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SECTION 30

USER ORIENTED MULTISPECTRAL DATA PROCESSING AT THE UNIVERSITY OF MICHIGAN*

by

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INTRODUCTION

This paper discusses the results of the second year of a coordinated program of application of proven and promising multispectral data processing techniques to practical problems posed by NASA center, government agency, and university investigators. The two goals of this program are to assess the feasibility of solving practical problems with available processing techniques, and to identify areas where more technique development is required. For the past two years, this program at the University of Michigan has been funded by NASA through the Manned Spacecraft Center at Houston.

During the past five years of working with investigators on practical problems, a number of processing techniques have been found useful. These techniques, summarized in Figure 1 and 2, have been called Type I and Type II techniques. The Type I techniques are simpler processing techniques usually applied to single or few channels of data. They include imagery, contouring and quantization, false color films, duplicate analog tapes, digitized data tapes, and canvas calibration panel reflectance measurements. The Type II processing techniques are more sophisticated techniques applied to the multispectral data set. They include signature extraction, optimum channel determination, likelihood ratio processor performance prediction (by computing probabilities of misclassification), object reflectance or radiance determination, preprocessing analysis, analog and digital implementations of the likelihood ratio classification map, and ratio maps.

This paper discusses several technical accomplishments of this year's data processing. Two new processing techniques (parameter mapping and ratio mapping) were developed in response to user requests. Under this contract we also processed half of the multispectral data collected for the Corn Blight Watch Experiment. Remaining sections of this paper will discuss technical highlights, the scope of this year's effort, and a list of cooperating agencies, NASA centers, and university personnel. It will conclude with suggested areas of further investigation.

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TECHNICAL HIGHLIGHTS

The data processing effort was highlighted by two kinds of technical achievements. First, two new processing techniques (parameter mapping and ratio mapping) were developed to solve specific investigator-posed problems. Second, our participation in the Corn Blight Watch experiment gave us the opportunity to evaluate the capabilities of existing multispectral data processing technques applied to semi-operational investigation.

While the parameter mapping and ratio mapping techniques were developed to solve specific problems, we feel that they have general applicability, and thus warrant fairly complete discussion here. Because of the scope of the Corn Blight Watch effort, it is discussed in the next section.

PARAMETER MAPPING

Parameter mapping, closely related to likelihood ratio pattern recognition, was implemented on SPARC to test a hypothesis offered by A.E. Coker of USGS-Tampa. He was attempting to assess pollution of ground water in central Florida occurring when fluoride rich, high pH, effluents from phosphate processing ponds seep through dikes and mix with the ground water supply. Large seepages of effluents from diked ponds can be detected because the surrounding vegetation is killed and a white salt crust appears on the soil surface. The problem is to detect small seepages of the dangerous and toxic effluent when concentrations are not large enough to kill vegetation.

Coker hypothesized that the reflectance spectra of the plants affected with fluoride would be modified, and that the amount of this modification was possibly proportional to the amount of fluoride pollution. To test this hypthesis we proposed a two step process. First, using conventional likelihood ratio techniques, all areas of a given vegetation type, affected or not, are recognized. Second, using a signature from a known normal area of vegetation, the distance between the signature of each scene point previously recognized and this "normal" signature is computed. The distance is displayed on black and white film as a continuous tone display with film density proportional to distance. Only points recognized as vegetation are printed on the film as various shades of gray. In this case, the parameter which is being mapped is the fluoride content of the plants. It is being mapped through the effect that this fluoride content has on the vegetation reflectance signature. This is illustrated in Figure 3, where a two dimensional, color-space plot of the signatures, decision boundaries, and distance is shown.

The implementation of this technique on the SPARC is shown in Figure

4. The likelihood ratio, formed from the probability density functions of the total vegetation signature and background signatures, is thresholded to form a conventional recognition signal. This is used to gate the signal from circuitry computing the statistical distance from the normal vegetation signature to the signature of the point being processed. This procedure is repeated for every point on the scan line, and processing proceeds at a real time rate.

Although the parameter mapping was developed for assessing the fluoride content of vegetation, we feel that the technique has general applicability in cases where stresses subtly alter the reflectance spectrum of vegetation. One such example is corn blight, where the stress, although not systemic, still modifies the reflectance of the corn through changes in plant geometry and in leaf spectra. Another example is the change in reflectance spectra of trees correlated with copper and molybdenum content of the soil reported by Canney (1).

Compared with likelihood ratio mapping techniques, where a training set for each degree of stress must be found, the parameter mapping offers a reduction of training set requirements. Only a training set for the class as a whole and for the "normal" condition must be found. The output is not a recognition map because no decision as to the degree of stress is made by the computer. We are anxious to apply this processing technique to other stress conditions to test its effectiveness.

RATIO MAPPING

Ratio mapping is a technique developed in response to an application proposed by Robert Vincent of the University of Michigan (2). For this technique, the ratio of two suitably calibrated channels is printed on either 70mm film or on computer paper in the form of a graymap.

Vincent found, after analysis of laboratory and field spectra collected by R.J.P. Lyon, that a ratio of radiances in two narrow wavelength intervals in the 8-14μm window could be correlated with the silica content of rocks. The basis for this conclusion was that all silica containing minerals display decreases in emissivity in reststrahlen bands in the 8-10μm region, and the position of these bands shifts to longer wavelengths with decrease in silica content (see Vincent and Thomson (3)). Ratios of radiance locate the position of the reststrahlen band because the emissivity directly affects the observed emitted radiation.

To test this technique, we developed both digital and analog ratio map capabilities. The analog ratio maps, shown in Figure 5, are produced by dividing the two signals in an analog divider which is part of the SPARC preprocessor. The resultant ratio is printed on 70mm film.

The digital implementation of the ratio map is slightly more sophisticated than the SPARC implementation and offers the advantage of easily obtained quantitative output at the disadvantage of slightly coarser and physically larger display. The CDC-1604 digital computer program RAITEM was developed to calibrate two channel thermal infrared data from the Honeywell layered detector (flown in Michigan's M-5 scanner system), form the ratio of the two channels' data, and correct the ratio for effects of varying object temperature. The correction is done by obtaining a radiometric estimate of temperature in a third thermal band, then using a table lookup procedure to determine the correction factor.

Although the ratio map technique was developed in response to a geology problem, the concept of ratio maps may be generally useful for other types of investigations. For example Pearcy (4) has proposed a blue - green ratio to delineate water masses in the Pacific Ocean off Oregon. Vincent has proposed a green-infrared ratio to indicate the presence of ferrous and ferric iron in rocks. There are indications that ratio maps may be useful in delineating plant stress.

Ratio maps are not recognition maps. No decisions are made by the computer before the results are printed. The output of ratio processing applied to visible data is relatively insensitive to changing illumination conditions--this is the basis of the ratio preprocessing techniques. Ratio techniques have yielded important information for geological investigations, and we look forward to applying them to other types of investigations.

FURTHER DEVELOPMENTS IN SIMULATION OF OTHER SENSORS

The simulation of other sensors is an important part of multispectral processing operations. Frequently, investigators want to evaluate how much better the multispectral data and processing performs a job than a more conventional photographic sensor and human processor. The question usually arises--what if the photography were processed in the same way as the scanner data. To help answer this question we have developed spectral simulations of photographic and other sensors.

Many investigators have been interested in determining whether problems can be solved using ERTS data. Last year we simulated the spectral response of ERTS-MSS channels (see Figures 6 and 7 where simulated responses are shown as dashed lines and assumed ERTS-MSS responses are shown as solid lines). This year we also simulated the spatial response of the ERTS system. This was accomplished by smoothing the scanner data to achieve 80m resolution element size. This smoothing was accomplished by averaging over points and scan lines of the original scanner data.

Figure 8 shows two digital graymaps of a 2 x 8 mile portion of Biscayne Bay data for which ERTS spectral and spatial simulations were performed.

The bottom map in Figure 8 is of spectrally simulated ERTS-MSS channel 3(0.7-0.8μm) at the original scanner data resolution of 10m. Prominent land features of southern Biscayne Bay are identified. The top map in Figure 8 is a simulation of the ERTS-MSS 80m. spatial resolution using the same data set. The important land features can still be identified. This suggests that at least, features of the size of Mangrove Point, Turkey Point, and Arsenicker Key will be delineated on the ERTS data.

No aircraft sensor can adequately simulate the 100 x 100 mi field of view of the ERTS sensor. The data shown in Figure 8 comprise about 0.16% of the data in an entire ERTS frame. Even a single RB-57 photograph covering 18 x 18 miles covers less than 4% of the area of an ERTS frame. It is clear that some of the problems being attacked with aircraft data will not be feasible from ERTS because of the lower spatial resolution. By simulating this lower resolution, some estimate of the feasibility may be obtained before getting ERTS data. Further, by simulating spatial resolutions intermediate between ERTS and scanner, we can assess the utility of various levels of resolution for solving problems.

CORN BLIGHT WATCH PARTICIPATION

In early May, we were asked to assist the Laboratory for Applications of Remote Sensing (LARS) in processing multispectral data collected as part of the Corn Blight Watch Experiment. Data were collected every two weeks over thirty segments of the intensive study area in western Indiana. We were asked to process half of this data, delineate levels of corn blight severity, and report results to LARS within two weeks after having received the data. This effort commenced in early July and continued through the middle of October, and some originally scheduled processing for investigators had to be deferred.

At the outset, we realized that the processing of the data would have to keep pace with the collection. Both LARS and we estimated that one segment per day was a suitable data processing rate for each facility. The aircraft program was thus scaled to collect thirty segments' data every two weeks.

To meet the goal of processing one segment's data each day, we organized a team of four supervisors and six SPARC operators. Supervisors selected corn and background training sets from available biweekly ground information, color IR film collected by the C-47, and previous processing experience with the segment. The SPARC and preprocessor were setup in the 8 target, 6 channel configuration. LARS selected separate sets of six channels for northern, central, and southern Indiana segments from an analysis of the previous mission's data.

Loops of data were prepared by the SPARC operators. These operators then setup the SPARC, implemented preprocessing where required, and trained SPARC. Despite careful planning of the aircraft data collection program to minimize the variations of observed radiance with scan angle, those effects were prominent enough to require preprocessing correction in about 80% of the data. These data were collected at about 5000 ft. above terrain under visibility conditions greater than 6 miles. Because these are quite reasonable conditions under which to collect data in operational programs, we conclude that preprocessing (or other accounting for angle-dependent variations of observed radiance) must be considered in the design of processors for operational applications.

Recognition maps of each corn blight class were produced and area counts were accumulated of each blight level detected by SPARC. The area counts were reported to LARS on standard forms. Also, supervisors analysed each recognition map, estimating the fraction of each corn field detected as each blight level. This information was reported to LARS every two weeks.

Some typical Corn Blight Watch SPARC maps are shown in Figures 9 and 10. In Figure 9, SPARC results from segment 212, Mission 43M (8/17/71) are color coded to portray corn of blight levels 0-3 (light) in green, corn of blight levels 4 and 5 (heavy) in red, and other areas as white. Fields in this figure are either predominantly green or red, with very few fields with a sizable mixture of green and red, indicating that there is a small range of blight levels within any one field, and that different fields are affected quite differently by southern corn leaf blight (SCLB), depending on cytoplasm type and location.

One source of confusion in the data analysis is illustrated by Figure 10. In this figure a portion of a corn recognition map for segment 211 is presented, along with color IR photography. There are several roughly circular areas of no recognition within corn field boundaries that were identified as weedy patches or areas of low corn growth from examination of the color IR photo. The processor failed to detect corn in these areas because there was little or no corn. If one is interested in estimating the acreage planted in corn by remote sensing means, some account will have to be made of areas within corn fields which do not contain corn. Per field classification is one possible solution to this problem.

QUANTITATIVE ASPECTS

Shown in Figure 11 is a list of investigators we have collaborated with this year, their affiliation, and the general nature of the problems investigated. The list is quite varied and indicates the general interest in multispectral data collection and processing within the user community. Shown in Figures 12 and 13 are the numbers of each of the Type I and Type II processing jobs performed. A considerable amount of both digital and

SPARC analysis work was accomplished. A great majority of the 102 SPARC jobs completed last year were for the corn blight watch experiment, but SPARC maps were also prepared for other investigators.

CONCLUSIONS

The first semi-operational test of multispectral data collection and processing techniques was conducted this year--Corn Blight Watch Experiment. From this valuable experience, as well as work with other investigators, we draw some conclusions and make recommendations for the course of future research.

We have demonstrated that multispectral data processing can solve a number of important and relevant problems under restricted data collection conditions and with few constraints on processing time. Because the investigations to date have been primarily feasibility studies, no agency is currently making use of processed multispectral data in decision making. To make this use feasible, we will have to expand proven techniques to larger data sets, process these data sets more efficiently, and identify and provide the information that decision makers want. We have previously noted that the signature extension problem is crucial to the extension to larger data sets. At the University of Michigan, we have obtained some encouraging results in this area (reported in this symposium by Nalepka), and work here should continue to be vigorously pursued. Two other areas should also be considered--processor efficiency and cost and post-processing information extraction.

Our Corn Blight Watch experience has taught us that the aircraft is able to gather high quality data much faster than current, research oriented processors are able to digest it. The C-47, flying four days per month, generated enough high quality data to keep both LARS and Michigan processors busy for the whole month. If the potential of the aircraft and spacecraft sensors are to be realized, faster more efficient processors will have to be built. We see the hybrid computer as such a system. By designing and constructing such an improved throughput system, results can be generated faster more cheaply. This will benefit both operational programs and feasibility studies.

The generation of processed results more cheaply and faster will not alone insure their acceptance by potential decision making users. We need to consider the post processing information extraction. An important start has been made in this area with the extraction of pond acreage and perimeter statistics for wildlife managers setting duck hunting limits in North Dakota. More of this effort must be undertaken. One part of this area which needs attention is mensuration. For some investigators, the desired final output is a map. Because of distortions introduced in the scanning process and because of aircraft platform instabilities, maps of the required fidelity have been difficult, if not impossible, to generate. Further, some investigators desire accurate acreage measurements of crops or other ground materials. This problem is linked with the problem of scanner cartography because the same kinds of distortions must be accounted for. It is clear that some unified approach to sensor platform and processor design is required to solve this problem most efficiently.

Collection of data from ERTS and Skylab sensors will impose new demands upon existing processing facilities, for data quantities will be sizably larger. We face the ERTS data with a number of processing technique proven useful for processing aircraft data. It is clear that many of these processing techniques will be useful for ERTS data, but that other processing techniques may be required to optimally exploit the unique characteristics of this data. Some of these techniques are now under development at Michigan, and will be discussed in other papers in this section.

REFERENCES

(1) Canney, F.C., Wenderoth, Sondra, Yost, Edward, December 1 to 3, 1970, "Relationship Between Vegetation Reflectance Spectra and Soil Geochemistry: New Data From Cathreart Mountain, Maine", Third Annual Earth Resources Program Review, Volume II Agriculture, Forestry, and Sensor Studies.

(2) Vincent, Robert K.,Horvath, Robert, Thomson, Fred, Work, Edgar A, April 1971, "Remote-Sensing Data-Analysis Projects Associated with the NASA Earth Resources Spectral Information System",NASA CR-WRL 3165-26-T.

(3) Vincent, Robert K., Thomson, Frederick J., May 1971, "Discrimination of Basic Silicate Rocks by Recognition Maps Processed from Aerial Infrared Data", Proceedings of the Seventh International Symosium on Remote Sensing of Environment, Vol. 1, pp. 247-252.

(4) Pearcy, W.G. (Dr.), Oregon State University, private communication.

TYPE I PROCESSING SERVICES

* Imagery
* Contouring and Quantization
* False Color Films
* Digital Tape
* Canvas Panel Reflectance Measurements
* Duplicate Analog Tape

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Figure 1

TYPE II PROCESSING SERVICES

*Signature Extraction and Analysis
  Optimum Channel Analysis
  Processor Performance
  Reflectance or Radiance
*Preprocessing Analysis
*Digital Recognition Map
*SPARC Recognition Map
  Likelihood Ratio
  Parameter Map
*Ratio Map

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Figure 2

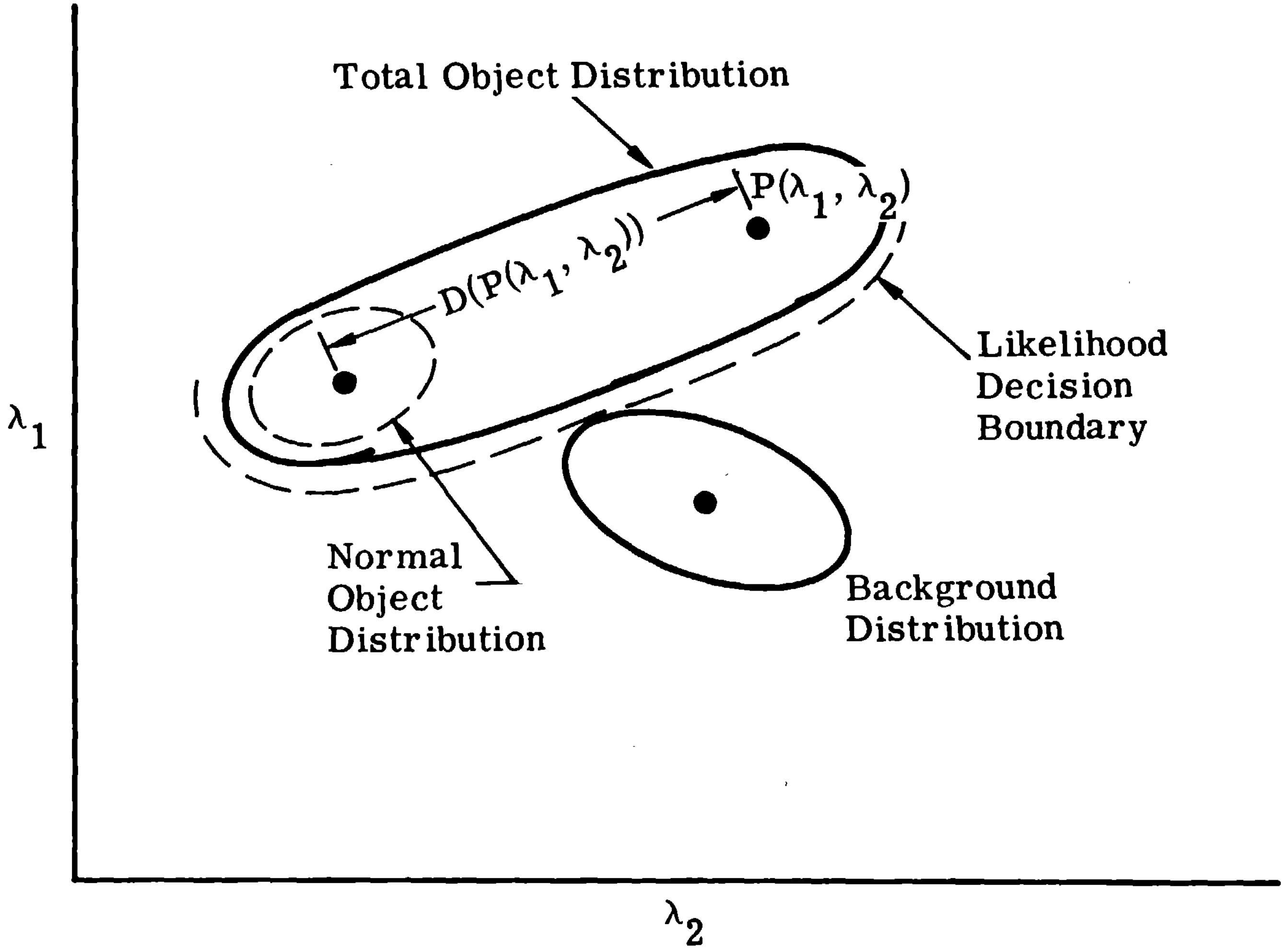
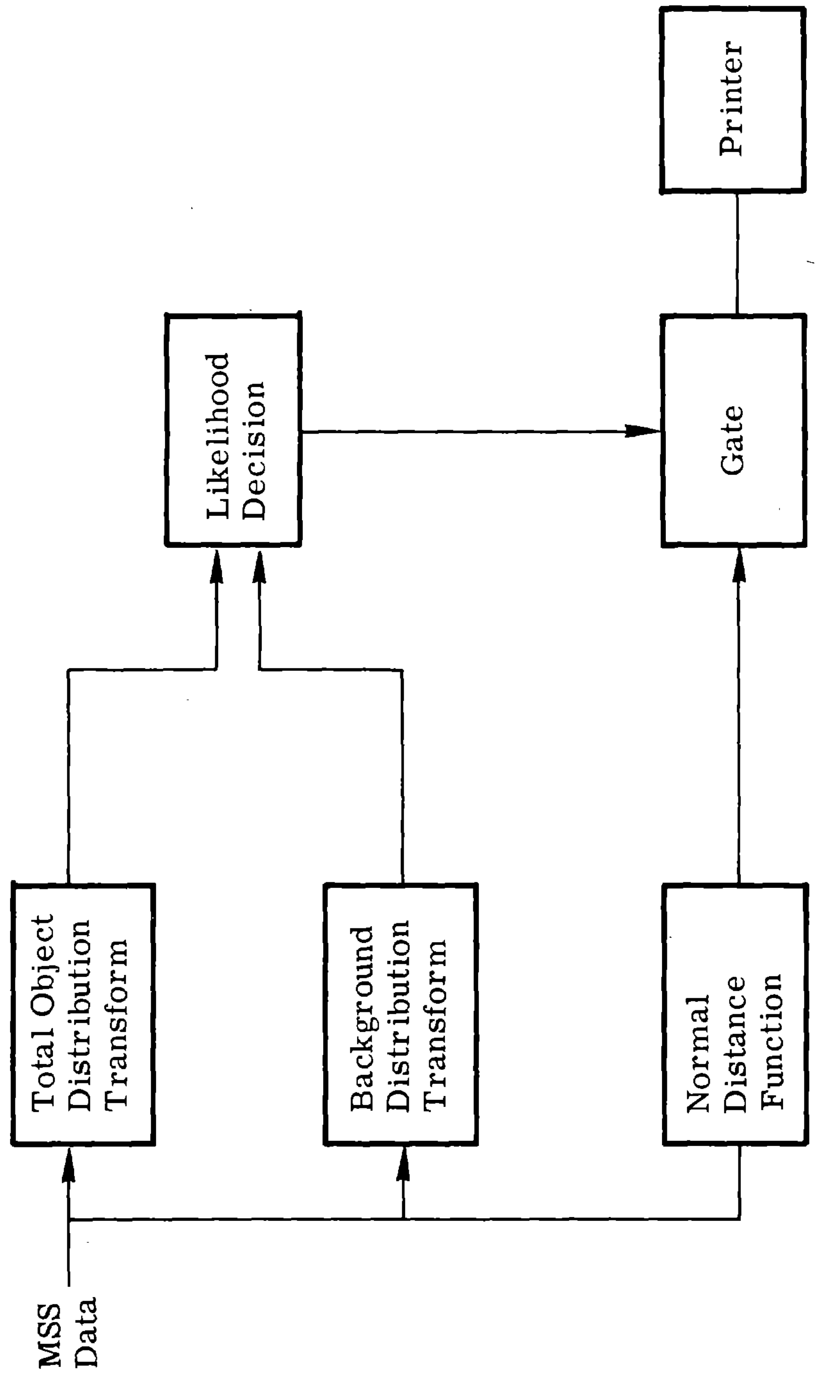
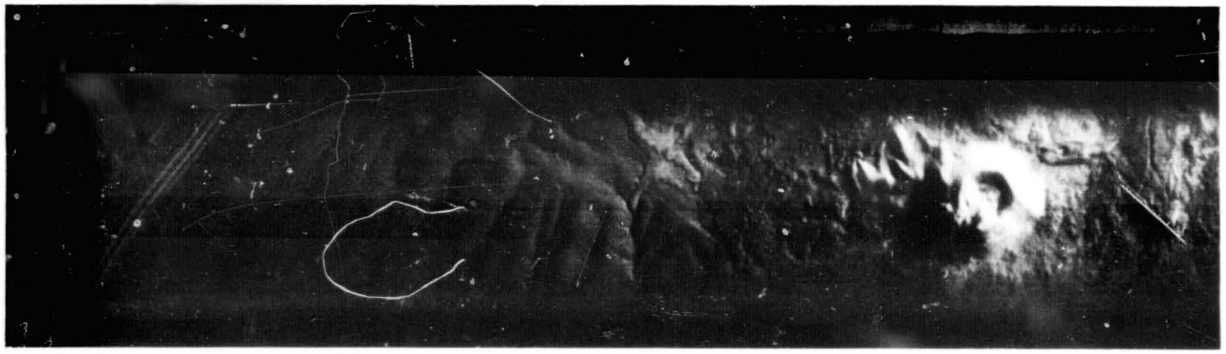


FIGURE 3. DEFINITION OF SIGNATURES FOR PARAMETER MAPPING

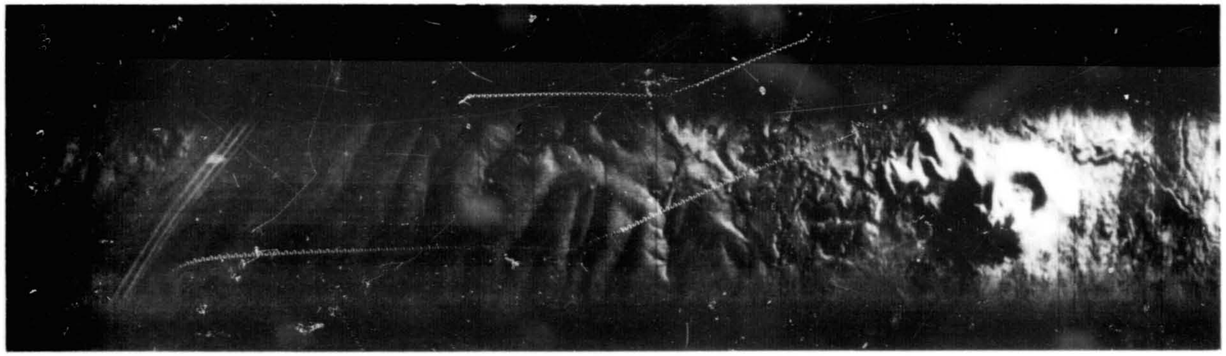


SIMPLIFIED BLOCK DIAGRAM OF SPARC SETUP FOR PARAMETER MAPPING

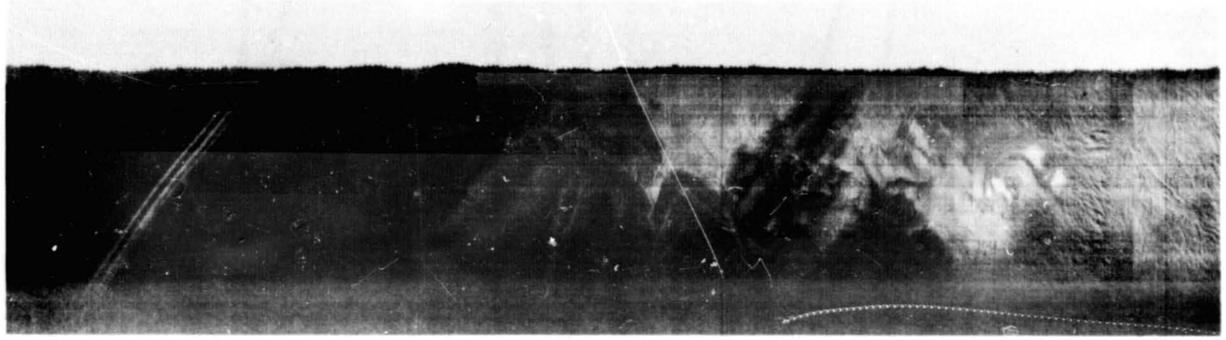
Figure 4



Channel 1: 8.2 - 10.9 μm



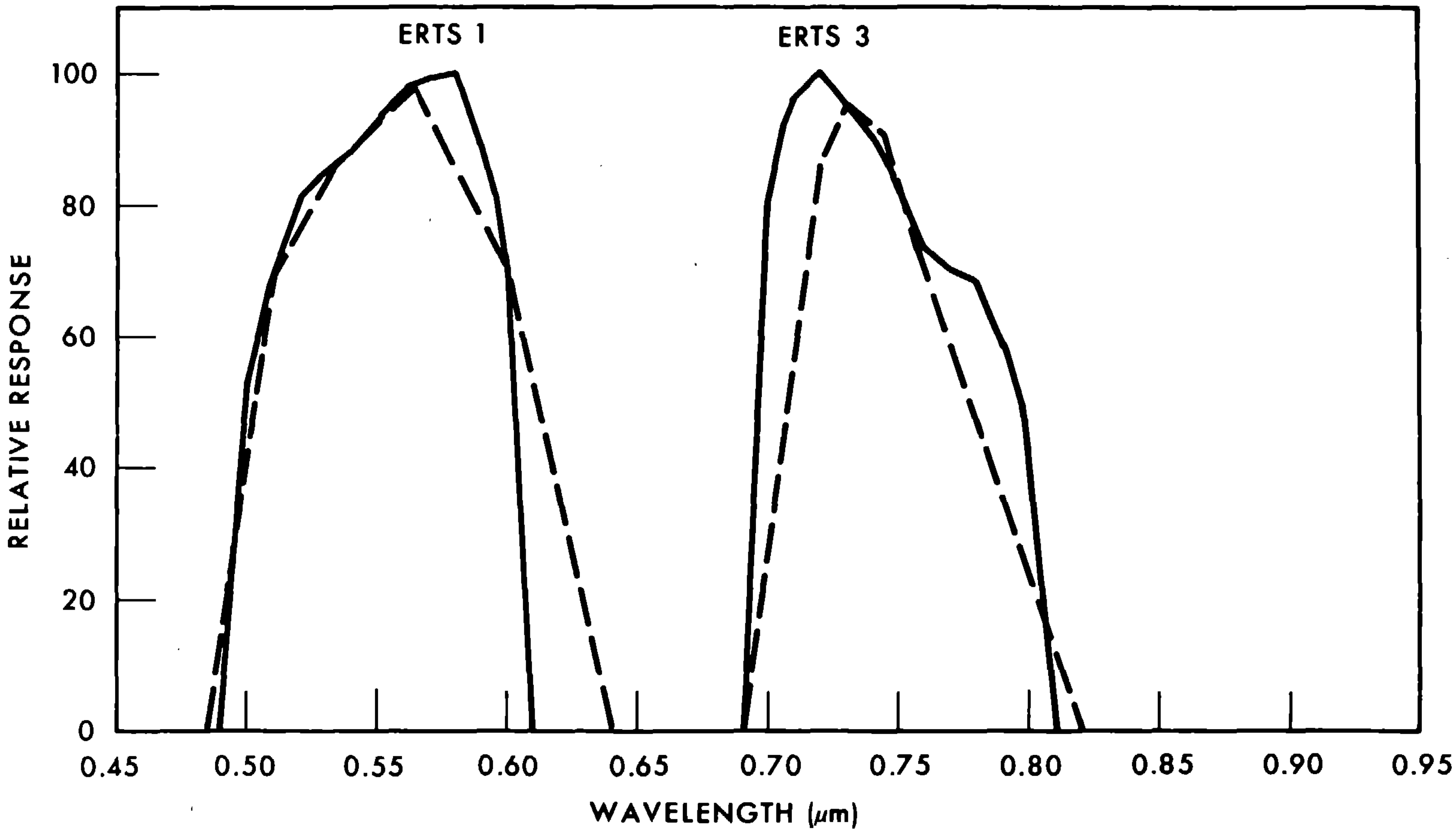
Channel 2: 9.4 - 12.1 μm



Ratio: $\frac{\text{Channel 1}}{\text{Channel 2}}$

ANALOG INFRARED IMAGES OF FLIGHT LINE 1, SECTION A NEAR PISGAH CRATER, CALIFORNIA

Figure 5



ACTUAL AND SIMULATED ERTS SENSITIVITY

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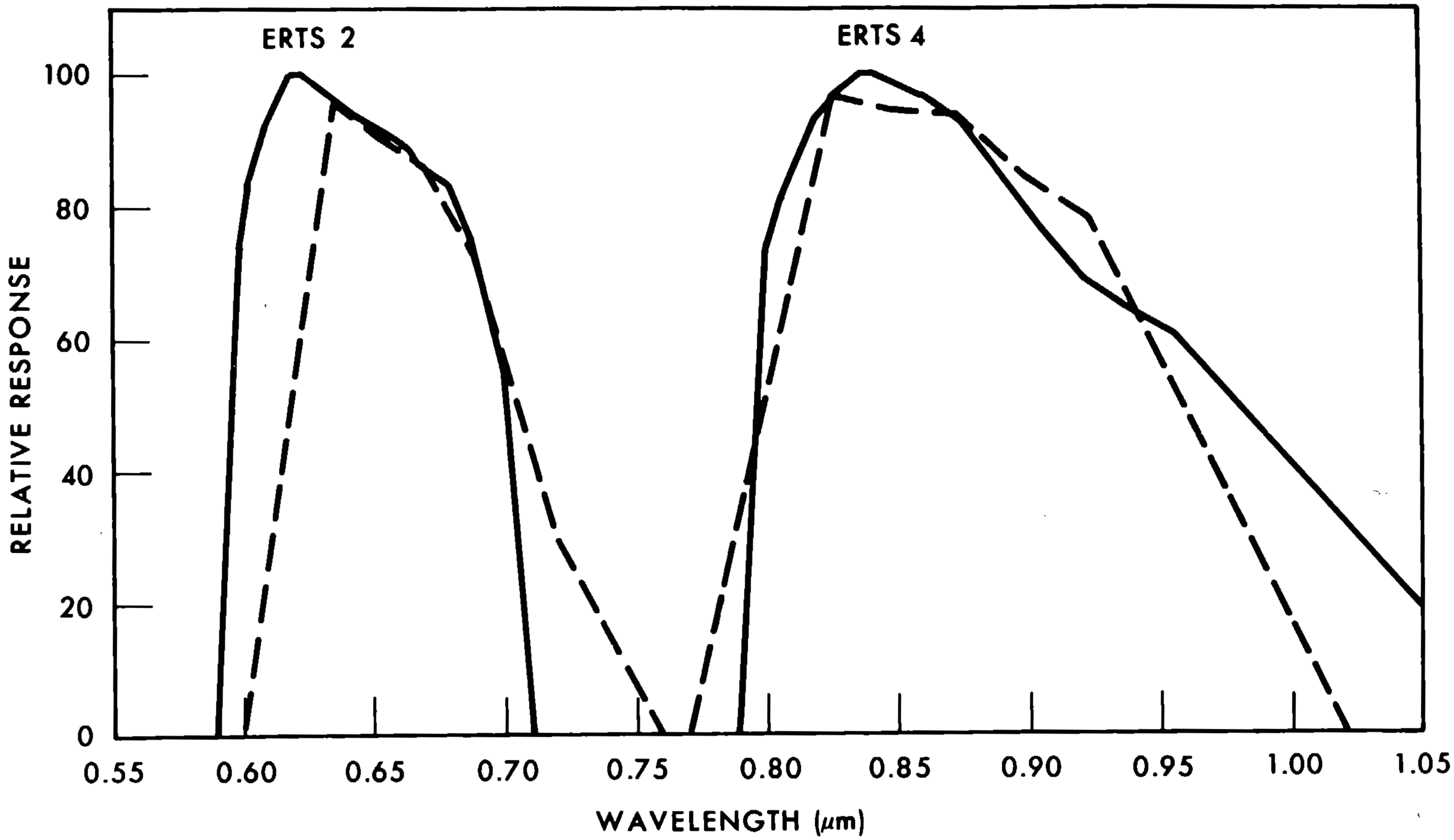
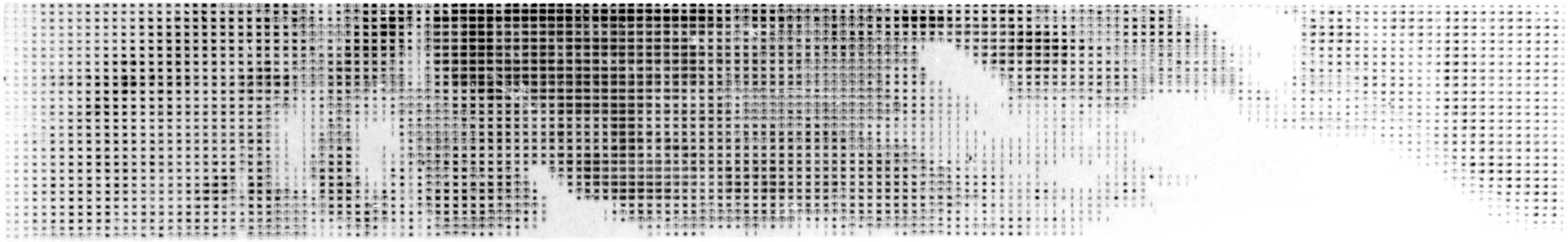
Figure 6

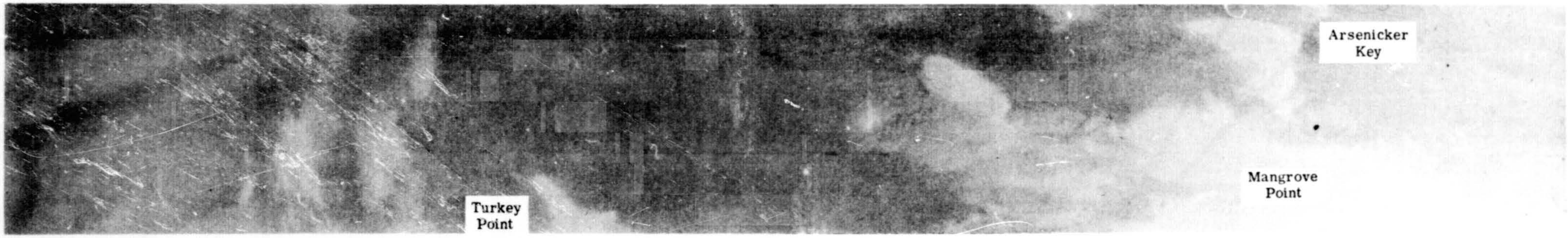


ACTUAL AND SIMULATED ERTS SENSITIVITY

Figure 7



Simulated 80m Resolution ERTS Data

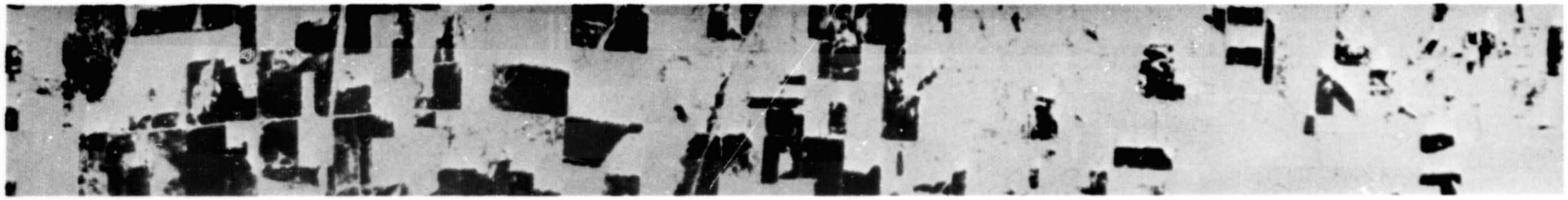


Scanner Data-10m Resolution

ERTS-MSS CHANNEL 3 SPATIAL RESOLUTION SIMULATION

Figure 8

0.72-0.92 μm Imagery

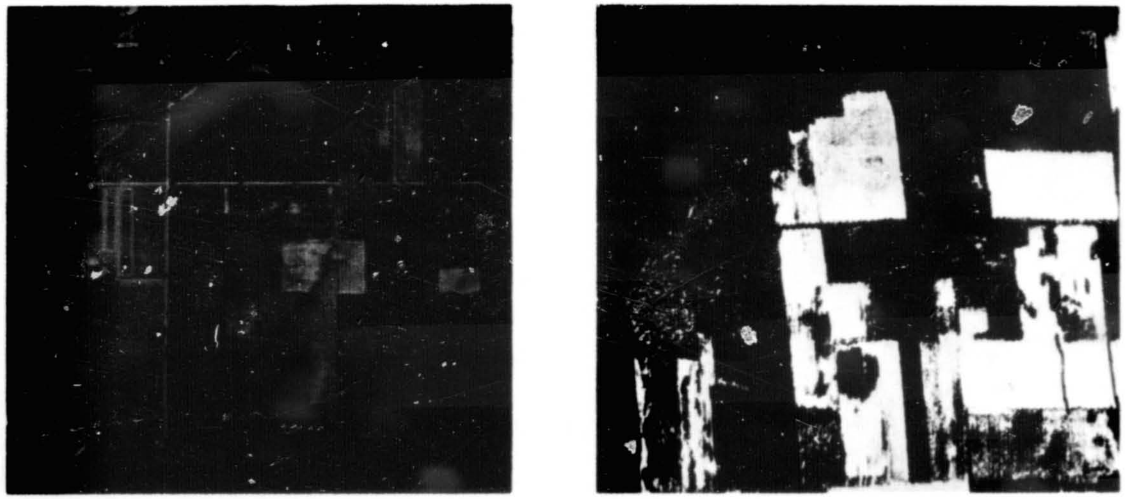


Color Coded Recognition Map

COLOR CODED RECOGNITION MAP OF CORN BLIGHT FOR SEGMENT 212 MISSION 43.
8/17/71, 1030 hrs.

Color	Material	Optimum Channels (μm)
Green	Corn, Blight levels 0-3	0.50-0.54
Red	Corn, blight levels 4 and 5	0.58-0.65
White	Not recognized	0.66-0.76
		0.72-0.92
		1.0 -1.4
		9.3 -11.7

Figure 9



Color IR Photo

Recognition Map

ILLUSTRATION OF DETECTION FAILURES IN CORN FIELDS. Segment 211, 7/16/71, 0916 hrs., 5000 ft above terrain. Six channel likelihood ratio processing.

Figure 10

Investigator	Affiliation	Area	Problem
Frank Canney	USGS-Denver	Catheart Mtn., Maine	Delineate copper and molybdenum stressed trees.
A.E. Coker	USGS-Tampa	Central Florida	Delineate Vegetative indicators of fluoride pollution of ground water.
Richard Driscoll	USDA-Ft. Collins, Colorado	Manitou Nat'l Forest	Map forest,rangeland, and wetland sites
Milton Kolipinski	USGS-Miami	Biscayne Bay, Florida	Study ability of spectrally and spatially simulated ERTS data to map underwater plant communities.
Robert Johnson	USDA-Bemidji, Minnesota	Chippewa Nat'l Forest Minnesota	Map forest species and ponds in Chippewa Nat'l Forest.
Harvey Nelson	BSFW-Jamestown, North Dakota	North Dakota	Map pond water distribution and surrounding vegetation indicative of waterfowl productivity.
William Pearcy	Oregon State University	Oregon Coast	Delineate ocean water types by measurements of water spectral radiance.
Robert Vincent	University of Michigan	Pisgah Crater, California	Delineate exposed rock types using thermal ratio - reststrahlen technique.

Figure 11

Investigator	Affiliation	Area	Problem
Kenneth Watson	USGS-Denver	Mill Creek, Oklahoma	Map exposed sedimentary rocks using visible data, provide rock reflectance statistics, and provide temperature statistics for correlation with thermal model.
Craig Wiegand	USDA-Weslaco	Weslaco, Texas	Map soil and vegetation using spectrometer, near infrared, and simulated photographic data.

Figure 11. - Concluded.

TYPE I PROCESSING 1970-71

*Imagery — 3100 miles
*Contouring and Quantization — 14 jobs
*False Color Films
*Digital Tape — 2 jobs
*Panel Reflectance Measurements — 2 jobs
*Duplicate Analog Tape — 1 job

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Figure 12

TYPE II PROCESSING 1970-71

* Signature Extraction and Analysis
    Optimum Channel Analysis — 7 jobs
    Processor Performance — 4 jobs
    Reflectance or Radiance — 6 jobs
* Preprocessing Analysis — 11 jobs
* Digital Recognition Map — 13 jobs
* SPARC Recognition Map
    Likelihood Ratio — 102 jobs
    Parameter Map — 1 job
* Ratio Map — 2 jobs

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Figure 13