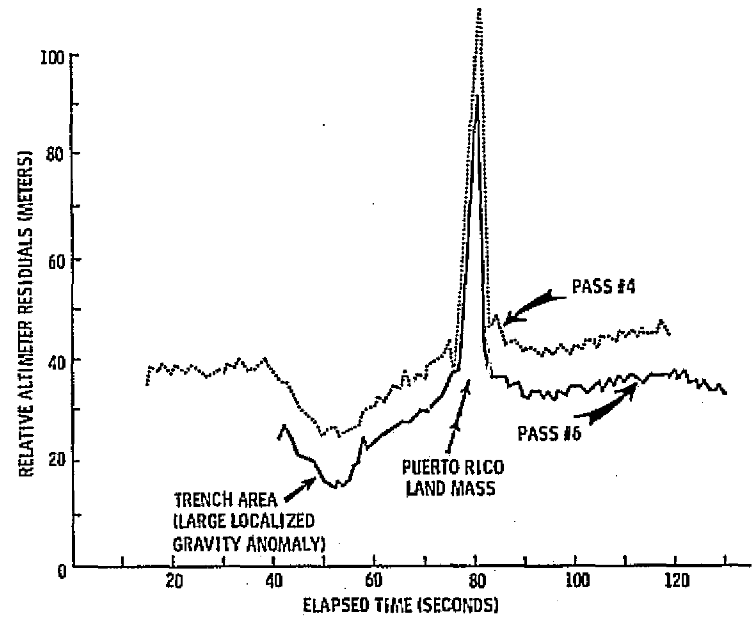
Radiometer/scatterometer data collected from Hurricane Ava.

Analysis of radiometer performance indicated that emitted radiant power was measured with an accuracy of at least 4 percent (corresponding to a brightness temperature accuracy of ±7° K) and with a precision of at least 2 percent (±1.5° K) for typical ground scenes. The S-193 scatterometer performance showed that the reflected signal was measured within an accuracy of 4 percent for typical ground scenes, with a precision of at least 2 percent. The scatterometer was able to measure reflected signals that varied in amplitude by a factor of greater than 10,000 to 1 with the accuracy and precision given above.

The altimeter was operated along a ground track crossing the Puerto Rican Trench, the site of a major anomaly in the Earth's gravitational field. Because of the anomaly, the surface of the ocean deviates considerably from mean sea level in this region. The decrease of actual sea level below mean sea level is clearly shown. The maximum depression measured in the flight experiment corresponds to approximately 20 meters. The altimeter measurements agree well with independent measurements of the actual sea level in this region. The altimeter performance was evaluated from measurements of sea surface in regions similar to the Puerto Rican Trench. The accuracy of the altitude measurement was ±7 meters with a precision of ±1 meter.



Skylab 2 ground track for altimeter data.

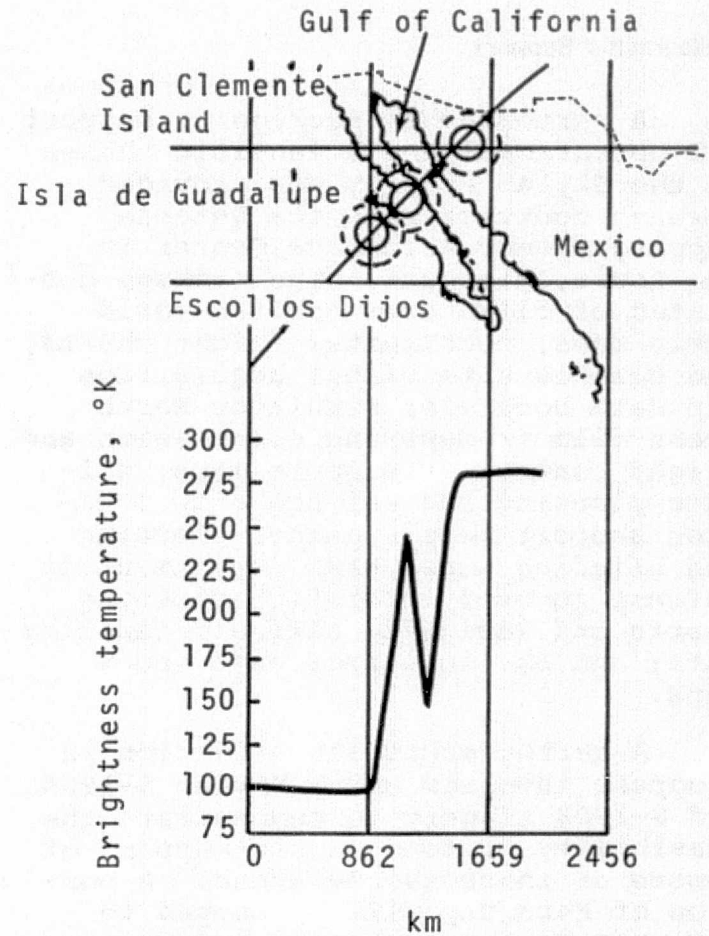


Altimeter range measurements.

Data were produced by the S-194 sensor as the spacecraft moved from Baja, California, across the Gulf of California and on into Mexico. The temperature curve can be calculated from knowledge of the land and sea microwave temperatures, the geography, the line of flight, and the antenna pattern and pointing direction. The land and sea microwave temperatures and the geography and flight line were accurately known. These data were used with preflight antenna pattern data and spacecraft pointing data to calculate a response curve along the line of flight. The experimental and calculated curves agreed closely, indicating that the antenna pattern and pointing direction were accurate.

Conclusion

The results of these performance assessment tasks have been brought together in a series of sensor performance reports that provide for all future EREP data users the detailed performance parameters of the sensors. The program has also provided an insight for future remote sensing programs into the problems involved, the types of parameters amenable to inflight assessment, and the types of targets required. The program has also provided some instances of the errors of assumption that can be introduced into spaceborne remote sensing data if actual flight data are not used to reassess prelaunch performance.

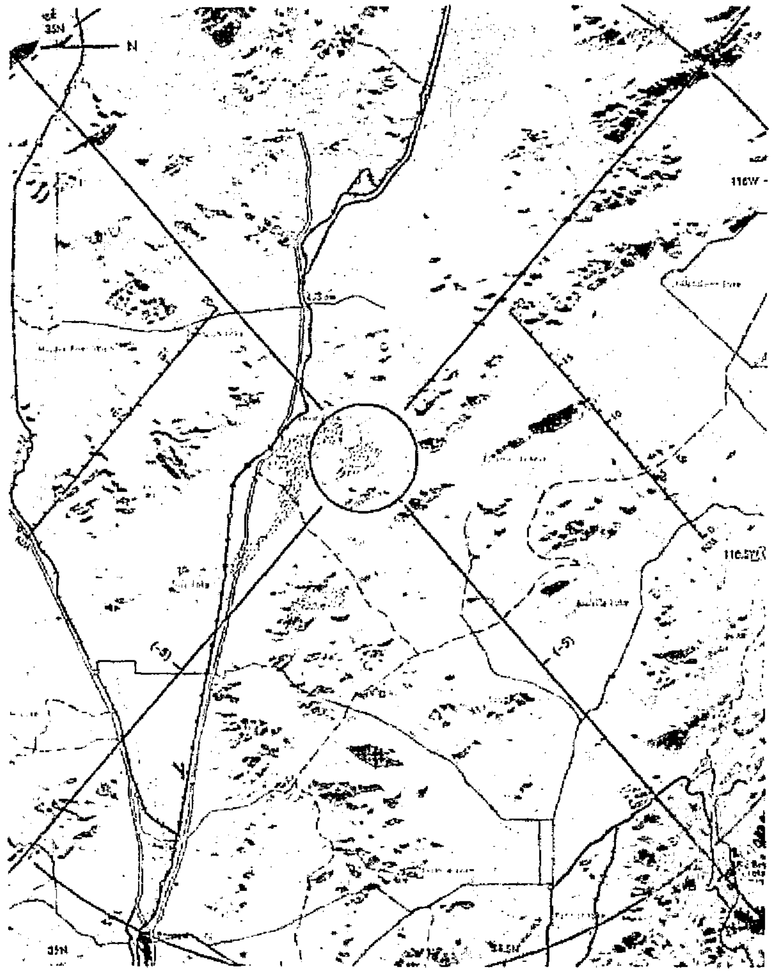


Example of data produced by the S-194 sensor. The antenna "footprint" is shown as circles on the flightpath. The solid circle represents the half-power point on the antenna pattern and corresponds to a circular area 124 kilometers in diameter. The first null in the antenna pattern (which measured 285 km in diameter) is shown by the dashed circle.

Cartographic Support

A cartographic package to support all operational and scientific phases of the Skylab Program was provided through contract with the Defense Mapping Agency Aerospace Center in St. Louis, Missouri. The package consisted of flightcrew orbital world strip maps, continental flight charts, and science site visual acquisition map data booklets; simulator Earth scene film transparencies; mission and flight controller support maps; science planning and science site location support maps; weather plotting and briefing maps; NASA/Department of Defense recovery operation planning charts and worldwide airfield facility data; and Skylab sensor data index maps.

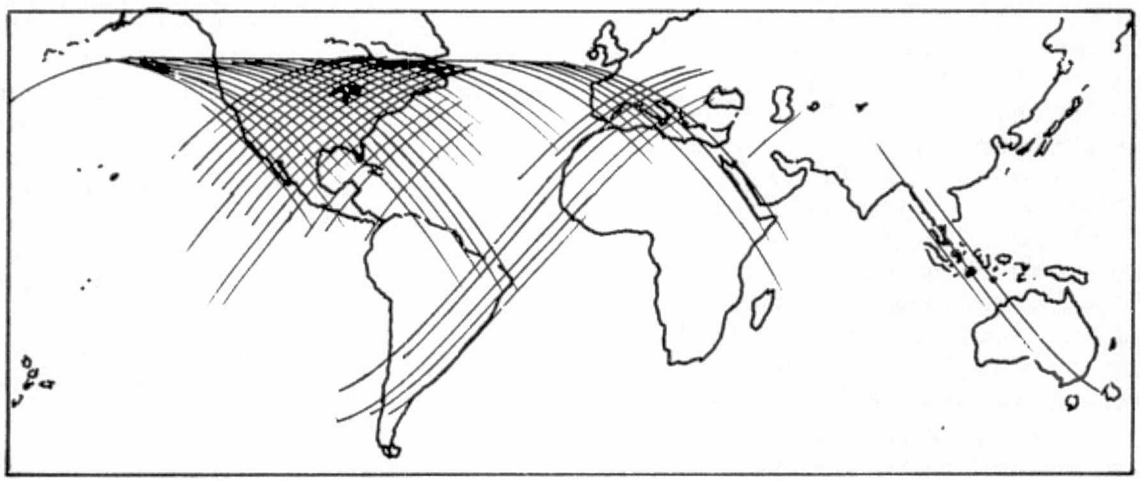
A cartographic investigation in progress involves using Skylab S-190A and S-190B imagery to demonstrate the feasibility of topographic mapping of remote or inaccessible areas. A portion of Paraguay will be mapped to demonstrate the technique and at the same time to produce maps of a previously unmapped area.



Topographic map showing Skylab crew what to expect to see through the S-191 viewfinder/tracker system at maximum zoom.

EREP Mission Data-Take Accomplishments

The planning and implementation of the EREP data passes on Skylab were very successful. The total of 110 passes accomplished during the mission exceeded the pre-Skylab 2 expectations of 65 passes. The EREP passes consisted of 89 Z-local vertical, 10 solar inertial, 6 lunar calibration, and 5 Earth limb data passes. The Z-local vertical and solar inertial passes gathered data over the 48 conterminous states of the United States, over 41 countries, and over various key sections of the Atlantic and Pacific Oceans. The lunar calibrations, successful in spacing and implementation, were designed to determine long-term sensor degradation by allowing the sensors to view a relatively stable scene free from interference by the Earth's atmosphere. The Earth limb looking passes, also very successful, were designed to acquire data on aerosols in the Earth's atmosphere.



Skylab data-take passes. The EREP passes obtained data on the United States, 41 foreign countries, and key areas of the Atlantic and Pacific Oceans.

Approximately 5,800 frame sets of S-190A multispectral photography, 5,600 frames of S-190B photography, 402 meters of data acquisition camera 16-millimeter film, and 69,494 meters of magnetic tape were used. These data will be analyzed by 137 principal investigators (99 domestic and 38 foreign), their coinvestigators, and the U.S. Departments of Interior, Agriculture, Commerce, and Defense.

Notable among the numerous significant achievements of the Skylab EREP missior were the following: The EREP collected data on June 6, 1973, on Hurricane Ava southwest of Acapulco, Mexico. An Air Force dropsonde in the eye of the hurricane measured a near-record low pressure of 91,500 newtons per square meter (915 millibars). A unique achievement occurred during the Skylab 2 mission with the near-concurrent acquisition of EREP, ERTS, high- and low-altitude aircraft, and ground-truth data over the Wabash River Basin, Indiana. This multistage sampling will allow a comparison of information derived from differing but complementary data sources and may allow an accurate determination of the transmissivity of the atmosphere over a wide wavelength range. During Skylabs 3 and 4, several solar inertial (oblique) data passes were accomplished over Paraguay with the S-190B camera. Coupled with the normal Z-local vertical data passes, these oblique passes may allow the convergent geometry to be established to perform topographic mapping activities within Paraguay. Paraguay has recently mapped areas that should allow for EREP application.

The goal of EREP pass planning was to optimize the type and amount of sensor data to meet the requirements of the investigators. These planning activities consisted of pass selection, execution, and pass evaluation. Selection of the ground track along which the EREP data were collected was based primarily on investigator requirements and weather.

The data collection requirements were defined for each investigation in the Mission Requirements Document. This document specifies for each investigation or test site the EREP sensor complement required, the percent of cloud cover acceptable over the site, the number of data takes required, and the seasonal needs and unique conditions (such as snow cover and ground moisture) that are to be met for each site. These parameters were considered for each potential EREP ground track; and in conjunction with the weather forecast, the best ground track was selected and the data pass implemented.

The two following tables indicate the EREP program structure disciplines, the completion status by both approved tasks, and the number of investigators who will perform analyses within the EREP program disciplines.

EREP COMPLETION STATUS

100 AGRICULTURE/RANGE/FORESTRY

- Crop Inventory
- Insect Infestation
- Soil Type
- Soil Moisture
- Range Inventory
- Forest Inventory
- Forest Insect Damage

200 GEOLOGICAL APPLICATIONS

- Mapping
- Metals Exploration
- Hydrocarbon Exploration
- Rock Types
- Volcanos
- Earth Movements

300 CONTINENTAL WATER RESOURCES STUDIES

- Ground Water
- Snow Mapping
- Drainage Basins
- Water Quality

400 OCEAN INVESTIGATIONS

- Sea State
- Sea/Lake Ice
- Temperature
- Currents
- Geodesy
- Living Marine Resources

500 ATMOSPHERIC INVESTIGATIONS

- Storms, Fronts, and Clouds
- Radiant Energy Balance
- Air Quality
- Atmos[illegible]ric Effects

600 COASTAL ZONES, SHOALS, AND BAYS

- Circulation and Pollution in Bays
- Underwater Topography and Sedimentation
- Bathymetry
- Coastal Circulation
- Wetlands Ecology

700 REMOTE SENSING TECHNIQUES DEVELOPMENT

- Pattern Recognition
- Microwave Signatures
- Data Processing
- Sensor Performance

800 REGIONAL PLANNING AND DEVELOPMENT

- Land Use C[illegible]fication Techniqu[illegible]
- Environment[illegible] I[illegible]acts Special [illegible]pics
- State and Foreign Resources
- Urban Applications
- Coastal/Plains Applications
- Mountain/Desert Applications

900 CARTOGRAPHY

- Photomapping
- Map Revision
- Map Accuracy
- Thematic Mapping

000 USER AGENCY STUDIES

EREP PROGRAM STRUCTURE

	Investigative area	Number of test sites	Number of test sites for which data were acquired	Number of principal investigators	Number of principal investigators for which data were acquired
100	Agriculture/range/forestry	33	31	17	17
200	Geological applications	56	46	35	34
300	Continental water resources studies	27	23	16	15
400	Ocean investigations	38	31	18	16
500	Atmospheric investigations	58	48	13	13
600	Coastal zones, shoals, and bays	18	17	11	11
700	Remote sensing techniques development	11	11	6	6
800	Regional planning and development	94	82	26	26
900	Cartography	40	36	9	9
000	User agency studies	89	84	–	–
	Totals	464	409	151	147

Advanced Studies and Planning

Participation on EOS Panels

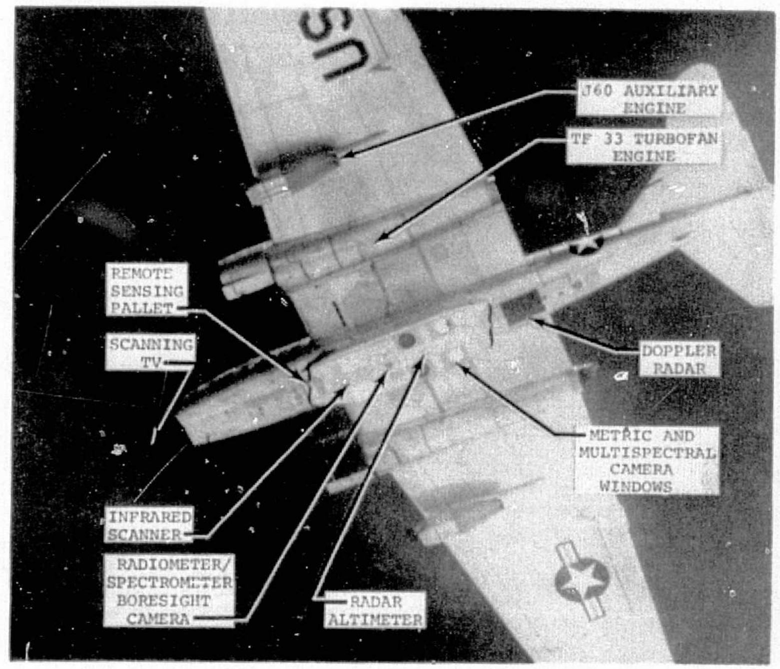
Personnel from the EOD participated in the Earth Observatory Satellite Payload Discussion Group meeting held in August at the GSFC. The participants, all from earth resources disciplines with experience in ERTS-1 data analysis, verified the sensor payload and mission parameters for the first Earth Observatory Satellite (EOS-A).

The researchers also established instrument characteristics and the application of particular measurements and identified tasks possible with EOS-A data but not possible with current ERTS-1 data. The proposed EOS-A payload will have better spatial resolutions and spectral coverage than ERTS-1 sensors.

Aircraft Underflights Supporting EREP

Personnel of the EOD helped to coordinate and determine the status of NASA remote sensor-equipped aircraft support for domestic EREP investigators. Aircraft flight planning was coordinated with the EREP pass selection activities to insure the best use of the aircraft to meet the investigator's needs.

The aircraft completed 75 percent of the required flights originating from Ellington Air Force Base, Houston, Texas; Ames Research Center, California; the NOAA; ERIM; and Colorado State University. The following areas were investigated: agriculture/range/forestry; geological applications; continental water resources; oceans; atmospheric regions; coastal zones, shoals, and bays; remote sensing technique development and sensor performance; regional planning and development; and cartography.



Remote sensor equipped RB-57F used in underflights to support domestic EREP investigators.

Program Planning

Earth Resources Program Planning Support

As the lead center for earth resources, JSC is required to critically examine various parts of NASA's Earth Resources Program and to provide recommendations to NASA Headquarters on program content of discipline needs. During 1973, discipline experts within EOD were requested to conduct and/or support the evaluation of ERTS and EREP proposals, ERTS results symposium sessions, future satellite payload assessment, and overall program assessments with inputs made to the Earth Resources Program summary. With the relatively frequent occurrence of these activities and their importance to the Earth Resources Program, the Earth Resources Program Office (ERPO) established standing discipline panels in September 1973 to perform the required functions and to advise its manager.

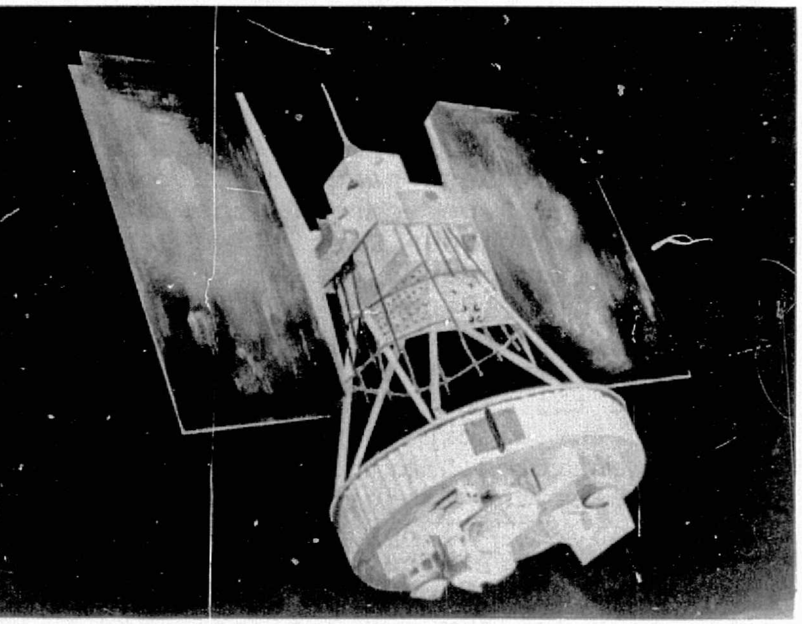
ERTS-1 Applications Investigation

Prior to the ERTS Symposium conducted in December 1973, NASA interviewed 209 domestic (of the more than 300 total) ERTS-1 investigators to identify results achieved to date and, more specifically, to identify the quantitative measure of ERTS capabilities and to estimate the feasibility of applications. The interviews, the first formal activity of the standing discipline panels, were held at the GSFC from October 23 to November 2, 1973. The panels at this symposium were the Interpretative Techniques Discipline Panel, the Agriculture/Range/Forestry Panel, the Land Use Panel, the Marine Resources Panel, the Geology Panel, the Water Resources Panel, and the Environmental Panel. Only three of these panels were represented by EOD personnel: the Interpretative Techniques Discipline Panel, the Agriculture/Range/Forestry Panel, and the Geology Panel.

In November 1973, the ERPO at JSC published the findings and the judgments of the discipline panels in two volumes entitled "Earth Resources Program Results and Projected Applications" and "ERTS-1 Application Investigations." The first volume summarizes the results by subdiscipline area and reviews the projected applications, users, feasibility, and needed work; the second volume consists of investigation evaluations and has a limited distribution.

Symposium on Significant Results Obtained from ERTS-1

The GSFC sponsored a symposium to present significant accomplishments from the ERTS-1 investigation. The event was held in New Carrollton, Maryland, March 5 through 9, 1973. On the last day of the symposium, discipline working groups (Interpretative Techniques Development Working Group, Geology Working Group, Mineral Resources Working Group, Agriculture/Range/Forestry Working Group, Land Use Working Group, and Marine Resources Working Group) summarized and criticized the ERTS-1 results in their respective disciplines. These opinions and recommendations were published as volume III of the procedures of the symposium (GSFC Document X-650-73-153).



The Earth Resources Technology Satellite. The significant accomplishments from ERTS-1 investigations were presented at the Goddard Space Flight Center Symposium.

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Appendix A

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Abbreviations and Acronyms

ASCS	Agricultural Stabilization and Conservation Service
BALGOL	computer language for the Burroughs computer at Stanford Research Institute
CITARS	Crop Identification Technology Assessment for Remote Sensing
CLUSTD	a single-pass clustering program for the nonsupervised classification of multispectral data developed by a visiting scientist from Oakland University in Rochester, Michigan
COD	Center Operations Directorate
EOD	Earth Observations Division
EOS-A	the Earth Observatory Satellite (first)
EREP	Earth Resources Experiment Package
ERIM	Environmental Research Institute of Michigan (located in Ann Arbor, Michigan)
EROS	Earth Resources Observations System
ERPO	Earth Resources Program Office
ERTS-1	the Earth Resources Technology Satellite (first)
FAP	Forestry Applications Project
FCOD	Flight Crew Operations Directorate
FOD	Flight Operations Directorate

FORTRAN	computer language commonly used for scientific applications
FSAS	Field Signature Acquisition System
FSS	Field Spectrometer System
GSFC	Goddard Space Flight Center (located in Greenbelt, Maryland)
HAZADD	Haze Addition
IR	infrared
ISOCLS	an algorithm program for grouping multispectral points into sets or clusters of similar data
JSC	the Lyndon B. Johnson Space Center
LARS	Laboratory for Applications of Remote Sensing (located at Purdue University, Lafayette, Indiana)
LARSYS III	the third version of the LARS system
LSI	Lunar Science Institute (located in Houston, Texas)
M^2S	Michigan multispectral scanner
MSAS	Microwave Signature Acquisition System
MSDS	Multispectral Scanner Data System
MSS	multispectral scanner
NASA	National Aeronautics and Space Administration

NOAA	National Oceanic and Atmospheric Administration
NPID	National Program of Inspection of Dams
PCM	pulse code modulation
PIMO	Principal Investigations Management Office
PREPS	Prediction of the Response of Earth-Pointed Sensors
REDAF	Research Data Facility
ROTAR	Reconstruction of Target Reflectance
S&AD	Science and Applications Directorate
SANG	Sun Angle Program
SCARP	Skylab Concentrated Atmospheric Radiation Project
SHNF	Sam Houston National Forest (located in east Texas)
SKYBET	Skylab Best Estimate of Trajectory
SSR	Staff Support Room
SST	Science Support Team
UPAP	Unit Planning Assistance Process
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey

Appendix B

Earth Observations Technical Publications

Alford, W. C.; Dragg, J. L.; Billingsley, F. C.; Chafanis, G.; Economy, R.; et al.: *Interpretation Techniques Development.* Symposium on Significant Results Obtained From Earth Resources Technology Satellite-4. Vol. III, Discipline Summary Report X-650-73-155, Goddard Space Flight Center (Greenbelt, Maryland), Mar. 5-9, 1973.

Anderson, A. C.: *Development of a Two-Channel Linear Discriminant Function for Detecting and Identifying Surface Water Using ERTS-1 Data.* NASA JSC-08450, Nov. 1973.

Anon.: *Basics of Remote Sensing.* NASA MSC-07777, 1973.

Anon.: *Detection of Prescribed Burn on National Forest.* NASA ERTS-007, 1973.

Anon.: *Determination of the Areal Extent of Wetlands From ERTS-1 Data.* NASA ERTS-006, 1973.

Anon.: *Exploring Earth Resources With Skylab.* NASA JSC-08432, Aug. 1973.

Anon.: *Remote Sensing for Forest Management.* NASA JSC-07908, 1973.

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Bizzell, R. M.; Wade, L. C.; Prior, H. L.; and Spiers, B.: *Results of an Agricultural Analysis of the ERTS-1 MSS Data at the Johnson Space Center.* ERTS-1 Symposium, Goddard Space Flight Center (Greenbelt, Maryland), Mar. 5, 1973.

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Chesnutwood, C. M.; Erb, R. B.; Garcia, J. G.; and Lundelius, M. A.: *A Comparison of Land Use Determinations Using Data From ERTS-1 and High-Altitude Aircraft.* ERTS Symposium (New Carrollton, Maryland), Mar. 5-9, 1973. (Also available as NASA SP-327.)

Collen, F.: *Calibration of Skylab Earth Terrain Cameras (S-190B).* NASA TM-73-002, 1973.

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Crea, W. J.: *Agriculture, Forestry, Range ERTS-1 Investigator Status Review.* Significant Results and Projected Applications Obtained From ERTS-1 Principal Investigator Interviews, Johnson Space Center (Houston, Texas), Dec. 1973, pp. 1-28.

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Dornbach, J. E.; and McKain, G. E.: *The Utility of ERTS-1 Data for Applications in Land-Use Classification.* Proceedings of the Third ERTS-1 Symposium (Washington, D.C.), Dec. 19, 1973.

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Erb, R. B.: *The Utility of ERTS-1 Data for Applications in Agriculture and Forestry.* Third ERTS Symposium (Washington, D.C.), Dec. 10-14, 1973.

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Vol. I - *ERTS-1 Agricultural Analysis,* NASA TM X-58117 (JSC-08456).
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Vol. III - *ERTS-1 Forest Analysis,* NASA TM X-58119 (JSC-08458).
Vol. IV - *ERTS-1 Range Analysis,* NASA TM X-58120 (JSC-08459).

Vol. V - *ERTS-1 Urban Land Use Analysis*, NASA TM X-58121 (JSC-08460).
Vol. VI - *ERTS-1 Signature Extension Analysis*, NASA TM X-58122 (JSC-08461).
Vol. VII - *ERTS-1 Land Use Analysis of the Houston Area Test Site*, NASA TM X-58124 (JSC-08463).

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1. Washington State Weed Association Annual Meeting (Yakima, Washington), Nov. 8, 1973.
2. Oklahoma Association of Conservation District Annual Meeting (McAlister), Oct. 30, 1973.
3. Kansas Farmers Co-op Annual Meeting (Haviland), May 1, 1973.
4. Oklahoma State University High Plains Annual Grains Conference (Guyman), Mar. 21, 1973.
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6. Coastal Bend Agri-Business Council Meeting (Robstown, Texas), Jan. 11, 1973.

Childs, L. F.: *Man's Effect on the Estuarine Environment.*
1. Environmental Awareness Workshop (Clear Lake City, Texas), Sept. 26, 1973.
2. Civil Engineering Distinguished Lectures Series (University of Illinois, Urbana), Apr. 11, 1973.
3. The AFS International Scholars Space Programs Orientation (NASA Johnson Space Center, Houston), Feb. 23, 1973.

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Childs, L. F.: *The NASA Earth Observations Program.*
1. National Dental Association Annual Meeting (Houston, Texas), Oct. 26, 1973.
2. Brazilian Naval War College (NASA Johnson Space Center, Houston), Oct. 5, 1973.
3. Distinguished Lectures Series (Brazosport Museum of Natural Sciences, Texas), Oct. 4, 1973.
4. Math-Science Appreciation Day (University of Wisconsin, Rice Lake), Apr. 10, 1973.
5. Patent Counsels Workshop (Nassau Bay, Texas), Apr. 3, 1973.
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7. Explorer Scouts Space Programs Orientation (NASA Johnson Space Center, Houston), Jan. 8, 1973.

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3. State of Texas Remote Sensing Task Force (Austin, Texas), June 1973.
4. North Central Division, Corps of Engineers (Chicago, Illinois), Aug. 1973.
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