FINAL REPORT
NASA GRANT NGL 15-005-112
JUNE 1,1969-MAY 31,1974

Research in Remote Sensing of Agriculture, Earth Resources, and Man's Environment

PRINCIPAL INVESTIGATOR
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Submitted by

The Laboratory for Applications of Remote Sensing

Purdue University, West Lafayette, Indiana

June 15, 1974

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I. INTRODUCTION

This is the final report for NASA Grant NGL 15-005-112.
The work done under this grant is the continuation of work
begun under several smaller, earlier NASA and USDA contracts.
Section II summarizes the funding involved in these contracts
as well as the subject grant.

Section III is a review of the results obtained during
this effort. It is apparent from the review that these
results contain many major contributions to the science
of remote sensing. Indeed, it is our belief that a very
great percentage of this nation's capability to process re-
motely sensed data by machine processing methods has resulted
directly or indirectly from the grant and its USDA predecessors.
In essence, for less than eight million dollars total cost,
a whole new technology has been created and largely placed
at the disposal of a user community. Rarely in the research
field has so much been obtained for so low a cost in so short
a time.

The details of the results outlined in Section III are
contained in some 160 reports previously transmitted to NASA,
many of which have also been placed in the open scientific
literature. Due to the volume involved, it would not be
desirable to reproduce them here. Therefore, only a biblio-
graphy including abstracts of these reports is provided;
these are presented in the Appendix.

Section IV draws some conclusions about this work. Of
course, the work is not completed. Useful as they are, the
techniques developed under this grant must be regarded as
only first steps to what can ultimately be achieved. Thus,
some remarks about the future are in order to establish a
proper perspective for this work. These are also provided
in Section IV.

II. Funding Summary and Related Contracts

As previously pointed out, the work done under the current
grant was a continuation of work begun at a lower level of
effort under earlier grants and contracts. These are listed
in Table 1. In each case the source of funds, we understand,
was the NASA Supporting Research and Technology Program.

Table 1
Funding Prior to June 1, 1969

AGENCY	CONTRACT OR GRANT	TERM	AMOUNT OF AWARD
NASA	NGR 15-005-028	11/1/65-3/31/67	$224,998
USDA	ARS 12-14-100-8307(20)	1/1 /66-1/18/67	150,000
USDA	ARS 12-14-100-8926(20)	2/16/67-1/31/68	246,000
USDA	ARS 12-14-100-9502(20)	1/11/68-9/30/68	154,100
USDA	ARS 12-14-100-9549(20)	10/1/68-11/30/69	429,000
USDA	ARS 12-14-100-10292(20)	12/1/69-5/30/70	251,565

$1,455,663

Table 2 shows the awards under Grant NGL 15-005-112. This grant was begun by the NASA Office of University Affairs based upon results obtained under the earlier studies. The earlier studies were for the purpose of developing appropriate measurement and machine data processing techniques for remote sensing in agriculture. It was apparent that after suitable development, the technology originally conceived would have application not only to agriculture, but to at least the fields of geology, geography and hydrology as well; thus, the studies were expanded in 1969. It is seen that the grant began at a $200,000 annual level, reached a peak of $1.7 million, then diminished by about one third.

Table 2

Funding
NASA Grant NGL 15-005-112
June 1, 1969 - May 31, 1974

Regular SR&T Studies

Supplement Number	69-70	70-71	71-72	72-73	73-74	74-75	TOTAL	Technical Officer	Acceptance Date
original	$200,000	135,000	65,000				400,000	Vitale	7/29/69
1		665,000	70,000	65,000			800,000	Park	8/4/70
unmarked		750,000	670,000	70,000	60,000		1,550,000	Park	4/30/71
3			922,571				922,571	Park	9/13/71
4				248,453	75,000	60,000	383,453	Vitale	6/8/72
6				550,000			550,000	Park	8/23/72
7				500,000			500,000	Potter	1/24/73
8				66,547			66,547	Potter	6/8/73
9					(135,000)	(60,000)	(195,000)	Vitale	6/8/73
10					333,435		333,435	Potter	6/22/73
12					481,000		481,000	Potter	8/31/73
14					482,565		482,565	Potter	12/6/73
Regular SR&T Subtotal	$200,000	1,550,000	1,727,571	1,500,000[4]	1,297,000[5]	0	$6,274,571		

Special Studies

	69-70	70-71	71-72	72-73	73-74	74-75	TOTAL	Technical Officer	Acceptance Date
5				10,890			10,890[1]	Vitale	7/10/72
11					22,240		22,240[2]	Potter	7/23/73
13					22,270		22,270[3]	Potter	10/25/73
All Studies TOTALS	200,000	1,550,000	1,727,571	1,510,890	1,341,510	0	6,329,971		

Notes: [1] Goddard Terminal
        [2] Department of Interior/Geographic Application Program
        [3] Langley Terminal

[4] Includes $76,000 for computation for three ERTS contracts
[5] Includes $195,000 for computation for five ERTS and Skylab contracts

This grant also provided funding for several special studies which were closely related to and emanated directly from the main task of developing and learning to apply machine processing methods. These are indicated in Figure 2 under the Special studies section and in the footnotes.

There is no satisfactory way of quantifying the value of the results obtained in such a creative effort. The narrative in the next section and the bibliography in the appendix give, perhaps, the clearest measure though it is only a qualitative one. However, Table 3 provides a recapulation of the number of reports which resulted from this grant. Again the details are in the Appendix.

Note that Table 3 does not include the three-volume final report of the 1971 Corn Blight Watch Experiment performed during 1972-1973, the 3,000-page documentation of LARSYS Version III completed in 1973, nor the multimedia LARSYS Educational Package.

Table 3

Grant Reports by Grant Year

69-70	70-71	71-72	72-73	73-74	TOTAL
16	29	35	40	40	160

III. Review of Research Activities

This section describes both earlier work (primarily supported by USDA) and that performed under Grant NGL 15-005-112.

Earlier Work

It was recognized in the first half of the 1960's that, along with developments in other aspects of earth observational remote sensing, there was a strong need for devising methods for processing data by machine. The motivation was the very large quantities of data expected and the need in some cases to have analyzed results available very quickly after the data were gathered. It was this aspect of the total national remote sensing program which was to be the special area of concentration at Purdue.

It had been recognized that the efficient development of such a technology would require personnel competent not only in the engineering aspects of machine data processing methods, but also in the user disciplines of the life and earth sciences as well; and, furthermore, that these personnel would need to function as a truly interdisciplinary team. Purdue's large schools of engineering and agriculture together with its long history of such types of research activities made it a natural place to pursue such a task.

The major aircraft scanner data missions utilized by LARS/Purdue personnel in the early years serve well as benchmarks of progress in the development of high-speed analysis techniques for earth resources data. Such missions were flown during the 1964 and 1966 growing seasons.

The many results from the 1964 mission have been reported in the LARS Annual Report, Volume 1 (Figure 1.) These missions served to demonstrate that film data of nine different wavelengths could be utilized to visually separate green vegetation, bare soil and water. They also revealed that faster, more cost effective methods for analyzing data would have to be found. Following that phase, a more quantitative approach was put forth which included three major endeavors:

Figure 1. Photograph of LARS Annual Reports, Volumes 1-4.
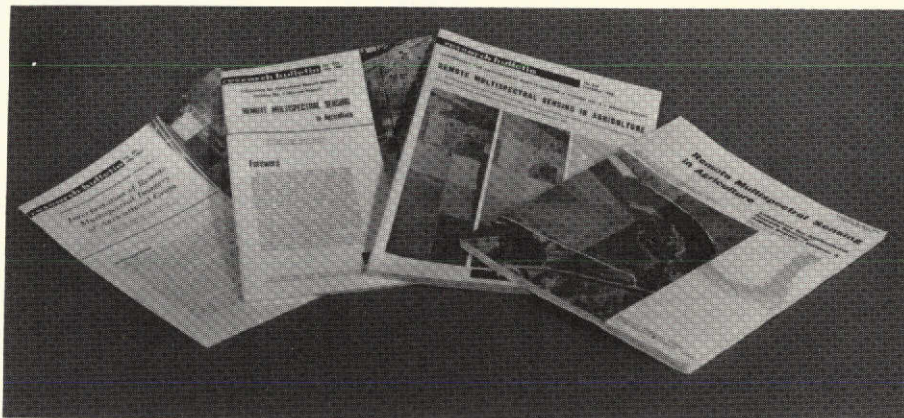
1. Pattern recognition techniques, which had been under study for some years in the engineering and mathematical literature and which appeared to provide a promising general approach to the machine analysis of multispectral data, would be explored.

2. Digital data handling methods would be used in order to maintain the integrity of the data particularly with regard to dynamic range and to provide maximum speed and convenience to the researchers. Rapid advancement in digital data handling techniques also appeared likely at this time.

3. An interdisciplinary approach would be used, employing a research team consisting of both physical scientists and life scientists. This interdisciplinary plan would allow for maximum progress in devising and utilizing a suitable analysis scheme.

The details of this approach were given in LARS Annual Report, Volume 2 (Figure 1), and it was on this basis that the 1966 datamissions were planned. The potential of the approach became increasingly apparent from early results. (LARS Information Note 021567; February, 1967). The complete results of the 1966 data missions are given in LARS Annual Reports, Volumes 3 and 4, (Figure 1).

Figure 2. Geologic Reconnaissance Map Made from
Apollo IX Photographic Data and Machine Processing
Methods in 1970.

In general, the results disclosed that a great deal of
refinement in the basic classification categories was possible
with the utilization of scanner data. Also, the new data hand-
ling and data analysis procedures were very satisfactory for
quantities of data of the order of 10^5 points (approximately
5 square miles at the resolution used). They also suggested
strongly that these techniques would be useful disciplines
other than agriculture.

Research under Grant NGL 15-005-112

It was at this point then (June 1, 1969) that the NASA
Grant was initiated. Its objective was to permit development
of this approach for large volumes of data and a broad portion
of the life and earth science (user) disciplines.

Researchers in strategic staff positions were, thus,
added in geology, hydrology, and geography. Research carried
out with these funds proved that the existing techniques,
designed for agriculture, were applicable to other disciplines,
and a number of new measurement and data processing techniques
were derived.

By the end of 1970 the use of color infrared photography,
multispectral scanner data, and machine analysis techniques
to identify and spectrally delineate features of the landscape
was greatly improved. Soil organic matter was successfully
mapped and advances were made in spectral identification of
differences in soil moisture content and clay content. Re-
finements were made in mapping of different crop species and
certain geological features. Differences in spectral imagery
of water caused by silt loads were studied. Spectral maps
of urban subdivisions were produced in a form useful to
land developers and planners. During that year research in
data processing, particularly in preprocessing methods,
overlay techniques, temporal analysis, data compression, re-
formatting, the application of a digital data display to
pattern recognition and approaches to the solution of spatial
analysis problems greatly advanced the background science and
technology of data processing.

Figure 2 shows an important result obtained with 1970
technology. Four photographs obtained during the Apollo IX
·SO65 experiment where used in this case. The photos were
scanned and digitized, then precisely registered with one another
using the current image registration system. Machine analysis
methods were used to divide the data into more than 20 classes
of geologic interest. Figure 3 shows the results of a detailed
study carried out on a very small portion of this frame. This
study, which was suggested by the result shown in Figure 2, led
to the location of some previously unknown lineaments. These
and associated studies on this data provided one of the clearest
indications of the promise of ERTS-1 at that time.

ARIZONA

Ogilby ·

Agricultural
Area

Scale
:125,000

Alluvium

Mesozoic Granite

Pre-tertiary Paleozoic Metamorphic

Tertiary Volcanics

Quaternary and Cenozoic
Volcanics (Basalt)

Precambrian Crystalline
Complex
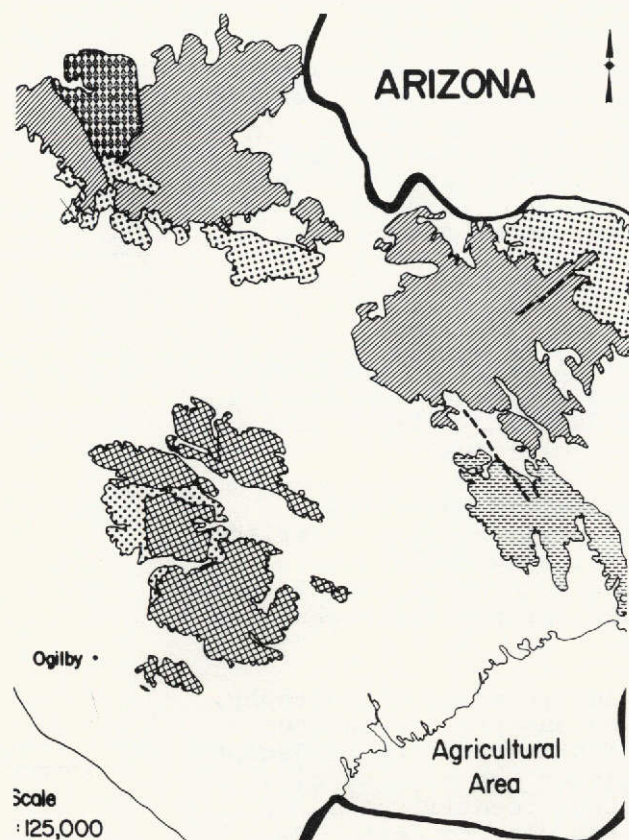
— — Fault (Approx. location)

Figure 3. Conventional Geologic Map (left) and Computer Classification
(right). The increased informational detail in the computer results
enabled analysts to discern the lineaments (shown as dotted lines in
the left figure).

The 1971 Corn Blight Watch Experiment

A spectral assay by remote sensing of the severity of southern corn leaf blight infection in western Indiana corn fields was made by LARS scientists in 1970. The results (Figure 4) pointed to the feasibility of monitoring by remote sensing the spread over the Corn Belt of a possible second epiphytotic in 1971.

Several branches of NASA and USDA, seven land grant universities and Willow Run Laboratories at the University of Michigan joined in the experiment. In this program a statistical design was developed for sampling the area by remote sensing and collecting ground truth. The flightlines and segments used are shown in Figure 5. The experiment provided a prototype remote sensing system in which techniques of data gathering, storage, retrieval, processing and analysis, and information dissemination were successfully integrated in a quasi-operational system environment.

The results presented at NASA/JSC in January 1972, again at a University of Michigan Symposium and recently published by NASA/JSC (Figure 6) showed that two stages of blight severity could be recognized and separated quantitatively over broad areas by remote sensing procedures. Different land uses including bare soil, corn, soybeans, small grains, pastures and wool lands were also accurately delineated.
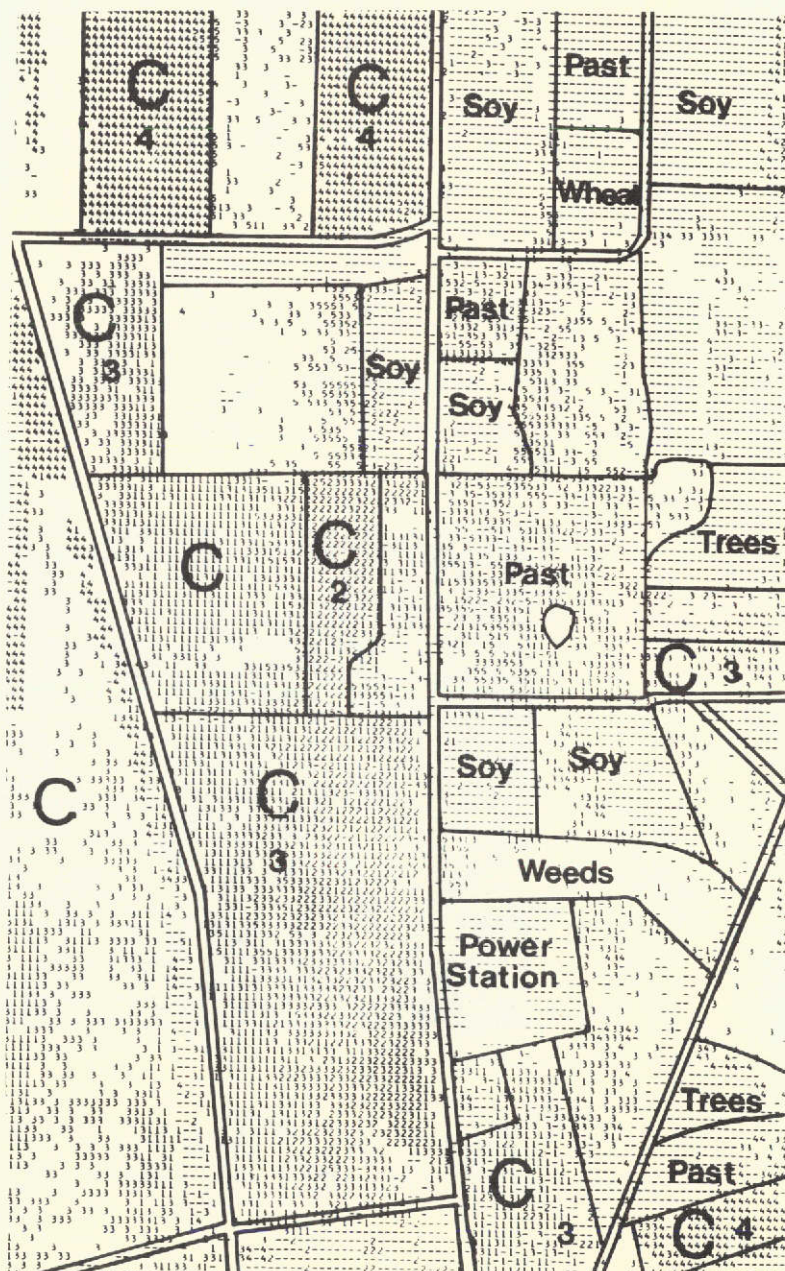
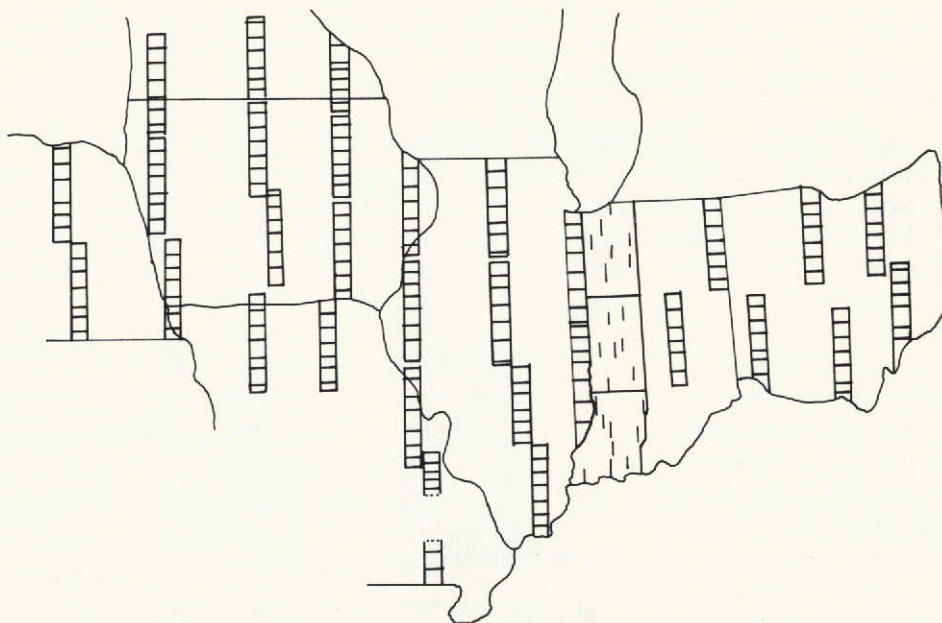Figure 4. Multispectral Data Showing Delineation of Five Levels of Corn Blight Severity.

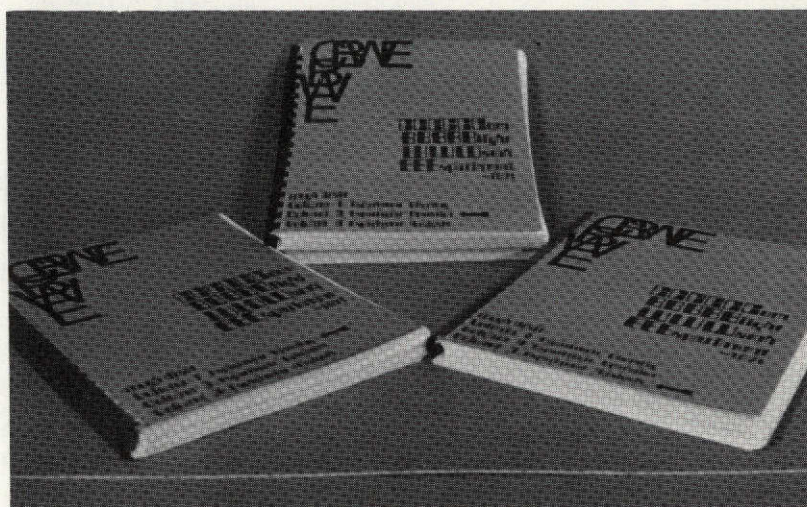Figure 5. Flightlines and Segments For the 1971
Corn Blight Watch Experiment

Figure 6. Photograph of the 1971 Corn
Blight Watch Experiment Final Report.

Figure 7 shows a typical map derived from the analysis.

Blight Severity Level
- ⬚⬚ 0.0-1.49
- ⬚⬚ 1.50-2.49
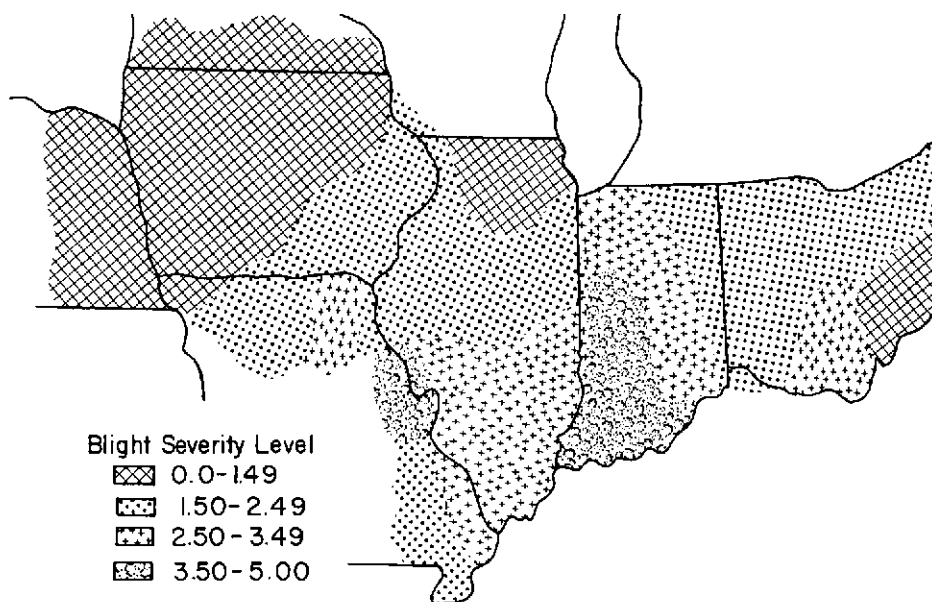- ⬚⬚ 2.50-3.49
- ⬚⬚ 3.50-5.00

Figure 7. A Generalized Blight Severity Map Drawn
From Analysis Results of One Biweekly Mission in the
1971 Corn Blight Watch Experiment.

Following the tests of remote sensing technology made
during the Corn Blight Watch, 1972 and 1973 have been devoted
to improvement of data analysis capabilities and their appli-
cation to satellite-acquired data. This grant has also pro-
vided the opportunity for evaluating the technology and
defining large scale applications of remote sensing along with
the research required for conducting wide-area surveys. Some
of the more significant accomplishments are described below.

Agricultural Crops

Research on identification of agricultural crop species
from ERTS data has resulted in accurate identification of such
crops or land uses as corn, soybeans, wheat, and rangeland.
Classification performance has been about the same as pre-
dicted from aircraft scanner data. This is particularly sig-
nificant in light of the much larger areas being classified
with ERTS data. Acreage estimates made from classifications
of ERTS data compare well to those made by the USDA. These
results suggest strongly the potential of this technology
for obtaining crop production information over large areas.
Figures 8 and 9 show the development in this user area
from a crop identification task over a few fields from air-
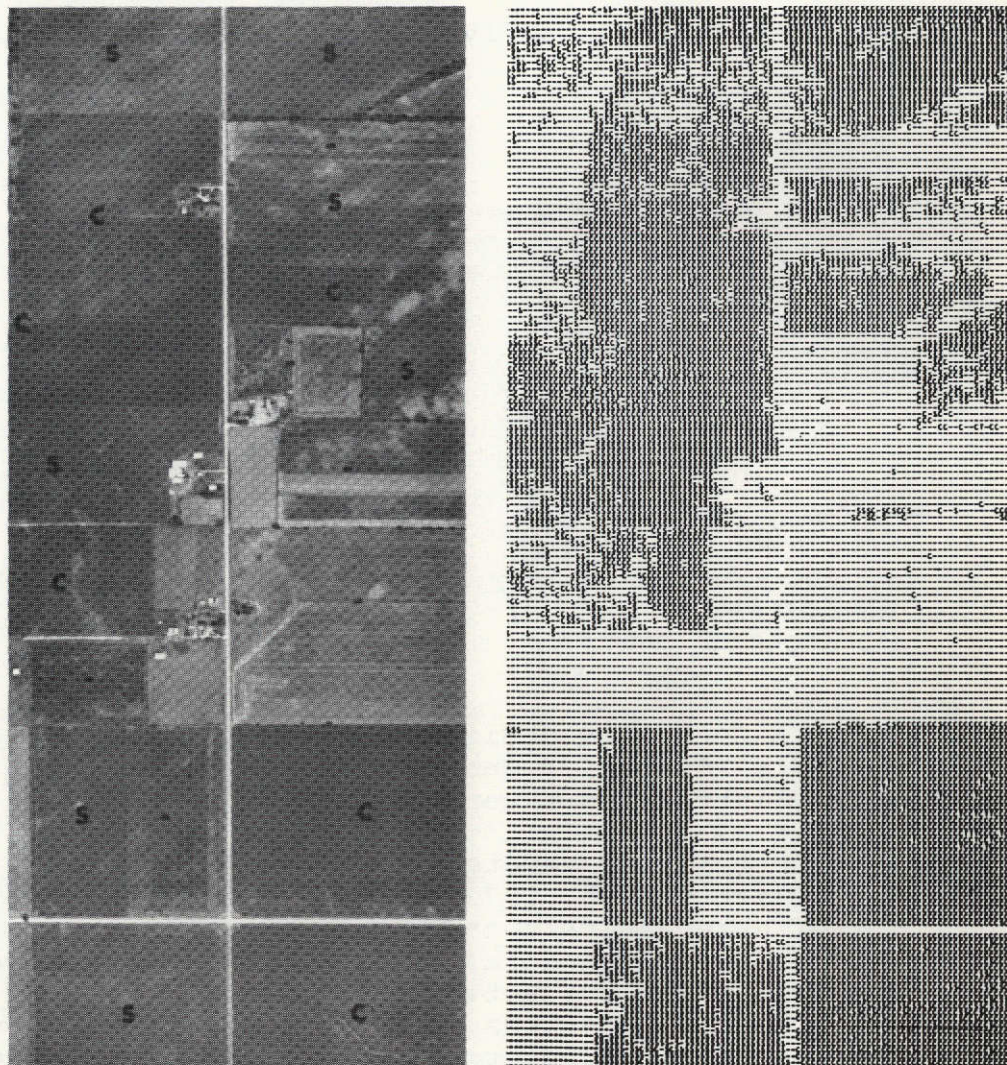borne data to a multicounty one using ERTS-1.

Figure 8. Aerial photograph and a computer-produced vegetative map of the same area. The computer map contains the following symbols: C=corn, S=soybeans, and -=pasture and stubble.

Figure 9. Computer Classification of ERTS Data
Identifying Corn (Black), Soybeans (Gray), and
all Others (White). (DeKalb Co., Illinois)

One of the capabilities expected to contribute to further
improvement of crop identification performance is registration
of multi-temporally acquired data. With this capability,
developed under this grant, it is now possible to fully
evaluate the characteristics and use of temporal information
for classification of crops and other cover types.

Soil Mapping

The potential value of remotely sensed data in soil in-
ventories has been advanced by studies relating soil properties
to computer-processed ERTS images. These images have provided
more correct information on the location of soil associations
than was available in previously existing maps in several
counties. The capability for geometrically correcting and
scaling ERTS MSS data has enabled us to begin interfacing
ERTS images to conventional soil and other maps. This capability
is, of course, useful to other applications such as land use
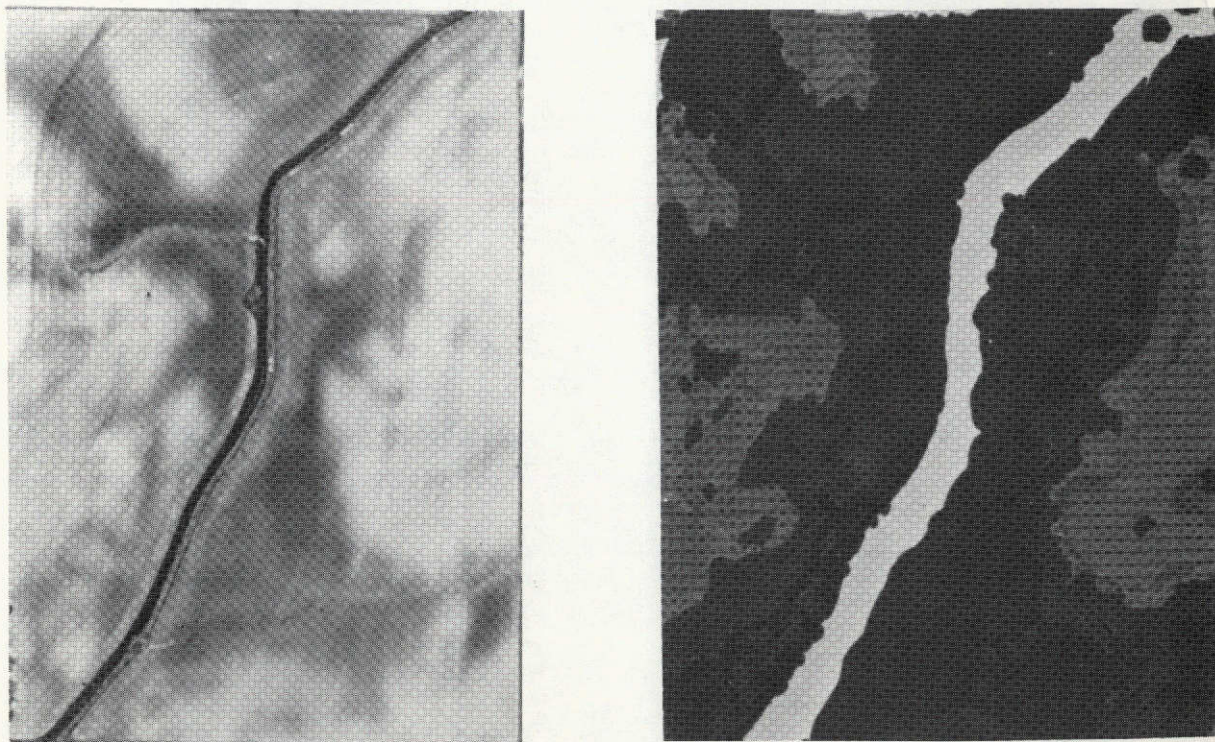and geological mapping.

Figure 10. Aerial Photograph and Soil Organic Matter Content Map
Produced by the Computer.

Figures 10 and 11 illustrate developments in this user
area. The former is a detailed soil organic matter map made
from airborne data while the latter is an unsupervised classi-
fication of geometrically corrected ERTS data from which soil
associations are readily interpretable. A standard generalized
soil association map has been overlaid for comparison.

Land Use

ERTS MSS data obtained over urban areas have been 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 den-
sity 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 in-
put to the urban regional planner. Not only can ERTS data
be a source of land use information but it can be used
to update and/or supplement existing land use data banks.

Figure 12 shows an early result using low-altitude air-
borne data over a small subdivision which has been analyzed
into classes of interest to precipitation run-off characteristics

Figure 11. An Unsupervised Classification of Geometrically
Corrected ERTS-1 Tippecanoe County, Indiana Data with a Stand-
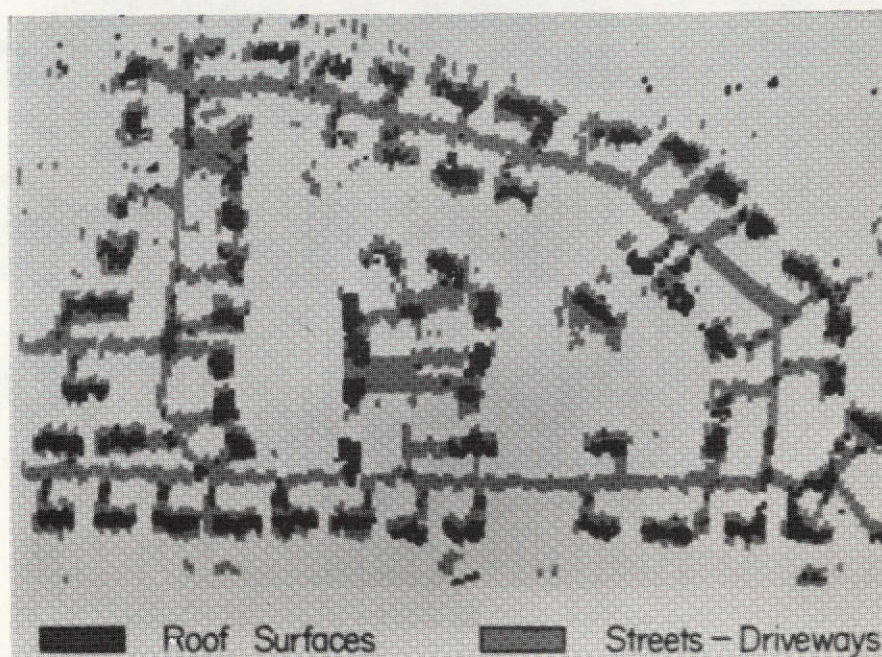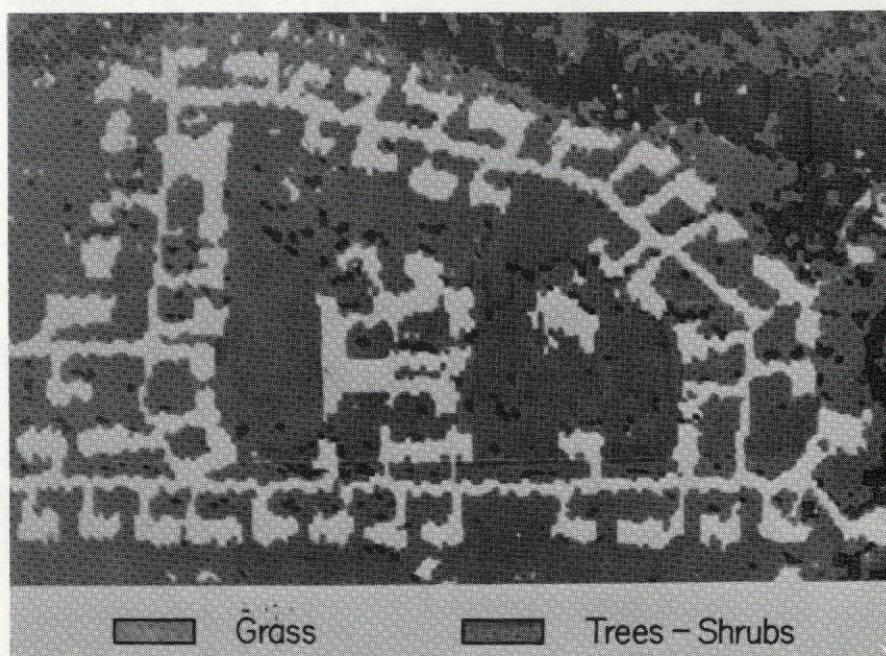ard Generalized Soil Map Overlaid for Comparison.

Figure 12. Computer Classification Display of Natural Materials
(Top) and Man-Made Materials Present in a Test Site.

of the area. Figure 13 shows the same technique applied to
geometrically uncorrected ERTS-1 data over the Gary-Hammond,
Indiana area. Test sample classification accuracies of the
order of 90% were achieved on this one and on replications
over Indianapolis, Chicago, and Milwaukee.

Geologic Mapping

An earlier example (Figure 2) showed a geologic mapping
result. Using ERTS-1 data as a supplement to mineral re-
connaissance techniques, an iso-lineament intersection map
was prepared for north-central Nevada. This is shown in
Figure 14. The imagery indicates a strong correlation between
major intersection areas and domal areas associated with
mineral districts. Based on this correlation, two major inter-
section areas with no known associated ore deposits were
interpreted to be potential exploration sites. Another investi-
gation evaluated the usefulness of multispectral scanner data
in recognizing and interpreting hydrothermal alteration in
rocks which may serve as clues to ore mineralization. The
results indicate that with additional research, space and air-
borne multispectral scanners may prove to be effective tools
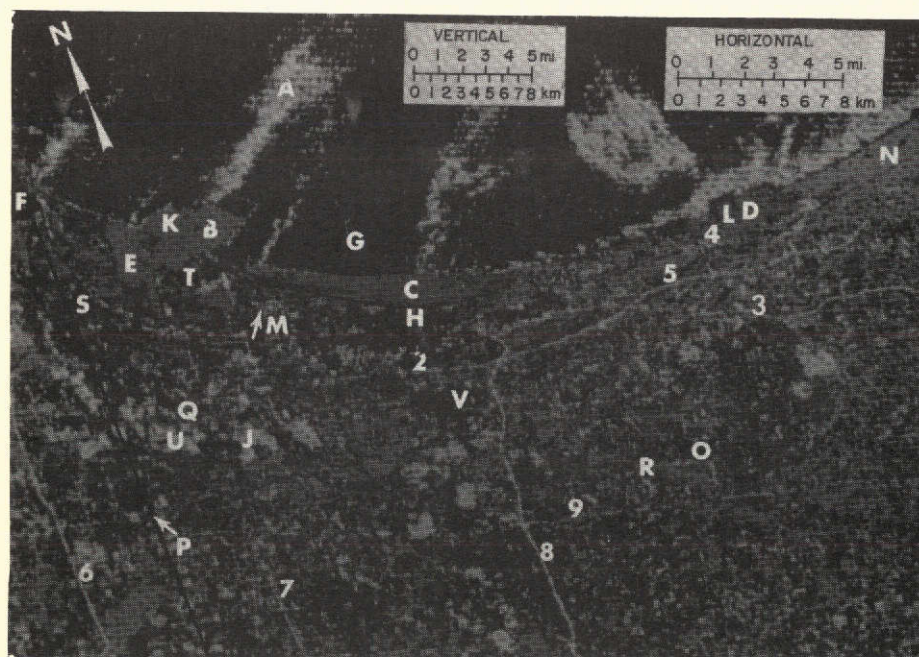to map and distinguish alteration patterns associated with ore
deposition.

Figure 13. (See figure caption on next page).

L	Feature, land use, or highway	Spectral class
A	Smoke plume	smoke
B	Inland Steel	commercial/industrial
C	United States Steel	commercial/industrial
D	Bethlehem Steel	commercial/industrial
E	Oil Refineries	commercial/industrial
F	Wolf Lake	water
G	Lake Michigan	water
H	Gary-Central Business District	commercial/industrial
J	Highland-subdivision	newer housing
K	Indiana Harbor	commercial/industrial
L	Port of Indiana	commercial/industrial
M	Gary Municipal Airport	newer housing
N	Indiana Dunes State Park	wooded
O	Agricultural area	grassy/agricultural
P	Indiana-Illinois state line	-----
Q	Wicker Memorial Park	grassy/agricultural
R	Trees along Deep River	wooded
S	Hammond-residential area	older housing
T	East Chicago-residential area	older housing
U	Munster-subdivision	newer housing
V	Gary-residential area	older housing
2	Interstate Highway 80-94	newer housing
3	Interstate Highway 80-90	newer housing
4	U.S. Highway 12	newer housing
5	Interstate Highway 94	newer housing
6	Illinois Highway 394	newer housing
7	U.S. Highway 41	newer housing
8	Interstate Highway 65	newer housing
9	U.S. Highway 30	

Figure 13. Photo from Digital Display of Computer-Implemented Land-Use Classification of Gary-Hammond 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 labeled points of interest are listed on the previous page.)
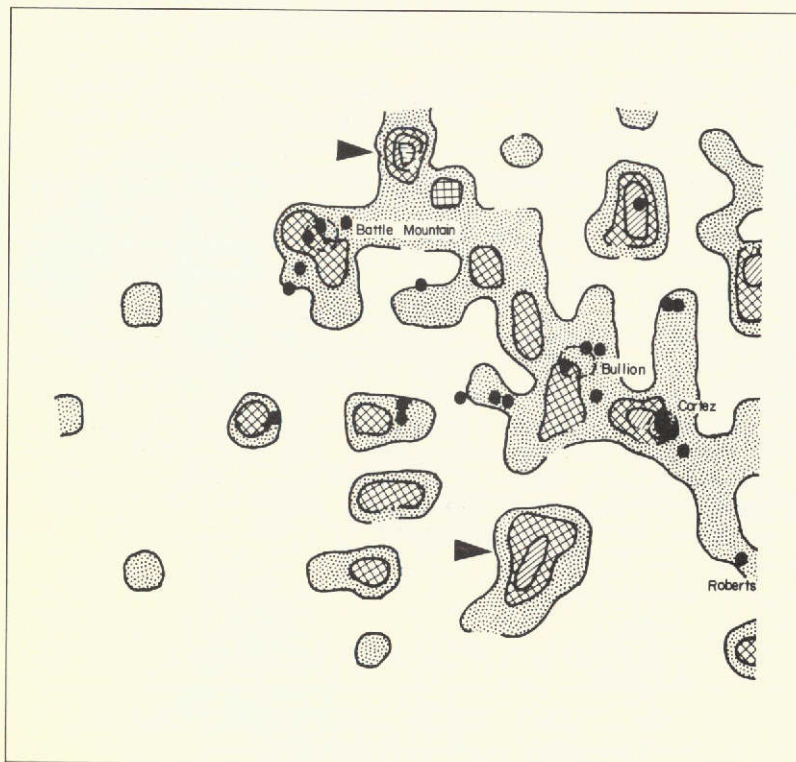
Figure 14. Simulated color infrared imagery from ERTS data
(North-central Nevada). From study of this data, geologists
have deduced that the areas indicated with arrows warrant
investigation as potential mining sites.

Forest Resources

Use of multispectral scanner data and computer-aided analysis techniques indicated that deciduous and coniferous cover types could be reliably mapped, and, in some cases, spectral differences between species within each of these major groups were measured. Spectral variability within forest canopies due to 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 (.4-.7μm), middle infrared (1.3-3μm), and thermal infrared (3-14μm). However, use of more than five wavelength bands in the classification did not cause significant increases in the classification accuracy, and in some cases will cause a decrease in accuracy.

Identification and mapping of areas of coniferous and deciduous forest cover can be reliably achieved with ERTS-1 multispectral scanner data, not only in areas having little topographic relief, but also in mountainous regions.

Water Resources

Water resources research involved two primary areas of activity: calibration of multispectral scanner 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 9.3-11.7μm portion of the thermal infrared 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 5,000 feet. Water pollutants could sometimes be delineated with multispectral scanner data even though they could not be detected on aerial photography. Because of the importance of water quality to fisheries resources, nuclear power plant sitings and other water resource management situations, use of multispectral scanner systems offers many potential advantages, although a much better understanding of the spectral characteristics of the water is needed.

Field and Laboratory Spectroradiometer System

The Exotech Model 20-C field spectroradiometer (0.4 to 14 µm) has been implemented as part of a system to produce in situ spectra to aid researchers in interpreting the effects of crop and soil conditions on multispectral scanner measurements. A photo of this system is shown in Figure 15. Field techniques have been developed to produce calibrated data for reflectance factor, reflection-distribution function, radiance and irradiance. The system features 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 has been constructed for this system, making possible even more carefully controlled experimentation under laboratory conditions.
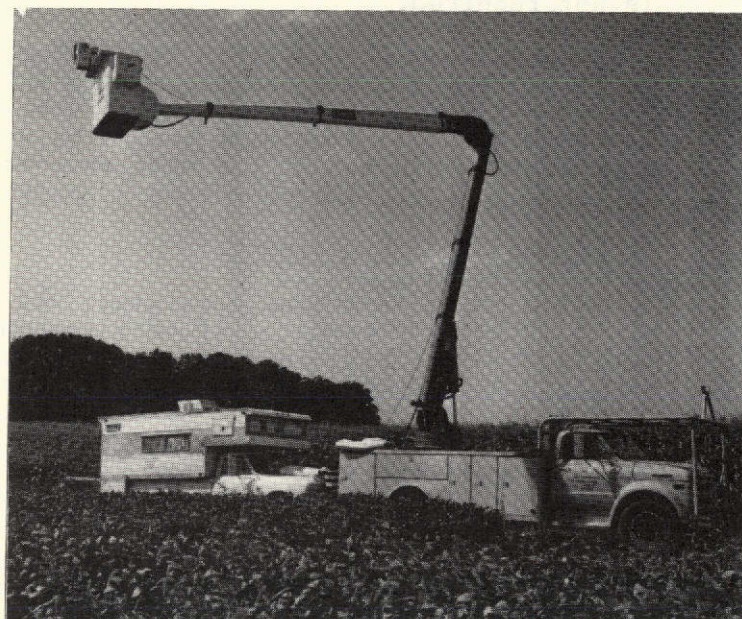
Figure 15. Fieldvan in the Field

LARSYS Software System

No doubt the most important document resulting from this grant is LARSYS Version 3. This software system, involving more than 20,000 lines of program code, together with its more than 3,000 pages of documentation, easily represent 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.

The documentation (Figure 16) consisting of the System Manual, Users Manual, Test Procedures Manual and Module Documentation, is more than adequate to allow for implementation of the complete system on another general purpose computer or for selection of individual portions for implementation where the full system capability and throughput is not required.

We believe it 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 the most current version of this system directly. This has been arranged at no cost to NASA.

Remote Terminal Experiment

The remote terminal experiment was proposed to address the questions of transfer of this technology to another site and to study a possible approach to operational data processing systems of the future. The elements for technology to others include not only hardware and software transfer, but knowledge or training on how to use the system. Previous efforts to simply give away the software has resulted in unnecessary expense, frustration and poor results on the part of the user, once it was implemented.

Relative to the second question, it has remained clear throughout the development that full access and control by the user in his own operational office is a very important boundary condition for eventual operational systems. This condition, however, seems in conflict with the advantages in system maintenance and updating, which a high degree of system centralization would provide. One is thus led to consider having a large centralized processing capability and data bank, but remoting control of that processing to individual user offices. In addition to cost advantages, such a degree of centralization would also provide advantages in making possible the standardization of special training materials, data formats, and the incorporation of system updates in order to stay current with this rapidly advancing technology.

The experiment was authorized by NASA/Headquarters in 1970 and appropriate hardware was installed at Purdue in early 1971. The 1971 Corn Blight Watch Experiment necessitated a delay in the experiment since both the equipment and the personnel involved were required for the Watch. However, after completion of the Watch, efforts to establish the system were renewed, software was appropriately modified, and remote terminals were installed. Figure 17 shows the location of terminals currently installed or under contract.
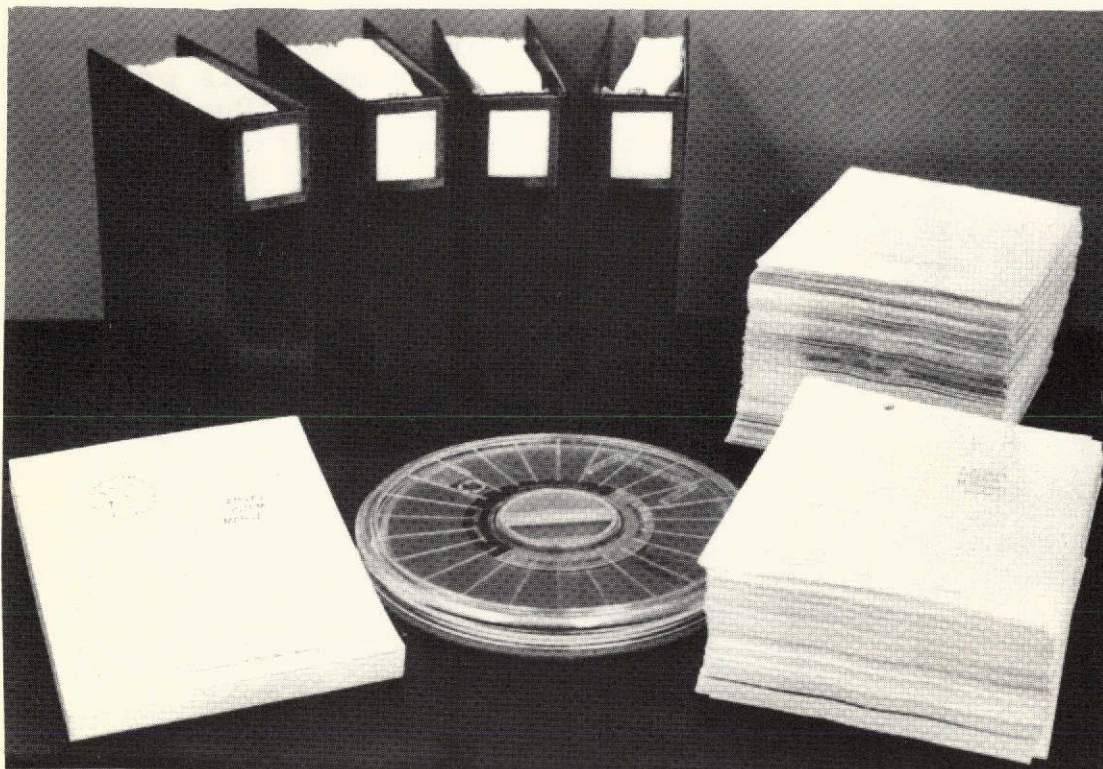
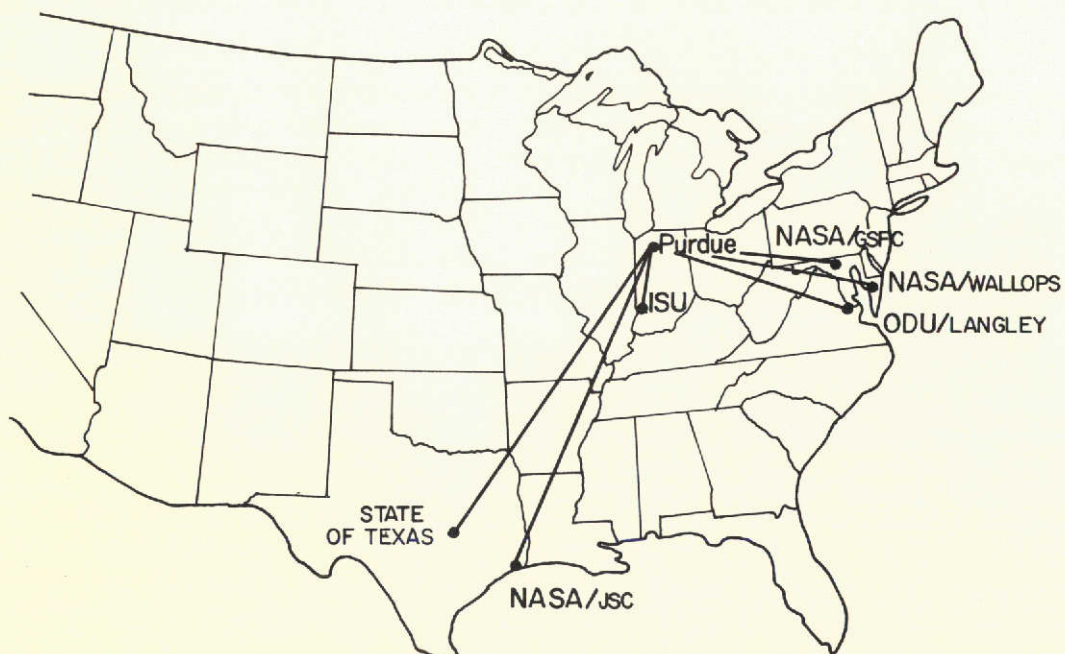Figure 16. Photograph of the LARSYS Version 3 Documentation.

Figure 17. Location of Remote Terminals Now Under Contract.

An important part of the remote terminal system has been the development of training materials. The materials presently consist of six mini-courses designed for individualized instruction, and employ a variety of media (Figure 18). A

Figure 18.   The LARSYS Remote Terminal Training Materials.

common background and orientation is provided by a programmed text. A tape/slide program gives the student an overview of the typical remote sensing data analysis sequence. After a demonstration of a remote terminal the student next gains hands-on experience at the remote terminal where he is aided by audio-taped directions (Figure 19). The final mini-course is a detailed guide to the analysis of multispectral data with case studies.

The terminal system has, so far, proven highly effective as a technology transfer method. More than 200 people have been trained on the system at various NASA centers. In order to now test the system in a true user environment, a self-funded terminal has recently been established in the Offices of the State of Texas. Further, another system will go on line this fall at Indiana State University, representing a still different type of environment in which to test the concept. Negotiations are also under way for location of a terminal in the EROS Data Center at Sioux Falls, South Dakota.
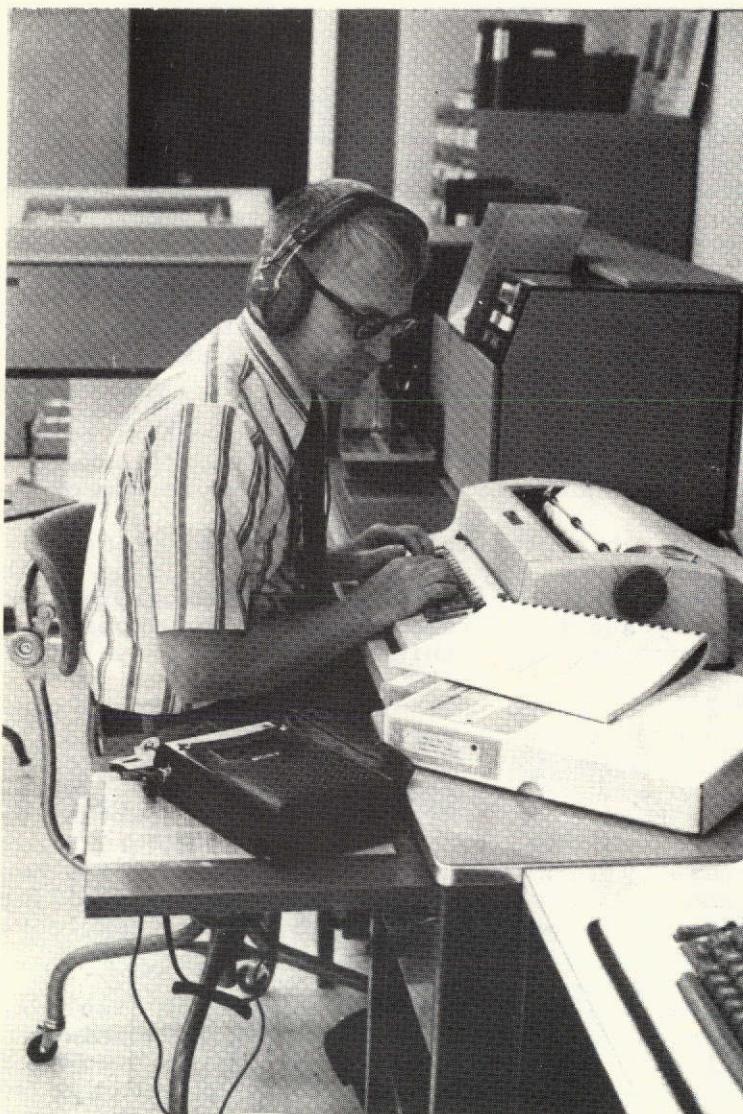
Figure 19. A Student Receiving Audio-
Tutorial Instruction at a Remote Terminal.

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 signifi-
cant amount of analysis of ERTS data. There remains the need
for development and integration of improved remote site hard-
ware in order that the system demonstrate its full potential
as a prototype operational system.

IV. Conclusions and Remarks on the Future

Figure 20 summarizes the major milestones achieved during
this research effort. One can see the continuous flow of
work, first moving completely in a research mode, then, as results
became available, beginning a trend towards testing of the
technology and application while at the same time continuing
research efforts.

Several major stems of the new technology were originated in this grant. Certainly the concept of using a type of multivariate analysis called pattern recognition was an important early development. This idea has been put to practice and its progression can be followed through the versions of LARSYS (Figure 20). Recognition of the need for a digital image data registration system and its early development were also carried out as part of this effort. Means for selecting optimal feature (spectral band) subsets was also another very significant development.

In the applications area, the recognition of different classes which might be identifiable and useful, first, in the field of agriculture and later in the entire spectrum of land and water uses, was an important and continuous line of development through this grant period. A number of major measurements capabilities, especially those involving calibration techniques and the development of a suitable spectroradiometer for both laboratory and field research have been important and notable developments under this grant.

It was earlier observed that much of the nation's capability for machine data processing of earth observational data is either directly or indirectly attributable to this research effort. There are a number of major elements which contributed to the success of this work. Perhaps the most important was the relationship established by NASA between NASA and Purdue. The responsiveness by both organizations to the other's needs, the effective and thorough communication and most of all, the mutual trust established were certainly of immeasureable value in the program.

We further believe that the team approach of highly specialized scientists resulted in more rapid and solid development than traditional approaches to research questions. In short, the total environment established at LARS we believed to be a useful prototype for attacking many societal problems where technology must first be researched and developed.

So far as the future is concerned, great though the achievements have been, the current capabilities must certainly be regarded as primitive in comparison to what ultimately can be brought into being. This suggests a two-pronged approach for the future. A strong effort must be carried out to bring into use in the varied user community the current capabilities represented by ERTS-type satellites and current processing methods.

A second effort conducted in parallel is needed to develop the second layer of the technology. Many areas have great potential for further development. The flight of ERTS-type satellites on a continuous basis makes available, in quantity, for the first time, multitemporal looks at the surface of the earth. Though much has been said about temporal analysis, little research in the area has been possible due primarily to lack of data availability. More sophisticated measuring devices, such as a

Skylab S192 type scanner operated on a continuous basis, will allow for the development of more sophisticated analysis algorithms, enabling the extraction of more accurate and more detailed information. Many long-standing problems still remain unsolved. For example, suitable means for designing on a quantitative basis the proper wavelength bands for a new scanner system on a quantifiable basis still elude us.

At Purdue we look forward to this next phase of work. Motivated by the need for this two-pronged effort, we have recently reorganized the LARS effort to conduct not only research activities, but technology transfer and applications activities as well. To this end we look forward to a continued association with NASA in whatever capacity seems mutually appropriate.

V. Acknowledgements

The list of people who made valuable contributions to this work is too long to recount here. Their names are recorded in the papers and reports listed in the Appendix. It is appropriate that those holding leadership roles at LARS be acknowledged. They are as follows:

Present LARS Program Leaders   Former LARS Program Leaders

Present LARS Program Leaders	Former LARS Program Leaders
P. E. Anuta	L. M. Eisgruber
M. F. Bauer	R. A. Holmes
M. F. Baumgardner	C. J. Johannsen
J. E. Cipra	R. B. MacDonald
R. M. Hoffer	
D. A. Landgrebe	
J. C. Lindenlaub	
J. B. Peterson	
T. L. Phillips	
B. F. Robinson	
L. F. Silva	
P. H. Swain	
R. A. Weismiller	

Figure 20. MAJOR MILESTONES OF THE LARS RESEARCH EFFORT

Year	Major Thrust	Data Collection	Data Processing	Applications
1964	Feasibility Studies	Multispectral Camera (Aircraft)	Photo Interpretation of Spectral Patterns	Identification of Natural Signatures
1965		DK-2 Laboratory		Laboratory Signatures
		Definition of Single Line of Sight Scanner		
1966	Definition of Approach	Multispectral Scanner (Aircraft)	Multi-level Slicing	Field Patterns
		Slow Scan Field Instrument		
1967	Development of Approach	Calibration Techniques Definition	LARSYS Version 1	Crop Classification-- 5 sq. miles
	Over Increasing			
1968	.Areas		Data Registration 1	Soils Classification
	.Disciplines		Feature Selection	Water Quality and Forest Classifications
	.Techniques			
1969		Multispectral Camera (Spacecraft)	LARSYS Version 2	Crop and Geologic Classification of Satellite Data
			Data Registration 2	
1970			Sample Classifier	ASCS Program Definition
			Data Compression	
			Clustering	Crop Yield Experiment
1971	Test of Technology	Single Line of Sight Scanner	Quasi-operational Data Processing	Corn Blight Watch Experiment
1972	Improvements of Techniques and Application to Spacecraft Data	Fast Scan Field Spectroradiometer	Remote Terminal Experiment	Crops, Soils, Geologic, Forests, Water, and Urban Land Use Classification over 1,000 - 13,000 sq. miles
		ERTS-1	Interactive Display	
		Ground Obser. From A/C		
1973	Evaluation of Technology and Definition of Large Scale Applications and Research Needs	SKYLAB	LARSYS Version 3	
			Geometric Correction	
			Temporal Analysis Capability	Crop Inventory Project
1974			Wavelength Band Selection	
			Educational Materials	

Figure 20. Major Milestones in the Research Effort.

Appendix

This appendix provides bibliographic information and, in most cases, abstracts of the 160 separate reports which have been previously provided to NASA as part of the reporting requirements of the grant. These reports are referred to as LARS Information Notes and, for record keeping purposes, they are each assigned a serializing number which is the month, day, and year on which the author made available the manuscript for duplication.

Figures 21, 22, and 23 are photographs of LARS Annual Reports Volumes 5 through 10-I. These volumes contain compilations of these reports as previously supplied to NASA.

It should be noted that a number of these reports have resulted from work cosponsored by other Contracts. During 1969-1971 this was work begun under the earlier USDA contracts referenced earlier. During 1972-1974 in nearly all cases (approximately 30 reports) the work itself was done under one of five ERTS or Skylab contracts; in this case, the contribution of Grant NGL 15-005-112 was for computer time only.
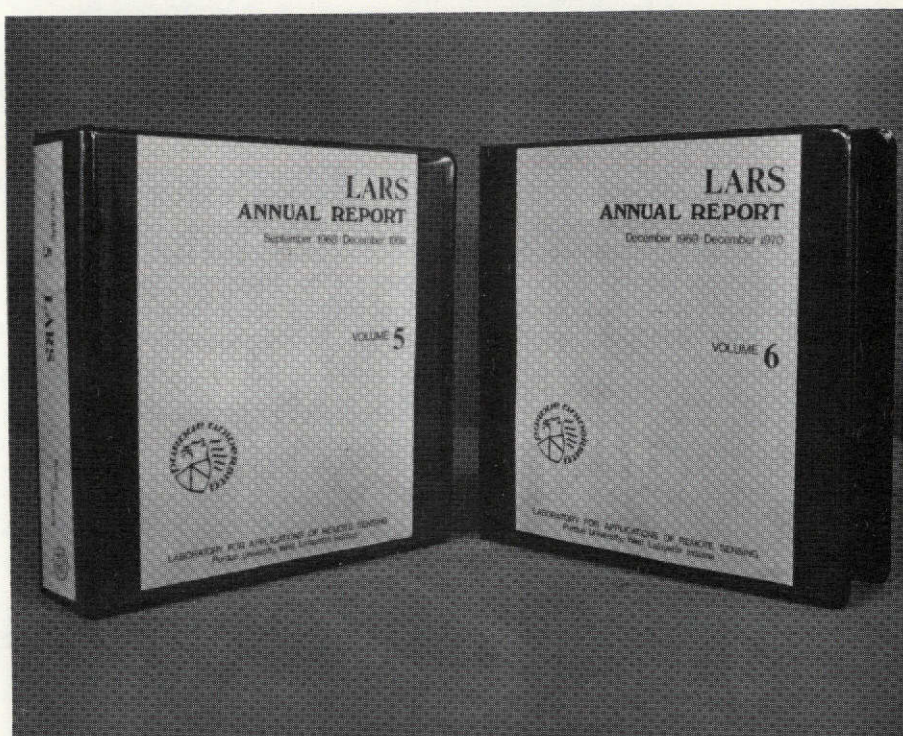
Figure 21. Photograph of LARS Annual Report Volumes 5 and 6.
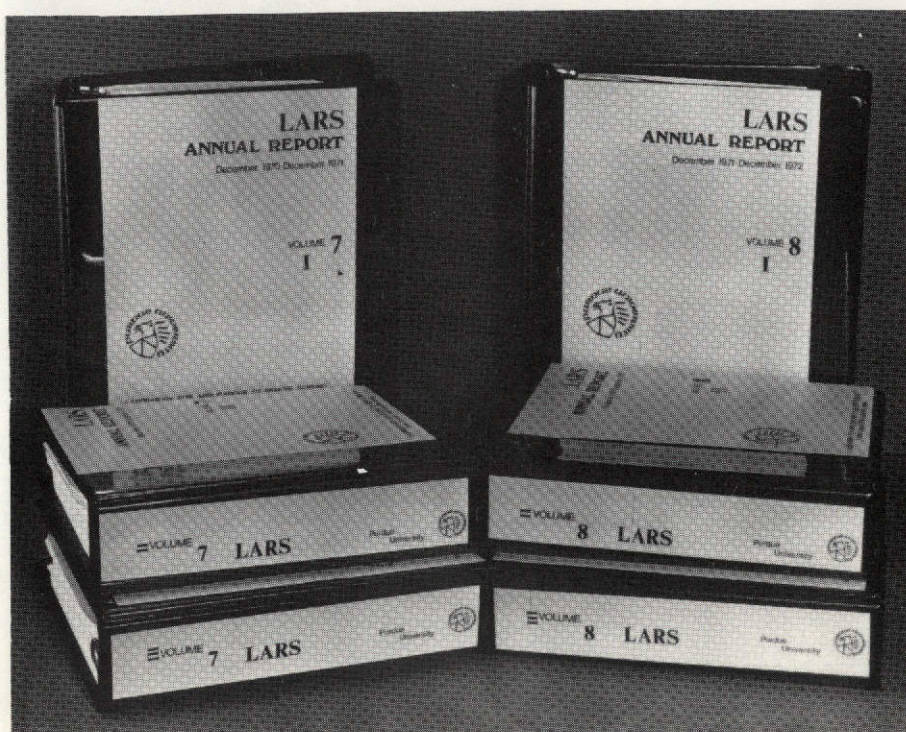

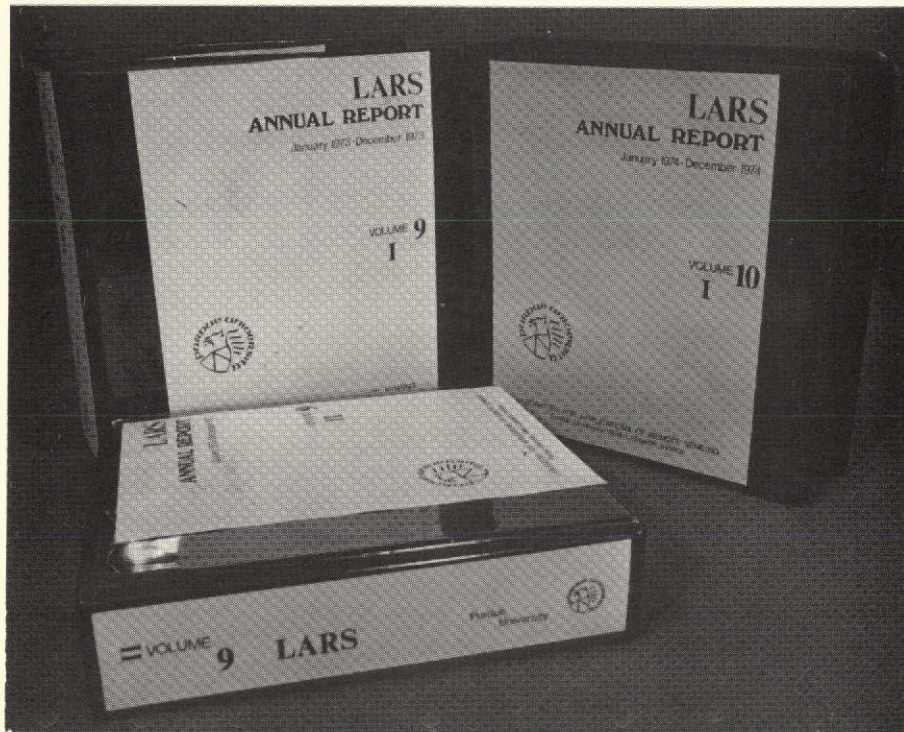Figure 22. Photograph of LARS Annual Report Volumes 7 and 8.

Figure 23. Photograph of LARS Annual Report
Volumes 9 and 10-I.

FY 6/1/69 - 5/31/70

060569* Huang, Teddy. Per Field Classifier for Agricultural Applications. 14 P.

062569* Stanley, W. S. Various Measures of Moisture Content of Air. 10 P.

071069* Phillips T. L. Calibration of Scanner Data for Operation Processing Programs at LARS. 7 P.

091569* Anuta, P. E. Digital Registration of Multispectral Video Imagery. Soc. of Photo-Optical Instrumentation Engineers, Vol. 7, No. 6, PP. 169-175.

120969* Staff. Steps Currently Recommended for a Standard Classification Task. 4 P.

121069* Anuta, P. Guide to Use of the Fast Fourier Transform Algorithm for Two Dimensional Imagery Correlation. 14 P.

121569* Phillips, T. The Implementation to the Maximum Likelihood Classification Rule Assuming a Gaussian Density Function with Addendum. 4 P.

122969* Wacker, A. A Cluster Approach to Finding Spatial Boundaries in Multispectral Imagery. 25 P.

030170* Breece, H. T., III and R. A. Holmes. BiDirectional Scattering Characteristics of Healthy Green Soybean and Corn Leaves in Vivo, Reprinted from Applied Optics, Vol. 10, P. 119, January 1971 9 P.

030270* Landgrebe, D. A. Data Analysis and Remotely Sensed Data. AIAA Earth Resources Observations and Information Systems Meeting, March 2-4, 1970, AIAA Paper No. 70-292. 14 P.

030570* Baumgardner, M., S. Kristof, C. Johannsen, A. Zachary. Effects of Organic Matter on Multispectral Properties of Soils. Proceedings of the Indiana Academy of Science for 1969. Nol. 79, PP. 413-422, 1970.

043070* Kristof, S. Preliminary Multispectral Studies of Soils. Journal of Soil and Water Conservation, Vol. 26, Number 1, PP. 15-18.

050170* Min, P., D. A. Landgrebe, and K. Fu. Feature Selection in Multiclass Pattern Recognition. 5 P.

051970* Swain, P. and K. S. Fu. Nonparametric and Linquistic Approached to Pattern Recognition.

*Supported in conjunction with another contract.

052270* Anuta, P. Spatial Registration of Multispectral and Multi-Temporal Digital Imagery Using Fast Fourier Transform Techniques. IEEE Transactions on Geoscience Electronics, Volume GE-8 (4) 353-368, 1970.

052770* Derry, J. A Preliminary Study of Image Quality Improvement Through Data Processing. 15 P.

*Supported in conjunction with another contract.

FY 6/1/70 - 5/31/71

070770* Anuta, P. Multispectral Classification of Crops in the Imperial Valley, California, from Digitized Apollo 9 Photography. 11 P.

072470* Robinson, B. and L. Silva. Portable Precision Thermistor Thermometer. 9 P.

083170* Staff. Southern Corn Leaf Blight. 16 P.

090870* Martin, T. Notes on an Experiment to Determine the Effect of Surface Geometry on the Emissivity of Water. 9 P.

091170* Staff. Southern Corn Leaf Blight, Status Report. No. 2. 17 P.

091470* Anuta, P. E. LARS/U. of Michigan Aircraft Scanner Data System Parameter Identification Study. 15 P.

093070* Smeded, H. W., K. L. Pierce, M. G. Tanguay, and R. M. Hoffer. Digital Computer Terrain Mapping from Multispectral Data. Reprinted from J. of Spacecraft and Rockets, Vol. 7, No. 9 PP. 1025-1031, Sept. 1970.

100570* MacDonald, R. A Look Ahead. 50 P.

101070* Landgrebe, D. A. Some Aspects of Remote Sensing Research. Presented at A.I.D. Symp. on Utility of Remote Sensing as An Aid to Developing Countries, Washington, D. C., November, 1970. 9 P.

102670* Whitsitt, S. Random Noise in Multispectral Classification. 31 P.

102870* Swain, P. H. and K. S. Fu. Stochastic Programmed Grammars for Syntactic Pattern Recognition. Reprinted from Pattern Recognition, Vol. 4, Great Britain. 17 P.

110970* LARS. Detection of Southern Corn Leaf Blight by Remote Sensing, Status Report. No. 3. 14 P.

111270* Johannsen, C. J. Detection of Available Soil Moisture by Remote Sensing Techniques. Also available as Ph.D. Thesis Purdue University, 1969. Dissertation Abstracts Order No. 70-8909. 1 P.

120170* Wacker, A. and D. A. Landgrebe. Boundaries in Multispectral Imagery by Clustering. 1970 IEEE Symp. on Adaptive Processes XI, PP. 4.1 - 4.8, December 7-9, 1970.

012671* Johannsen, C. J., M. F. Baumgardner, and D. Wiersma. Effect of Changing Soil Moisture on Corn Leaf Moisture. Proceedings of the Indiana Academy of Science for 1970, Volume 80, 1971. 7 P.

*Supported in conjunction with another contract.

012771* Horvath, E., O. Montgomery and B. Van Zile. The Effect of Altitude on the Multispectral Mapping of Soil Organic Matter. Proceedings of the Indiana Academy of Science for 1970. Volume 80, 1971. 7 P.

012871* Johannsen, C. J. and M. F. Baumgardner. Leaf Moisture Variation Within Corn Leaf Sections. Proceedings of Indiana Academy of Science for 1970, Volume 80, 1971. 8 P.

012971* Hoffer, R. and F. Goodrick. Geographic Considerations in Automatic Cover Type Identification. Proceedings of the Indiana Academy of Science for 1970, Vol. 80, 1971. 15 P.

020871 Swain, P. H. and A. G. Wacker. Comparison of the Divergence and B-Distance in Feature Selection. 9 P. The Bhattacharyya distance ("B-distance") is compared experimentally with the divergence as a criterion for feature selection in pattern recognition. The results obtained using B-distance generally approximate those obtained when the typewriter options available with LARS' divergence algorithm are used to best effect. This suggests that the B-distance offers a more automated approach to feature selection than has been available. A saturating function of the divergence is found to perform almost as well as B-distance, but is substantially more efficient in terms of the computations required.

021171* Landgrebe, D. Description and Results of the LARS/GE Data Compression Study. 32 P. The results of determining the effect of some General Electric Co. data compression scheme and noise on machine analyzed data is shown in Table 10, page 12. However, of perhaps more general interest are two points discussed on pages 13-15. These grapically illustrate 1) the importance of understanding interchannel correlation in data and 2) the relative importance of spectral band selection as compared to other system parameters such as data compression and noise.

021671* Hoffer, R. M. and F. E. Goodrick. DK-2 Multiple Spectral Plotting. 9 P. Over 2100 plant leaf spectra and 150 soil spectra were obtained by LARS staff during 1966 on a Beckman DK-2 spectrophotometer. Many results have been analyzed from this data and are reported in other LARS papers and reports.

This information note is to give information on what spectra are available and how students in remote sensing courses can use existing computer programs to analyze the data and become familiar with reflectance phenomena. Examples of different program options are given. Figure 1 and 2 are good examples.

022571 Atwell, B. Calibration of Thermal Channels of the University of Michigan Scanner. A tutorial exposition of a calibration procedure.

*Supported in conjunction with another contract.

032371* Anuta, P. and R. MacDonald. Crop Surveys from Multiband Photography Using Digital Techniques. Remote Sensing of Environment 2, PP 53-67, 1971. Results of "Per Point" and "Per Field" machine classification of Apollo IX digitized photograp are given. (See figures 8 through 10.) Techniques for training classifiers using clustering are described and results are compared for various spectral bands.

040671 Cipra, J. E., M. F. Baumgardner, E. R. Stoner, and R. B. MacDonald. Measuring Radiance Characteristics of Soil with a Field Spectroradiometer. The Soil Science Society of America Proceedings, Vol. 35, Number 6, November - December, 1971. 4 P.

041571 Landgrebe, D. A. Systems Approach to the Use of Remote Sensing. Presented at the International Workshop on Earth Resources Survey Systems, Ann Arbor, MI, May, 1971. 44 P. This paper is a tutorial discussion of earth resources information systems which utilize satellite as sensor platforms. It is begun by pointing out that information may be derived by sensing and analyzing the spectral, spatial and temporal variations of electromagnetic fields eminating from the earth surface. After giving an overview system organization, the two broad categories of system types are discussed. These are systems in which high quality imagery is essential and those more numerically oriented. Sensors are also discussed with this categorization of systems in mind.

The multispectral approach and pattern recognition are described as an example of data analysis procedure for numerically oriented systems. The steps necessary in using a pattern recognition scheme are described and illustrated with data obtained from Apollo IX. Both manual and machine aid training techniques are described for the pattern recognition algorithm.

041771 Atwell, R. H., R. B. MacDonald and L. A. Bartolucci. Thermal Mapping of Streams From Airborne Radiometric Scanning. Volume 7, No. 2, April, 1971, Water Resources Bulletin (Journal of the American Water Resources Association). PP. 228-242.

050571 Swain, P. and A. Wacker. Statistical Model for Data Acquisition Aircraft. 4 P. Solution to a problem in aircraft scheduling in the face of probable cloud conditions. Problem. Given N_1 flightlines to be covered in Q days. Assume on any given day that any flightline is "flyable" with probability p (independent of all other flightlines). However, due to limited resources, at most N_2 flightlines can be covered in a day.

What is the expected number of flightlines covered in Q days?

051371 Bauer, M. E., P. E. Anuta, P. H. Swain, R. B. MacDonald, and R. P. Mroczynski. Detection of Southern Corn Leaf Blight by Remote Sensing. Presented at the 7th International Symposium on Remote Sensing of Environment, May 17-21, 1971. Ann Arbor, MI. 20 P. Six levels of blight could be distinguished by ground observation. Three levels were detected by color infrared photography using standard photo-interpretation

*Supported in conjunction with another contract.

techniques. Up to five levels of infection were distinguished by
computer analysis of multispectral scanner data. The results of this
research led to the planning and execution of the Corn Leaf Blight
Watch Experiment currently being conducted. See Figure 2 for computer
classification of blight.

052771 Silva, L. F., J. E. Cipra and R. M. Hoffer. Extended Field
Wavelength Spectroradiometry. Presented at the 7th International
Symposium on Remote Sensing of Environment, PP. 1983-2016, Ann Arbor,
MI, May 17-21, 1971. The proper interpretation of multispectral scan-
ner data is enhanced by the use of spectral data taken under field con-
ditions. The application of such field data to the analysis of mul-
tispectral information may allow the interpretation of second order
differences in the airborne observations. A field spectral instrument,
therefore, should cover the wavelength range of multispectral scanners
currently in use. This paper describes an instrument capable of
covering the wavelength range from 0.37 micrometers to 14 micrometers
with a spectral resolution sufficient for proper interpretation of mul-
tispectral data. The instrument is rugged and capable of operation in
relatively adverse field conditons.

FY 6/1/71 - 5/31/72

061371   Anuta, P. E., S. Kristof, Et Al.   Crop, Soil and Geologi-
cal Mapping from Digitized Multispectral Satellite Photography.   Pre-
sented at the 7th International Symposium of Remote Sensing of Environ-
ment, PP. 1983-2016, Ann Arbor, Michigan, May 17-21, 1971

061471   Kristof, S. and A. Zachary.   Mapping Soil Types from
Multiband Scanner Data.   Presented at the 7th International Symposium
on Remote Sensing of Environment.   Ann Arbor, Michigan, May 17-21, 1971.
14P.   This study shows the first attempt at mapping conventional soil
series boundaries using multispectral scanner data and computer-
implemented pattern recognition techniques.   It was found that sur-
face properties such as roughness, surface color, texture, moisture
content and other factors greatly influence the results.

It was found that ratio values of visible to infrared response
were helpful in characterizing spectral properties of soil.   This has
lead to modeling studies which would consider the effects of soil
properties on spectral response important to satellite studies.   LARS
is currently working with the Soil Conservation Service in the use of
these techniques.   Figure 5 is a good example of mapping soil series.

061571   Hoffer, R. and F. Goodrick.   Variables in Automatic Clas-
sification over Extended Remote Sensing Test Sites.   Presented at the
7th International Symposium on Remote Sensing of Environment, Ann
Arbor, MI., May 17-21, 1971.   15 P.

061671   Stoner, E and E. Horvath.   The Effect of Cultural Prac-
tices on Multispectral Response from Surface Soil.   Presented at the
7th International Symposium on Remote Sensing of Environment, Ann
Arbor, MI., May 17-21, 1971.   15 P.

061771   Ready, P., P. Wintz, S. Whitsitt, and D. A. Landgrebe.
Effects of Compression and Random Noise on Multispectral Data.   Pre-
sented at the 7th International Symposium on Remote Sensing of Environ-
ment, Ann Arbor, MI., May 17-21, 1971.   23 P.

061871   Roth, C. and M. Baumgardner.   Correlation Study with
Ground Truth and Multispectral Data Effect of Size of Training Field.
Presented at the 7th International Symposium on Remote Sensing of
Environment, Ann Arbor, MI., May 17-21, 1971.   10 P.

071971   Hoffer, R. M.   Remote Sensing -- A Tool for Resource
Management.   Presented at the 3rd International Symp. on Hydrology.

072071   Ready, P., P. Wintz, and D. Landgrebe.   A Linear Trans-
formation for Data Compression and Feature Selection in Multispectral
Imagery.   48 P.   Some data compression techniques specifically designed
for multispectral image data were tested.   The techniques make use of
both spectral and spatial correlation in the data.   Results are sum-
marized in Figures 14 and 22.

091071 Hoffer, R. M., P. E. Anuta, and T. L. Phillips. Appli-
cation of ADP Techniques to Multiband and Multiemulsion Digitized
Photography. Presented at the American Society of Photogrammetry --
American Congress of Surveyors and Mappers, San Francisco, CA. „
Sept. 1971. 19 P. Reprinted in Photogrammetric Engineering as "ADP,
Multiband and Multiemulsion Digitized Photos", Oct. 1972, 13 P.
Automatic data processing (ADP) techniques using a digital computer
for data handling and analysis have allowed quantitative examination
of aerial photography. Scanning microdensitometer techniques were
utilized to digitize both multiband and multiemulsion photography.
This digital density data from 1:120,000 scale aerial photos were
spatially registered by computer and then analyzed, using statistical
pattern recognition algorithms. The feasibility for automatic recog-
nition of several cover types is indicated. Similar results were
obtained from the digitized multiband and multiemulsion photographic
data.

100671 Baumgardner, M. F. Agricultural Applications of Remote
Sensing. Presented at the Technical Consultation of the Application
of Remote Sensing to the Management of World Food and Agricultural
Resources Meeting, Sponsored by The Food and Agricultural Organization
of the U.S., Rome, Italy, September, 1971. 25 P. The responsibility
of agriculture to food and clothe the rapidly expanding population
of the world calls for a more adequate agricultural information system.
It is suggested that remote sensing and computer-implemented data
processing techniques may play a significant role in providing such
a system. A wide array of potential applications of remote sensing
to the development and management of agricultural resources is dis-
cussed.

100771 Wacker, A. and D. Landgrebe. The Minimum Distance
Approach to Classification. Also available as Ph.D. Thesis and as
Technical Report TR-EE 71-37, both from the School of Electrical
Engineering, Purdue University, January, 1972. 345 P.

102171 Riemer, T. Image Enhancement through Data Processing.
Under direction of C. McGillem. 26 P.

102771* Al-Abbas, H., P. Swain, and M. Baumgardner. Remote
Sensing Multispectral Radiance Response Versus Organic Matter and
Clay Content of Soils. 24 P.

110471 Lindenlaub, J. Remote Sensing Analysis. A Basic Prepara-
tion. 90 P.

111571 Hoffer, R. M. and L. A. Bartolucci. Calibration Techniques
for Remote Sensing Measurements of Water Temperature. Abridged
Version of 111671. 4 P. Proceedings of the Indiana Academy of Science
for 1971. 81 150-53. Remote sensing techniques, involving optical-
mechanical scanners mounted in aircraft, offer great potential for meet-
ing some of the needs for more quantitative information on our water
(and other) resources. One technique used in remote sensing allows
the absolute temperature of water surfaces to be determined from several

*Supported in conjunction with another contract.

thousand feet of altitude to within 0.5 degree Centigrade. Two methods
for calibration of thermal infrared scanner data were described. The
accuracy of these techniques was shown. The limitations of the cali-
bration procedures and use of airborne scanner systems were discussed.

111671 Hoffer, R. M. and L. A. Bartolucci. Remote Sensing Tech-
niques for Measurement of Water Temperatures. Proceedings of the Indi-
ana Academy of Science for 1971. 81 150-53. This paper is a larger
version of the paper appearing in 111571.

111771* West, T. R. Engineering Soils Mapping in Indiana by
Computer from Remote Sensing Data. Proceedings of the Indiana Academy
of Science for 1971. 81 210-16. As an example of the LARS mapping
technique, a detailed analysis of soils area in north-central Indiana
is presented. In this study the correct classification of sandy flood-
plain soils versus till plain soils was obtained from 98+% of the
ground area elements (remote sensing units) for the training fields.
Similarly a 76+% correct discrimination between the two materials was
made for the test fields in the flightline. This degree of accuracy
indicates that the analysis of these data using the LARS techniques
was successful in differentiating the materials sufficiently well to
be of considerable use in reconnaissance surveys.

120171* Birth, G. and G. Zachariah. A Spectrophotometer for
Biological Applications. Presented at the Quarterly Meetings of the
American Society of Agricultural Engineers, Chicago, Illinois. Decem-
ber, 1971. 12 P.

120271 Lindenlaub, J. and J. Keat. Use of Scan Overlap Redun-
dancy to Enhance Multispectral Aircraft Scanner Data. 24 P. The use
of scan-overlap redundancy to improve the signal-to-noise ratio of
multispectral scanner data is investigated. The trade-off between
poorer resolution and improved signal-to-noise ratio as a function of
the number of scan lines averaged is studied analytically. The line
averaging procedure is implemented and the effects upon classification
accuracy are studied.

120371 Hoffer, R. The Importance of Ground Truth in Remote
Sensing. Presented at the U.N. Panel Meeting of the Establishment
and Implementation of Research Programmes in Remote Sensing, Sao Jose
Dos Campos, Brazil. 12 P. Proper interpretation of remote sensor
data requires a good understanding of energy-matter interactions, and
is dependent upon adequate surface observation ("ground truth") infor-
mation concerning the characteristics of the materials being studied.
Several possible causes for variation in spectral response of vege-
tation cover are defined. The importance of temporal considerations
in the interpretation of remote sensor data is discussed, as well as
the platform altitudes and sensor systems and their relationship to
the types of surface observation data obtained. The advantages of an
interdisciplinary approach to various phases of remote sensing re-
search is also commented upon.

*Supported in conjunction with another contract.

122571* Sinclair, T. R., R. M. Hoffer and M. M. Schreiber. Reflectance and Internal Structure of Leaves from Several Crops During a Growing Season. Agronomy Journal 63 864-868, Nov-Dec 1971. The reflectance spectra from 500 to 2600 nm were measured for the leaves of six agronomic crops. Leaf samples were collected at three periods during the growing season; water content was determined and cross sections of the internal leaf structure were observed microscopically. The reflectance spectra of all fresh, green leaves were very similar. However, reflectance at all wavelengths increased as the crop matured and their leaves senesced. Decreased absorption by chlorophyll apparently increased the reflectance of the visible wavelengths (500 to 700 nm). Similarly, water loss accompanying senescence resulted in an increased reflectance in the far infrared wavelengths (1300 to 2600 nm). Changes in the internal structure of leaves caused increases in the near infrared wavelengths (700 to 1300 nm).

010672 Bauer, M. E. Remote Sensing as a Means of Detecting Crop Disease. 16 P.

010772* West, T. R. Engineering Soils Mapping from Multispectral Imagery Using Automatic Classification Techniques. Presented at the 51st Annual Meeting of the Highway Research Board, Washington, D.C. Jan., 1972. Number 421, PP. 58-65.

012172 Bauer, M. E. The Corn Blight Problem -- 1970 and 1971. Presented at the 4th Ann. Earth Resources Program Review. MSC, Houston, Texas. January, 1972. 19 P.

012272 Phillips, T. L. and Staff. 1971 Corn Blight Watch Experiment Data Processing Analysis, and Interpretation. Presented at the 4th Ann. Earth Resources Program Review. MSC, Houston, Texas, January, 1972. 20 P.

012372 Johannsen, C. J., M. E. Bauer, and Staff. Corn Blight Watch Experiment Results. Presented at the 4th Ann. Earth Resources Program Review. MSC, Houston, Texas. January, 1972. 22 P.

012472 Swain, P. H. and Staff. Data Processing I: Advancements in Machine Analysis of Multispectral Data. Presented at the 4th Annual Earth Resources Program Review, Manned Spacecraft Center, Houston, TX. Jan. 1972. 13 P.

012572 Landgrebe, D. A. Data Processing II: Advancements in Large-Scale Data Processing Systems for Remote Sensing. Presented at the 4th Annual Earth Resources Program Review, Manned Spacecraft Center, Houston, TX. Jan., 1972. 30 P.

012672 Baumgardner, M. F. and Staff. Differentiating Elements of the Soil-Vegetation Complex. Presented at the 4th Annual Earth Resources Program Review, Manned Spacecraft Center, Houston, TX. Jan. 1972. 24 P.

012772 Hoffer, R. M. and Staff. Land Utilization and Water Resource Inventories over Extended Test Sites. Presented at the 4th Annual Earth Resources Program Review, Manned Spacecraft Center, Houston, TX. Jan., 1972. 37 P.

*Supported in conjunction with another contract.

012872 Silva, L. F. and Staff. Measurements Program in Remote Sensing at Purdue University. Presented at the 4th Annual Earth Resources Program Review, Manned Spacecraft Center, Houston, TX. Jan., 1972. 34 P.

021072 Eisgruber, L. M. The Effect of Subsampling Ratios on Precision of Estimates from Remote Sensing. 27 P. Large-scale applications of remote sensing will frequently involve questions of sampling, since complete coverage of a large geographic region and subsequent analysis of data tend to become technically and economically infeasible. This paper presents a conceptual (three-stage) sampling model which can be useful for a variety of remote sensing applications. Empirical values of the error of estimate for one such application are also computed. The application in question is the estimation of corn in a given region. This empirical analysis is based on multispectral data collected over Western Indiana in conjunction with the Corn Blight Watch Experiment (1971).

030772 Wacker, A. G. and D. A. Landgrebe. Minimum Distance Classification in Remote Sensing. Presented at the 1st Symposium for Remote Sensing, Feb. 1972, Ottawa, Canada. 25 P. A study was begun to find ways to factor into the analysis process information about the spatial relationship between individual resolution elements of a digitally represented image. The original motivation was to seek classifier accuracy improvement over that which could be obtained when using spectral response alone. The minimum distance approach is such a method.

After first presenting the theory of the method, this information note compares results using this approach with those using spectral response alone. It also shows comparative results for parametric vs. nonparametric classifier implementations and various training procedures.

More complete results from this same study are given in LARS Information Note 100771.

030872 Eisgruber, L. M. Potential Benefits of Remote Sensing Theoretical Framework and Empirical Estimate. 16 P. This paper first defines the concepts of "social cost" and "social benefits" in the classical economic sense. A specific model, the so called "inventory adjustment model" is then presented and it is argued that this model is useful in assessing the appropriate magnitude of social costs for certain types of research and applications of remote sensing. This model is then used to analyze potential improvements of crop estimates (which are now provided by the U.S. Department of Agriculture, which affect the crop markets behavior, and which have economic significance for a wide spectrum of users). Marginal social benefits are computed for various levels of the error of production estimates for corn, soybeans, and wheat.

050572   Ready, P. J. and P. A. Wintz.   Multispectral Data Compression through Transform Coding and Block Quantization.   Ph.D., Thesis, School of Electrical Engineering, TR-EE 72-2, Purdue University, 1972.   149 P.   Transform coding and block quantization techniques are applied to multispectral data for data compression purposes.   Two types of multispectral data are considered, (1) aircraft scanner data, and (2) digitized satellite imagery.   The multispectral source is defined and an appropriate mathematical model proposed.

The Karhunen-Loeve, Fourier, and Hadamard encoders are considered and are compared to the rate distortion function for the equivalent Gaussian source and to the performance of the single sample PCM encoder.

Minimization of the total encoder system error over the number of retained transform coefficients and corresponding bit distribution for a fixed data rate and block size is considered and an appropriate solution proposed.   Minimization of the block size is considered and an approxiate solution proposed.   Minimization of the sampling error over the data block size for the continuous source is also considered.

The Karhunen-Loeve transformation is applied to the spectral dimension of the multispectral source and the resulting principal components are evaluated as feature vectors for use in data classification.

Experimental results using the transform encoder and several different (i.e., one-, two-, and three-dimensional) data blocks are presented for both the satellite and aircraft data sets.   Performance of the encoders over the three test regions within the satellite data are evaluated and compared.

FY 6/1/72 - 5/31/73

    060272 Jurica, G. M. and W. L. Murray. Influence of Haze Layers
Upon Remotely-Sensed Surface Properties. Presented at the Conference
on Atmospheric Radiation, Fort Collins, Colorado, August 7-9, 1972. 3P.
Aircraft measurements of surface-reflected solar radiation obtained
during 1971 displayed unexpected angular variations in brightness.
The possibility that haze layers below the aircraft may have contri-
buted to these relative measurements of scattered radiation has been
tested. Initial computations of the radiation scattered
by a typical haze layer yield a variation across the aircraft flight
path which agrees well with the observed data.

    080172* Anuta, P. E., T.L. Phillips, and D. A. Landgrebe. Data
Handling and Analysis for the 1971 Corn Blight Watch Experiment.
Presented at the National Telecommunications Conference, Houston, Tx.,
December, 1972. 16P. This paper presents the methodology developed
for storing, retrieving, analyzing the data, and disseminating the
analysis results for the 1971 Corn Blight Watch Experiment. An im-
portant part of the methodology was digital technique which was developed
for analysis of the multispectral scanner data. The conclusions are
that (1) the state-of-the-art of remote sensor data acquisition and
analysis was significantly advanced by this experiment and (2) the accurate
detecting of southern corn leaf blight by the remote sensing techniques
employed shows promise; however, technological advances in sensors,
calibration and analysis techniques are required to accurately detect
corn blight in earlier stages.

    080372 Hoffer, R. M. ADP of Multispectral Scanner Data for Land
Use Mapping. Presented at the 2nd Unesco/IGU Symposium on Geographical
Information Systems, Ottawa, Canada, August 1-9, 1972. 24P. Many
disciplines on long recognized needs for reliable, faster land use
information over large geographical areas. The use of MSS data in
ADP, including considerations in selecting classes, methods of classifi-
cation and a description of LARS computer hardware is discussed, followed
by prospective temporal work. The application of ADP techniques to
multispectral data has been proven feasible and will figure strongly
in the handling of temporal and spatial data taken over large geographical
areas.

    092972* Landgrebe, D. A., R. M. Hoffer, R. F. Goodrick and Staff.
An Early Analysis of ERTS-1 Data. 21 P. (Presented at the Earth Re-
sources Technology Satellite-1 Symposium, Goddard Space Flight Center,
Greenbelt, Md. September 29, 1972) A data set collected by ERTS-1
on the first data collection pass over the U.S. was provided to LARS/
Purdue for immediate analysis and evaluation. Special classes first
defined in lieu of ground information for the full data frame and two
sub-frames were augmented by a subsequent ground mission and related
to ground cover types using a computer classification procedure. Water
resources, geological features, and evidence of agricultural and forestry
activities were identified and classified.

*Supported in conjunction with another contract.

100272* MacDonald, R. B., M. E. Bauer, R. D. Allen, J. W. Clifton, and J. D. Erickson. <u>Results of the 1971 Corn Blight Watch Experiment.</u> 8th International Symposium on Remote Sensing of Environment, Ann Arbor, MI,. October 2-6, 1972. 33P. This paper describes the implementation of the CBWE, major results of the Experiment and their significance. Until publication of the final report this paper will probably be the only near-complete report describing major aspects of the Experiment.

100372 Cipra, J. E., P. H. Swain, J. H. Gill, M. F. Baumgardner, and S. H. Kristof. <u>Definition of Spectrally Separable Classes for Soil Survey Research.</u> 8th International Symposium on Remote Sensing of Environment, Ann Arbor, MI. Oct. 2-6, 1972. 5P.

100972 Hoffer, R. M. <u>Agricultural and Forest Resource Surveys from Space.</u> Presented at the 23 rd International Astronautical Congress, Vienna, Austria, October 9-14, 1972. 12P. Basic informational needs of various user groups and their relationship to the analysis of remote sensor data is discussed. A data analysis sequence for use with the remote sensor data is developed, followed by a discussion of the potentials for achieving even the most complex level of information requirements, as indicated by the results obtained by the 1971 Corn Blight Watch and the early analysis of ERTS-1 data in Oklahoma and Indiana. Applications of remote sensing to agricultural and forestry needs are also mentioned.

101472* Landgrebe, D. A. <u>Automatic Classification of Soils and Vegetation with ERTS-1 Data.</u> 9P. 8th International Astronautical Congress, Vienna, Austria, October 9-14, 1972. This paper is an abbreviated form of a more complete report entitled "Preliminary Findings from Analysis of ERTS Observations" presented at the NASA Goddard Space Flight Center, Greenbelt, Md., September 29, 1972.

102372 Kristof, S. J. and M. F. Baumgardner. <u>Changes of Multispectral Soils Patterns with Increasing Crop Canopy.</u> 30P. By using the orange portion of the visible spectrum to cluster relative radiance of the soils, we produced maps of soil patterns with a striking similarity to those of the aerial photography. These patterns became less distinct as the maize canopy increased. The reflective infrared bands were used to indicate areas where the maize had deteriorated due to infection or nutrient deficiency. Panchromatic aerial photography had been obtained in early May 1970 and multispectral scanner missions had been flown on May 6, June 30, August 11 and September 5, 1970 obtaining energy measurements in 13 wavelength bands.

.110872 Baumgardner, M. F., S. J. Kristof, and W. N. Melhorn. <u>Mapping of Soils and Geologic Features with Data from Satellite-Borne Multispectral Scanners.</u> To be presented at the 10 th International Congress of Soil Science, Moscow, U.S.S.R., August 12-20, 1974. 11P. The ERTS-1 satellite provides opportunity for quick inventory and assessment of geologic, soils, and vegetative cover aspects of large-scale areas. Collin County, Texas, a 2270 km^2 area of relatively simple geology and soil associations was chosen for initial study, using ERTS-1 4-channel multispectral scanner data analyzed by computer-implemented pattern recognition techniques developed at LARS. The results indicate excellent visual correlation, on a gross scale, between automatically produced maps and existing geologic and soils maps and field information.

* Supported in conjunction with another contract

110972 Zachary, A. L., J. E. Cipra, R. I. Diderickson, S. J. Kristof and M. F. Baumgardner. Application of Multispectral Remote Sensing to Soil Survey Research in Indiana. Presented at the ASA Meetings in Tucson, Arizona. 1972. 11P. This study compared computer-implemented mappings based on spectral properties of bare soil surfaces with mapping units of interest to soil surveyors. Some soil types could be differentiated by their spectral properties and the maps seemed useful for delineating boundaries between soils in many cases.

111072 Stoner, F. R. and M. F. Baumgardner. Multispectral Determination of Vegetative cover in Corn Crop Canopies. M.S. Thesis, June, 1972. School of Agriculture, Purdue University. 115P. This study compared computer-implemented mappings based on spectral properties of bare soil surfaces with mapping units of interest to soil surveyors. Some soil types could be differentiated by their spectral properties and the maps seemed useful for delineating boundaries between soils in many cases.

111172 Stoner, F.R., M.F. Baumgardner and P.H. Swain. Determining Density of Maize Canopy: I. Digitized Photography. 26p. Submitted to Agronomy Journal. This research studied the relationship between different densities of maize canopies and the energy reflected by these canopies. Spectral and spatial data were obtained from color and color infrared photographs taken 10 m above the maize canopies of selected plots. Microdensitometry and digitization of the three photographically separated dye layers of color infrared film showed that the near infrared dye layer is the most valuable in canopy density determinations. Computer analysis of the digitized photography provided an accurate method of determining canopy density.

111272 Stoner, F.R., M.F. Baumgardner, and J. E. Cipra. Determining Density of Maize Canopy: II. Airborne Multispectral Scanner Data. 16p. Submitted to Agronomy Journal. Leaf area index measurements were taken from twelve subplots during two overflights of an eleven-channel multispectral scanner. Ratios of scanner values related very well to leaf area index for a given flight date, but could not be generalized between data from different flights because of uncertainty in scanner response on different dates. The results indicate that spectral data from maize canopies could be of value in determining canopy density.

111372 Stoner, F.R., M.F. Baumgardner, P.F. Anuta and J.E. Cipra. Determining Density of Maize Canopy: III. Temporal Considerations. 32p. Submitted to Agronomy Journal. A set of ground reflectance panels were to normalize scanner data obtained on two different dates and to relate laboratory reflectance measurements to scanner response. Thus, ratios of scanner data could be related to leaf area index over time. Reflectance increased in the 0.72 to 1.3 μm wavelength range and decreased in the 0.65 μm chlorophyll absorption band as leaf area

increased. This confirmed the validity of using the ratio of the response from a near infrared wavelength band to that of the red wavelength band in relating multispectral scanner data to leaf area index in maize.

111472* Al-Abbas, A.H., R. Barr, J.D. Hall, F.L. Crane and M.F. Baumgardner. The Spectral Characteristics of Normal and Nutrient-Deficient Maize Leaves. Reflectance, transmittance and absorbance spectra of normal and mineral-deficient (N,P,K,S,Mg and Ca) maize leaves were analyzed using computer techniques at 30 wavelengths from 500 to 2600 nm. The results of the analysis of variance on reflectance, transmittance and absorbance showed significant differences (P=0.01) in the visible wavelengths among leaves with different nutrient treatments. These results should provide basic knowledge for the interpretation of air- and space-borne spectral measurements.

111572 Swain, P.H. Pattern Recognition: A Basis for Remote Sensing Data Analysis. 41p. Presented at the Short Course on Remote Sensing Technology and Application, Lafayette, Indiana. July 31-August 11, 1972. Pattern recognition plays a central role in numerically oriented remote sensing data analysis. This Information Note describes the theoretical basis for the pattern recognition algorithms used in LARSYS, the multispectral data analysis software system developed by the Laboratory for Applications of Remote Sensing.

111672 LeBlanc, P.H., C. J. Johannsen and J. E. Yahner. Land Use Classification Utilizing Remote Multispectral Scanner Data And Computer Analysis Techniques. M.S. Thesis, Purdue University. 1972. 98p. This research was designed to evaluate the utility of Multi-spectral scanner data and automatic data processing techniques to differentiate and map land use categories in a complex urban scene. Data were obtained over a small residential subdivision with an airborne multispectral scanner and were analyzed by pattern recognition techniques. Several surface features including trees and shrubs, grass, streets, driveways, and rooftops were easily separated and mapped by computer-implemented spectral analysis.

111772 McGillem, C.D. and T.E. Riemer. Moire Patterns and Two-Dimensional Aliasing in Line Scanner Data Acquisition Systems. 23p. IEEE Transactions on Geoscience Electronics. Jan. 1974. Vol. GE-12, No. 1, pp. 1-8. The basic mechanism underlaying the generation of Moire patterns in line scanner data acquisition systems is examined. A general expression is developed in terms of typical system parameters for the reproduced image of such systems and the interaction of the image spectrum; the raster frequency and digital sampling frequency of the A/D conversion process are discussed and examples given. System design requirements for avoiding Moire pattern generation and two-dimensional aliasing are discussed.

*Supported in conjunction with another contract.

111872 Emmert, R.A. and C. D. McGillem. Conjugate Point Determination for Multitemporal Data Overlay. Also available as a Ph.D. Thesis and as Technical Report TR-EE 73-5, both from the School of Electrical Engineering, Purdue University, 191p. The machine processing of spatially variant multitemporal data such as imagery obtained at different times requires that these data be in geometrical registration. The processor may then identify the datum for a specified ground resolution element in each of the sets of imagery being analyzed.
Misregistration between corresponding subsets of imagery contains both a displacement and a geometrical distortion component consisting of rotation, skew and scale change. The affine transformation is postulated to characterize this misregistration between data subsets. Search techniques utilizing the module of the Fourier transforms of these data are developed for estimating the coefficients of geometrical distortion components of this model. After correction of the distortion components, the displacement is located by the cross-correlation of a template obtained from one set of data, termed the reference, with the second, or background data. This template, derived for the optimum discrimination of the reference data embedded in the background, is determined by the solution of a system of equations involving the reference data, the covariance matrix of these data, and constraints on the magnitude and energy of the filter response.
An experimental evaluation of the registration technique is carried out for artificially generated images and for multispectral scanner images taken at different times.

011573 Jurica, G.M. Atmospheric Effects on Radiation Measurements. Presented at the Short Course on Remote Sensing Technology and Applications, Lafayette, Indiana. July 31 to August 11, 1972, 22p. The principles of radiative energy transfer relevant to remote sensing technology are briefly described. They are then utilized to assess the importance of the atmosphere in the remote detection of earth surface properties. It is concluded that through the removal of unwanted atmospheric effects the information extracted from remote sensing data can be increased.

022073* Duan, J.R. and P.A. Wintz. Error Free Coding. Presented at the 1973 Picture Coding Symposium, University of S. California, Jan. 22-24. 5p.

022373   Kumar, R. and L. Silva. Light Ray Tracing Through a Leaf Cross Section. Applied Optics, Vol. 12, No. 12, December, 1973. pp. 2950-2954.   A light ray, incident at about 5° to the normal, is geometrically plotted through the drawing of the cross section of a soybean leaf using Fresnel's Equations and Snell's Law. The optical mediums of the leaf considered for ray tracing are: air, cell sap, chloroplast and cell wall. The above ray is also drawn through the same leaf cross section considering cell wall and air as the only optical mediums. The values of the reflection and transmission found from ray tracing agree closely with the experimental results obtained using a Beckman KD-2A Spectroreflectometer.

*Supported in conjunction with another contract.

022473 Kumar, R. and L. Silva. Reflectance Model of a Plant Leaf. 28p. A light ray is plotted through the drawing of the cross section of a soybean leaf geometrically using Fresnel's Equations and Snell's Law. The values of reflection and transmission from the ray tracing agree closely with the experimental results.

022573 Riemer, T.E. and C.D. McGillem. Constrained Optimization of Image Restoration Filters. Applied Optics, Sept. 1973, Vol. 12, No. 9. pp. 2027-2029. A linear shift-invariant preprocessing technique is described which requires no specific knowledge of the image parameters and which is sufficiently general to allow the effective radius of the composite imaging system to be minimized while constraining other system parameters to remain within specified limits.

022673 Riemer, T.D. and C.D. McGillem. A Linear Shift-Invariant Image Preprocessing Technique for Multispectral Scanner Systems. A linear shift-invariant image preprocessing technique is examined which requires no specific knowledge of any parameter of the original image and which is sufficiently general to allow the effective radius of the composit imaging system to be arbitrarily shaped and reduced, subject primarily to the noise power constraint. In addition, the size of the point-spread function to the preprocessing filter can be arbitrarily controlled, thus minimizing truncation errors.

022773 Todd, W.J., P.W. Mausel and M.F. Baumgardner. An Analysis of Milwaukee County Land Use By Machine-Processing of Earth Resources Technology Satellite Data. 28p. Land use information systems are becoming increasingly important to investigators interested in large urban complexes. The Milwaukee County subframe (ERTS pass of 8/9/73) was dissected into a number of spectral classes including "suburban," "wooded suburb," "industry," "inner city," "grassy (open areas)," "water," "cloud," and "shadow." Classifications providing such information in the future should be of great use to the urban planner.

022873 Todd, W., P.Mausel and K. Wenner. Preparation of Urban Land Use Inventories by Machine Processing of ERTS MSS Data. Presented at the Symposium on Significant Results Obtained from ERTS-1, Goddard Space Center, Greenbelt, Md., Mar. 5-9, 1973. Spectral classes of urban phenomena identified from Earth Resources Technology Satellite (ERTS) multispectral scanner data in Milwaukee included "Suburban", "Inner City", "Industry", "Grassy" (open area), "Road", Wooded Suburb", "Water", "Cloud", and "Shadow". The Milwaukee spectral class statistics were used to classify the Chicago area, within the same ERTS frame, and similar results were achieved. In another ERTS frame, Marion County (Indianapolis) data were classified into similar classes. The Marion County ERTS study was supported by a land use classification of an area near downtown Indianapolis that utilized 12-band MSS data collected by aircraft from 3000 feet. The results of the ERTS analyses suggest that satellite data will be useful tool for the urban planner for monitoring urban land use.

030173* Bauer, M.F. and J. E. Cipra. Identification of Agricultural Crops by Computer Processing of ERTS MSS Data. 9p. Presented at the Symposium on Significant Results Obtained from ERTS-1, Goddard Space Flight Center, Greenbelt, Md. March 5-9, 1973. Quantitative evaluation of computer-processed ERTS MSS data classifications has shown that major crop species (corn and soybeans) can be accurately identified. The classifications of satellite data over a 2000-square mile area not only covered using aircraft, but also yielded improved results through the use of temporal and spatial data in addition to the spectral information. Furthermore, training sets could be extended over far larger areas than was ever possible with aircraft scanner data. And, preliminary comparisons of acreage estimates from ERTS data and ground-based systems agreed well. The results demonstrate the potential utility of this technology for obtaining crop production information.

030273* Melhorn, W., and S. Sinnock. Recognition of Surface Lithologic and Topographic Patterns in Southwest Colorado with ADP Techniques. 12p. A slightly smaller version under the same title was presented at the Symposium on Significant Results Obtained from ERTS-1, Goddard Space Flight Center, Greenbelt, Md. March 5-9, 1973. Analysis of ERTS-1 multispectral data by automatic pattern recognition procedures is applicable toward grappling with current and future resource stresses by providing a means for refining existing geologic maps. The procedures used in the current analysis already yield encouraging results toward the eventual machine recognition of extensive surface lithologic and topographic patterns. Automatic mapping of a series of hogbacks, strike valleys, and alluvial surfaces along the northwest flank of the San Juan Basin in Colorado can be obtained by minimal man-machine interaction. The determination of causes for separable spectral signatures is dependent upon extensive correlation of micro- and macro- field-based ground truth observations and aircraft underflight data with the satellite data.

030373*[1]Baumgardner, M.F., S.J. Kristof and J.A. Henderson. Identification and Mapping of Soils, Vegetation, and Water Resources by Computer Analysis of ERTS MSS Data. Presented at the Symposium on Significant Results Obtained from ERTS-1 Data, Goddard SFC, Greenbelt, Md., March 5-9, 1973. Multispectral scanner data from the Earth Resources Technology Satellite (ERTS) were analyzed by supervised and non-supervised computer implemented techniques. Data from ERTS passes on 9 October, 14 November, and 2 December were overlayed and used in the spectral analysis of Lynn County, Texas. Best classification results for row crops, bare soil, forages, rangelands, and urban classes were obtained with the 9 October ERTS data.

*Supported in conjunction with another contract.
[1]This presentation has not been published.

030573 Coggeshall, M.E. and R.M. Hoffer. Basic Forest Cover Mapping Using Digital Remote Sensor Data and ADP Techniques. M.S. Thesis, Purdue University. 131p. Remote sensing equipment and automatic data processing techniques offer much potential for the procurement of information necessary to meet the demand for more intensive management of our forest resources.

On the basis of automatically calculated statistics derived from manually selected "training" samples, the feature selection Processor of LARSYS was directed to select, upon consideration of various groups of the four available spectral regions, a series of "best" channel combinations whose automatic classification performances (for six cover types, including both deciduous and coniferous forest) were tested, analyzed and further compared with automatic classification results obtained from digitized color infrared photography.

Results indicate: 1) that the use of five, of the available 12, channels offers an acceptable compromise between classification accuracy and computer time; 2) that five channels (one each from the visible green and red, and the near, middle and thermal infrared) can classify basic forest cover with accuracies well in excess of 90 percent; 3) that a combination of the visible region plus either the near or middle infrared will provide sufficient spectral information for accurate basic forest cover mapping; and 4) that the qualitative nature of photographic data does not lend itself to reliable quantitative analysis.

030773 Kristof, S.J., M.F. Baumgardner and C.J. Johannsen. Spectral Mapping of Soil Organic Matter. 15p. Multispectral remote sensing data were examined for use in the mapping of soil organic matter content. Computer-implemented pattern recognition techniques were used to analyze data collected in May 1969 and May 1970 by an airborne multispectral scanner over a 40-km flightline. Two fields within the flightline were selected for intensive study. Approximately 400 surface soil samples from these fields were obtained for organic matter analysis. The analytical data were used as training sets for computer-implemented analysis of the spectral data.

It was found that within the geographical limitations included in this study, multispectral data and automatic data processing techniques could be used very effectively to delineate and map surface soils areas containing different levels of soil organic matter.

030873[1] Stockton, J. The influence of Internal Drainage on Multispectral Reflectance from Surface Soils. Presented at the Meetings of the American Society of Agronomy, Miami, Florida. Nov., 1972. The relationships between internal soil drainage and multispectral reflectance were examined to determine if an internal soil drainage map could be obtained using multispectral reflectance measurements.

A correlation coefficient of 0.84 was obtained for internal drainage class vs. multispectral response. The internal drainage map produced exhibited a test accuracy of 83.2%. The map produced appears to be quite acceptable.

[1]This presentation has not been published.

031573 Landgrebe, D.A. Machine Processing for Remotely Acquired Data. A slightly revised version of this paper will be published as a chapter in Remote Sensing of Environment, edited by Joseph Lintz, Jr. and David S. Simonett, C 1974, Addison-Wesley Publishing Co., Reading, Mass. 46p. This paper presents a general discussion intended to introduce the prospective user to multivariate data analysis techniques as applied to the processing of remotely acquired earth observational data. Not only are numerically-oriented remote sensing systems discussed, but attention is given to image-oriented systems, the other main branch of remote sensing, in order to establish the relationship between the two.

031673* Henderson, J.A., J.V. Gardner and J.E. Cipra. An Interpretation of a Geologic Map of Fannin County, Texas, Prepared by ADP Techniques from ERTS MSS Data. Presented at the 2nd Annual Remote Sensing of Earth Resources Conference. University of Tennessee Space Institute, Tullahoma, Tenn. March 26-38, 1973. 10p. ERTS MSS Data from Fannin County, Texas were analyzed to investigate the possibility of detecting geologic changes in an agricultural area from satellite altitudes. Digital MSS data were analyzed using the LARSYS software system and results were displayed on printouts using the LARSYS software system and results were displayed on printouts from a line printer and also on a digital image display system. The results from these analyses seem to show that gross lithologic changes can be distinguished if changes in vegetation and soils reflect changes in lithology.

040373* Sinclair, T.R., M.M. Schreiber, and R.M. Hoffer. Diffuse Reflectance Hypothesis for the Pathway of Solar Radiation Through Leaves. Agronomy Journal, 65 276-83, March-April, 1973. The Willstätter and Stoll theory explains leaf reflectance as criterical or total reflection of light at cell wall-air interfaces of spongy mesophyll tissue, and is based on observations of the spectral properties of leaves in the visible wavelengths. Our data, obtained in the 0.72 to 1.3 µm (reflective infrared) wavelengths, showed that unexpectedly high levels of reflectance occurred from palisade tissue and from dehydrated leaves that had collapsed internal structures.
    A modification of the Willstatter-Stoll theory, termed the diffuse reflectance hypothesis, allows a satisfactory explanation of the observed spectral properties of leaves in the reflective infrared, as well as the visible wavelengths.

041773 Kettig, R.L. and D. A. Landgrebe. Automatic Boundary Finding and Sample Classification of Remotely Sensed Multispectral Data. 36p. Initial methods for analyzing earth observation data involved the use of only spectral variations measured from the scene. The work reported in this paper provides a method for making some use of spatial variations as well. The results of some very preliminary tests of this new method show significant improvements in accuracy.

*Supported in conjunction with another contract.

042373 Bartolucci, L.A., R.M. Hoffer, and T. R. West. Automatic Data Processing of Remotely Sensed Data for Temperature Mapping of Surface Water. 143p. M.S. Thesis, August, 1973, Dept. of Geosciences, Purdue University. A necessary aspect of any adequate water quality regulating procedure is a rapid and accurate data acquisition and processing system. Currently, computer-aided processing of remotely sensed data offers a satisfactory method for accurate determination of certain water quality parameters, " a significant one being surface water temperature.

In this study, quantitative determinations of water temperatures and thermal mapping of streams and water bodies over two areas in Indiana were accomplished through the use of "internal scanner calibration" and computerized data processing techniques developed at LARS.

In this way, water-temperature maps were produced with accuracies of 0.2^oC from emissive infrared data collected at an altitude of 1,5000 meters. In addition, the effects of the non-linear relationship between emitted energy by a black body and its temperature were analyzed, and the influence of the atmosphere on the accuracy of radiant temperature measurements was determined for different flight altitudes. Finally, a "scan-line averaging" technique and a "layered classifier" were utilized as a processing sequence for the effective application of remotely sensed data to thermal mapping of surface water for use on an operational basis.

042473 Mikhail, E.M. and J.R. Baker. Geometric Aspects and Digital Analysis of Multispectral (MSS) Data Arrays. Presented at the American Society of Photogrammetry, Spring Convention, Washington, D.C. March 7-11, 1973. pp. 528-62. MSS data arrays were altered in an effort to improve them geometrically and thus generate a map-like orthographic projection image. These alterations were performed only after analyses of the following were conducted: perturbations in aircraft orientation; effects of panoramic recording and topographic image displacement; and restitution by projection equations, polynomials and interpolative procedures. Results are not yet complete, though it is evident that the processed data have improved geometrical quality.

042673 Swain, P.H. and R.C. King. Two Effective Feature Selection Criteria for Multispectral Remote Sensing. 5p. Presented at the International Joint Conference on Pattern Recognition, Washington, D.C. November, 1973. This paper relates the results of an empirical study aimed at characterizing quantitatively the relations between probability of error and statistical distance measures used for feature selection in multiclass pattern recognition. It has been possible to substantiate that Jeffreys-Matusita Distance and a saturating transform of divergence are effective feature selection criteria and, further, to explain why this should be the case.

042773[1] Bauer, M.D. and J.E. Cipra. Effects of Systemic and Non-Systemic Stresses on the Multispectral Reflectance of Corn. Presented at the Annual Meetings of the American Society of Agronomy, Miami, Florida. November, 1972. Measurements of multispectral reflectance were made of many Indiana corn fields throughout the 1971 growing season as part of the Corn Blight Watch Experiment. Compared to healthy corn, southern corn leaf blight infection increased reflectance in the chlorophyll absorption wavelengths and decreased reflectance in the green and reflective infrared wavelengths. These relationships were utilized in classifying the fields into blight severity levels. Further studies utilizing a field spectroradiometer are being conducted to determine the multispectral reflectance of stressed corn. The stresses are southern corn leaf blight, water deficits, and nutrient deficiencies. The experiment objectives are to determine (1) the threshold of detectability by remotely sensed measurements of systemic and non-systemic stresses of corn and (2) the kind and magnitude of change in spectral response as the severity of stress increases. The results will be evaluated in terms of the potential for identifying the vigor and productivity of crop fields using multispectral reflectance measurements made from air- and spacecraft.

042873* Mathews, H.L., R.L. Cunningham, J.E. Cipra and T.R. West. Application of Multispectral Remote Sensing to Soil Survey Research in Southeastern Pennsylvania. Published in the Soil Science Society of America proceedings. 1973. Computer analyses of multispectral imagery collected from aircraft shows promise for reducing preparation time and increasing the accuracy of soil survey maps. The study area in southeastern Pennsylvania included soils formed from limestone, shale, sandstone, alluvium, and local colluvium. Four study sites ranging in size from 8.5 to 30 ha were selected from a 72 km flightline. Surface reflectance properties of nonvegetated fields were classified using pattern recognition techniques. Computer printout maps showing areal distribution of soil spectral classes were compared with field conditions. Limestone, shale, sandstone, and local colluvial soils were separated with a high degree of accuracy. Erosion classes separated by spectral maps were comparable in location and extent to field observations. The feasibility of preparing computer display maps for potential use as soil mapping aids was demonstrated.

052073[1] West, T.R. Computer-Aided Analysis of Multispectral Remote Sensing Data Applied to Highway Engineering Geology. Presented at the First Pan American Symposium on Remote Sensing, April 27-May 2, 1973, Panama City, Panama.

052173[1] Bartolucci, L.A., R.M. Hoffer and J.R. Gammon. Effects of Altitude and Wavelength Band Selection on Remote Measurements of Water Temperature. Presented at the First Pan American Symposium on Remote Sensing, April 27-May 2, 1973, Panama City, Panama.

*Supported in conjunction with another contract.
[1]This presentation has not been published.

FY 6/1/73 to 5/31/74

061873 Todd, W.J., P.W. Mausel and M.F. Baumgardner. Urban Land Use Monitoring from Computer-Implemented Processing of Airborne Multispectral Sensor Data. Large metropolitan areas are in need of timely, accurate land use data. Twelve bands of multispectral data collected by airplane from 2000 feet over a portion of the West Fork White River near downtown Indianapolis were analyzed by computer-implemented processing. A land use classification was obtained, with good to excellent recognition of rooftops (three types), roads (two types), coarse grasses (two types), sparse grass (two types), trees, bare soils, water (two types), and shadows. The work described in this report was sponsored by NASA under Grant No. 15-005-112.

062273 Landgrebe, D.A. Analysis Research for Earth Resource Information Systems: Where Do We Stand? 27P. Presented at the 19th Annual Meeting of the American Astronautical Society, Dallas, Texas. June 19-21, 1973. This paper discusses some aspects of future operational earth resource information systems from the vantage point of machine data processing research now being conducted. It illustrates the advantages of a data system of large dynamic range, discusses the very large decreases in cost of machine processing which will be possible in an operational environment, and discusses how this complex technology can be available to a large, diverse user community providing the needed centralization for economy and at the same time giving the required flexibility to each individual user.

062573* Leamer, R.W., V.T. Myers and L.F. Silva. A Spectroradiometer for Field Use. Review of Scientific Instruments. Vol. 44, No. 5, May 1973. The configurations and operation of a field spectroradiometer system that measures the intensity of incident and reflected radiation from .37μm to 2.52μm and emitted radiation from 2.76μm to 13.88μm are described. The entire system is designed to operate in an outdoor environment. Provision has been made for photographic annotation of the field data set ups.

062773* Gupta, J.N. and P.A. Wintz. Closed Boundary Finding Feature Selection and Classification Approach to Multi-Image Modeling. 31P. A boundary algorithm is developed involving the image characteristics such as grey level edges and neighboring second order statistical properties of the data set. A comparison has been made between two methods of feature selection and it is observed that K-L transformation technique of feature selection is superior to the Minimum Transformed Divergence method of feature selection for boundary finding.

*Supported in conjunction with another contract.

062873   Lindenlaub, J.C.   Guide to Multispectral Data Analysis Using LARSYS.   80P.   Part of the LARSYS Educational Package, the Guide presents a detailed breakdown of the philosophy of multispectral data analysis methods.   Steps in the analysis are described, explanations of why they are necessary are given and explanations of how the steps are carried out are presented.   A detailed example parallels the description and the reader is urged to carry out a coordinated case study in conjunction with his study of the Guide.

071373*   Robertson, T.V. and K.S. Fu.   Multispectral Image Partitioning.   96P.   Also available as a Ph.D. Thesis and Tech. Report TR-EE 73-26, both from the School of Electrical Engineering, Purdue University, August, 1973.   An algorithm is presented that divides a multispectral image into successively smaller parts until all parts larger than a certain minimum size are likely to contain a single target entity.   The algorithm is modelled theoretically and shown to produce an arbitrarily good portion of an idealized image.   The algorithm is used to recognize crops and cities in remotely sensed images, and to partition a chest radiograph and a photograph of a girl.

072473   Kumar, R. and L. Silva.   Emission and Reflection From Healthy and Stressed Natural Targets with Computer Analysis of Spectroradiometric and Multispectral Scanner Data.   Also available as Ph.D. Thesis and as Technical Report TR-EE 73-37, both from the School of Electrical Engineering, Purdue University, December, 1973. 427P. The purpose of this research is to study the emission and reflection from healthy and stressed natural targets, with special emphasis on corn plants.   The study includes: Infrared Radiometry of Plants, Reflectance Model of a Plant Leaf, Simplified Thermal Emission Model of a Plant Canopy, Field Experiments with Longwavelength Spectroradiometer and Analysis of Multispectral Scanner Data of Blighted Corn Plants in Selected Flightlines.

072673   Mausel, P.W. and C.J. Johannsen.   An Application of Remotely-Sensed Data to Agricultural Land Use Distribution Analysis. The Professional Geographer.   Vol. XXV, No. 3. August, 1973. PP. 242-247.   This paper explores the background, procedures and potentials of computer-aided analysis of multispectral data as applied to a problem of geographic and remote sensing interest.   This includes (a) a classification of basic land use classes, (b) a check on the accuracy, (c) a computer-implemented determination of land uses as a function of distances from roads, (d) an analysis of the statistical significance of variations of land use from one location to another and (e) a discussion of selected geographic implications.

091273   Lindenlaub, J.C.   The LARSYS Educational Package.   Instructor's Notes. 44P.

*Supported in conjunction with another contract.

091373 Lindenlaub, J.C. The LARSYS Software System. An Overview. 135P.

100773 Landgrebe, D.A., F.C. Billingsley, and J.D. Nichols. Machine Processing Methods for Earth Observational Data. Presented at the International Astronautical Federation Congress, Baku, USSR. October 7-13, 1973. A brief review of the development over the last decade of earth resource informations systems is presented. Machine data preprocessing and analysis methods are surveyed and illustrated. These include preprocessing steps intended to modify geometric and radiometric aspects of earth observational image data to enhance the ability of either human interpreters or machine algorithms to extract information from data. Illustrations of processed and analyzed images from spaceborne sensors including the Earth Resources Technology Satellite are discussed.

101073 Levandowski, D.W., T.V. Jennings and W.T. Lehman. Applications of ERTS-1 Imagery to Mapping of Lineaments Favorable to the Localization of Ore Deposits in North Central Nevada. Proceedings of the meeting of the Geologic Society of America and related societies, Nov. 14, 1973. 19P. The purpose of this study is to demonstrate the value of ERTS-1 data as a supplement to mineral reconnaissance techniques. An iso-lineament intersection map prepared from composite color images at north-central Nevada indicates a strong correlation between major intersection areas and domal areas associated with mineral districts. Based on this correlation, two major intersection areas with no known associated ore deposits are integrated to be buried domal areas and potential exploration targets.

101373 Swain, P.H., T.L. Phillips and J.C. Lindenlaub. The Role of Computer Networks in Remote Sensing Data Analysis. Proceedings of the Conference on Machine Processing of Remotely Sensed Data, Laboratory for Applications of Remote Sensing, Purdue University, W. Lafayette, Indiana. October, 1973. IEEE Catalog No. 73 CHO 834-2 GE. PP. 1A-12 to 1A-18. For remote sensing data analysis, a time sharing-based computer network offers several potentially significant advantages over dispersed, unconnected computer facilities. In order to evaluate the merits of such a computer network, a prototype remote sensing data processing system consisting of a central computer located at LARS and terminals at various remote sensing organizations has been established. This paper discusses the rationale for such a system and some of the details of a project designed to provide an indication as to how computer networks might be used in the future to provide data analysis facilities to geographically dispersed users of remote sensing data.

101473 Emmert, R.A. and C.D. McGillem. Multitemporal Geometric Distortion Correction Utilizing the Affine Transformation. Proceedings of the Conference on Machine Processing of Remotely Sensed Data, Laboratory for Applications of Remote Sensing, Purdue University, W. Lafayette, Indiana. October, 1973, IEEE Catalog No. 73 CHO 834-2 GE. PP. 1B-24 to 1B-32. The misregistration between data subsets is

modeled by an affine transformation. The properties of the Fourier transform of a two-dimensional function under the affine transformation are given, and examples of these relations between the spatial and spatial frequency domains are shown. Techniques for the estimation of the coefficients of the distortion model using the spatial frequency information are developed, and an example of the use of this method for the correction of line scanner imagery is given.

101573* Ellefsen, R., P.H. Swain and J.R. Wray. Urban Land-Use Mapping by Machine Processing of ERTS-1 Multispectral Data: A San Francisco Bay Area Example. Proceedings of the Conference on Machine Processing of Remotely Sensed Data, Laboratory for Applications of Remote Sensing, Purdue University, W. Lafayette, Indiana. October, 1973, IEEE Catalog No. 73 CHO 834-2GE. PP. 2A-7 to 2A-22. Classification of ERTS-1 data for urban land-use applications was achieved by grouping twenty-eight spectral classes into eleven functional classes. Reliability was checked by comparing computer results to contemporaneous high-altitude color air photographs on a pixel-by-pixel basis. Performance results are excellent considering the grossness of the data and the complexity of the urban landscape.

101673* Todd, W.J., and M.F. Baumgardner. Land Use Classification of Marion County, Indiana by Spectral Analysis of Digitized Satellite Data. Proceedings of the Conference on Machine Processing of Remotely Sensed Data, Laboratory for Applications of Remote Sensing, Purdue University, W. Lafayette, Indiana. October, 1973. IEEE Catalog No. 73 CHO 834-2GE. PP. 2A-23 to 2A-32. 9 pages. Land use planners would benefit from the periodic updating of data banks by computer analysis of ERTS MSS data. Four bands of digitized, multispectral data collected by ERTS-1 on 30 September, 1972 over Marion County, Indiana were analyzed by machine processing to obtain an urban land use classification. Spectrally separable classes used in the classification scheme, which was tested to be 87 per cent accurate, included commerce/industry, multifamily (older) residential, single-family (newer) residential, grassy (open, agricultural) areas, woodland, water, cloud, and cloud shadow.

101773 Cipra, J.E. Mapping Soil Associations Using ERTS MSS Data. Proceedings of the Conference on Machine Processing of Remotely Sensed Data, Laboratory for Applications of Remote Sensing, Purdue University, W. Lafayette, Indiana. October, 1973. IEEE Catalog No. 73 CHO 834-2 GE. PP. 3A-1 to 3A-10. 10 pages. Geometrically corrected ERTS MSS data collected June 9, 1973 were analyzed by specially developed techniques using the computer. Resulting computer maps from a digital image display were overlayed to existing soil association maps of Tippecanoe County, Indiana. Four soil associations were clearly mapped by the computer analysis, and additional soils information useful to the ongoing USDA Soil Conservation Service soil mapping program was noted.

101873* Robertson, T.V. Extraction and Classification of Objects in Multispectral Images. Proceedings of the Conference on Machine Processing of Remotely Sensed Data, Laboratory for Applications of

*Supported in conjunction with another contract.

Remote Sensing, Purdue University, W. Lafayette, Indiana. October, 1973. IEEE Catalog No. 73 CHO 834-2 GE. PP. 3B-27 to 3B-34. Presented here is an algorithm that partitions a digitized multispectral image into parts that correspond to objects in the scene being sensed. The algorithm partitions an image into successively smaller rectangles and produces a partition that tends to minimize a criterion function.

Supervised and unsupervised classification techniques can be applied to partitioned images. This partition-then-classify approach is used to process images sensed from aircraft and the ERTS-1 satellite, and the method is shown to give relatively accurate results in classifying agricultural areas and extracting urban areas.

101973* Duan, J.R. and P.A. Wintz. Information-Preserving Coding for Multispectral Data. Proceedings of the Conference on Machine Processing of Remotely Sensed Data, Laboratory for Applications of Remote Sensing, Purdue University, W. Lafayette, Indiana. October, 1973. IEEE Catalog No. 73 CHO 834-2 GE. PP. 4A-28 to 4A-35. 7 pages. A general formulation of the data compression system is presented. A method of instantaneous expansion of quantization levels by reserving two codewords in the codebook to perform a folding over in quantization is implemented for error free coding of data with imcomplete knowledge of the probability density function. Results for simple DPCM with folding and an adaptive transform coding technique followed by a DPCM technique are compared using ERTS-1 data.

102073* Gupta, J.N., R.L. Kettig, D.A. Landgrebe and P.A. Wintz. Machine Boundary Finding and Sample Classification of Remotely Sensed Data. Proceedings of the Conference on Machine Processing of Remotely Sensed Data, Laboratory for Applications of Remote Sensing, Purdue University, W. Lafayette, Indiana. October, 1973. IEEE Catalog No. CHO 834-2 GE. PP. 4B-25 to 4B-35. 10 pages. Initially, methods for analyzing earth observational data involved the use of only spectral variations measured from the scene. The work reported in this paper provides a method for making some use of spatial variations as well. The results of some preliminary tests of this new method are presented in this paper.

102573* Mausel, P.W., W.J. Todd, M.F. Baumgardner, R.A. Mitchell and J.B. Cook. Evaluation of Surface Water Resources from Machine-Processing of ERTS Multispectral Data. 15 pages. The acquisition of water resources data is important to metropolitan areas. Four bands of digitized, multispectral data collected by ERTS-1 over Marion County on 30 September, 1972 were analyzed by computer processing to obtain water resources information. Four spectrally separable water classes were used in the classification scheme. The spectral classes of water are related primarily to differences in water depth and turbidity and to amount and type of suspended particles and aquatic growth in the water.

*Supported in conjunction with another contract.

103073* Anuta, P. Geometric Correction of ERTS-1 Digital Multi-spectral Scanner Data. 23 pages. ERTS-1 MSS data produced in digital form contains geometric distortions which are undesirable for users wishing to relate the data to maps. A digital computer algorithm was developed which performs certain geometric connections to improve the geometric quality of this data. The corrected data has been accurate enough to enable overlay of the ERTS data on 1:24,000 scale topographic maps and the usefulness of the data has been considerably improved by these corrections.

110173* Sharples, J.A. The Corn Blight Watch Experiment Economic Implications for Use of Remote Sensing for Collecting Data on Major Crops. 11 pages. From the Corn Blight Watch Experiment several con-clusions can be drawn about the use of remote sensing for estimating the acreage and periodic condition of major crops: (a) the role of remote sensing as a data collection technique appears to be one of augmenting the enumerator in the field rather than replacing him; (b) in the foreseeable future remote sensing should not be expected to lower the cost of collecting traditional information on major crops; (c) a major advantage of using remote sensing is that the output--a photograph or a scanner data tape--acts as a store of information about all features within the geographical area covered by the scanner.

110273* Murray, W.L. and J.E. Jurica. The Atmospheric Effect in Remote Sensing Earth Surface Reflectivities. Also available as an M.S. Thesis, Dept. of Geosciences, Purdue University. August, 1973. 61 pages. Under certain circumstances the presence of the atmosphere can hinder the identification of earth surface features by remote sensing techni-ques. An accurate model of atmospheric radiation transfer at visible wavelengths has been used to determine the extent of signal modifica-tion for differing illumination and atmospheric conditions. Effects equivalent to more than a 10 percent change in surface reflectivity are observed for some conditions.

110873* Anuta, P.E. and M.E. Bauer. A Procedure for Utilizing the Temporal Dimension for Automatic Classification and Change Analysis of Multispectral Imagery. 23 pages. Sequential coverage of the same area by remote sensors and subsequent registration of the data makes time dependent phenomena measurements available for computer analysis. The paper describes methods for analyzing temporally registered remote sensor multispectral imagery for classification improvement and change detection. Results for crop classification, crop change detection and urban change detection were encouraging; however, only one brief example is given.

111473* Sinnock, S. and W.N. Melhorn. Evolution of the Upper Color-ado River as Interpreted from ERTS-1 Imagery. Proceedings of the Fourth Annual Conference on Applications of Remote Sensing in Arid Lands. Tuscon, Ariz. Nov. 14-16, 1973. 22 pages. Manual interpretation of ERTS-1 MSS imagery has led to the recognition of anomolous surface patterns on the Uncompahgre Plateau in Southwestern Colorado. These anomolous patterns are interpreted as erosional scars produced by Tertiary fluvial network.

*Supported in conjunction with another contract.

The master stream of this network migrated by lithologic and joint control from the present San Juan Mountains to the present Colorado River location.

111573* Melhorn, W.N., S. Sinnock and R. Mroczynski. Applications of Machine Processed ERTS-1 Data to Regional Land Use Inventories in Western Colorado. Proceedings of the Fourth Annual Conference on Applications of Remote Sensing in Arid Lands. Tuscon, Ariz. Nov. 14-16, 1973. 19 pages. The paper details an investigation of cover-type mapping in arid west-central Colorado as a function of topography, altitude, and climatic zonation. Machine classification of ERTS-1 imagery of selected geographic transects across the Uncompahgre Plateau--Grand Valley area indicates that automatic processing can identify specific zone type assemblages and provide meaningful statistics on the percentage of zones of each assemblage. These percentages are in approximate accord with values obtained by conventional ground-based assessment.

120673 Hitchcock, H.C. Remote Sensing, Computers, and Land Use Planning. This paper briefly describes remote sensing and computer-aided analysis of MSS data. It shows several potential and present areas of application in land use planning.

121073 Hoffer, R.M. and the LARS Staff. Techniques for Computer-Aided Analysis of ERTS-1 Data, Useful in Geologic, Forest and Water Resource Surveys. Proceedings of the Third ERTS Symposium Washington, D.C. Dec. 10-14, 1973. 23 pages. Forestry, geology, and water resource applications were the focus of this study, which involved the use of computer-implemented pattern-recognition techniques to analyze ERTS-1 data. The results have proven the value of computer-aided analysis techniques even in areas of mountainous terrain.

Several analysis capabilities have been developed during these ERTS-1 investigations. A procedure to rotate, deskew, and geometrically scale the MSS data results in 1:24,000 scale printouts that can be directly overlayed on 7 1/2 minute U.S.G.S. topographic maps. Several scales of computer-enhanced "false color-infrared" composites of MSS data can be obtained from a digital display unit, and emphasize the tremendous detail present in the ERTS-1 data. A grid can also be superimposed on the displayed data to aid in specifying areas of interest, such as avalanche tracks or areas of burned-over timberland. Temporal overlays of six sets of data have allowed both qualitative and quantitative analysis of changes in the areal extent of the snowpack.

Computer-aided analysis of the data allows one to obtain both cover-type maps and tables showing acreage of the various cover types, even for areas having irregular boundaries, such as individual watersheds. Spectral analysis of snow and clouds, water and shadow areas, and forest cover of varying overstory density have revealed several important results.

*Supported in conjunction with another contract.

121173   Baumgardner, M.F., J.A. Henderson, Jr. and Staff.
Mapping Soils Crops and Rangelands by Machine Analysis of Multi-Temporal
ERTS-1 Data.   Proceedings of the Third ERTS Symposium.   Washington, D.C.
Dec. 10-14, 1973.   30 pages.   ERTS-1 data, obtained during the period
25 August 1972 to 5 September 1973 over a range of test sites in the
Central United States, have been used for identifying and mapping dif-
ferences in soil patterns, species and conditions of cultivated crops,
and conditions of rangelands.   Multispectral scanner data from multiple
ERTS passes over certain test sites have provided the opportunity to
study temporal changes in the scene.

Geometric correction was performed on the digital data for several
dates and for several test sites.   This made much easier the task of
locating specific data points and of comparing the analytical results
with other maps and data sources.

Multispectral classification delineating soils boundaries in dif-
ferent test sites compared well with existing soil association maps
prepared by conventional means.

Spectral analysis of ERTS data was used to identify, map, and
make areal measurements of wheat in western Kansas.

Multispectral analysis of ERTS-1 data provided patterns in range-
lands which can be related to soils differences, range management
practices, and the extent of infestation of grasslands by mesquite
(Prosopis fuliflora) and juniper (Juniperus spp.)

121373   Landgrebe, D.A. and the LARS Staff.   An Evaluation of
Machine Processing Techniques of ERTS-1 Data User Applications.   Pro-
ceedings of the Third ERTS Symposium.   Washington, D.C. Dec. 10-14,
1973.   30 pages.   This paper provides further results on machine proces-
sing of ERTS-1 data for user applications. Earlier papers at the first
and second ERTS Symposiums gave results in general land use categories,
crop classification and urban land use.   The current paper gives re-
sults in soil association mapping and further urban land use analysis.
It also gives results on geometric correction and temporal registration
of ERTS data.

011074   Grams, H.L.   Purdue/LARS Computer User's Guide.   28 pages.

022274*   Henderson, J.A., Jr. M.F. Baumgardner and C. Walker.
Preparing Resource Inventories in the Southern Great Plains by Machine-
Processing of ERTS-1 Multispectral Data.   Proceedings of the Fourth
Annual Conference on Applications of Remote Sensing of Arid Lands.
Tuscon, Ariz. Nov. 14-16, 1973.   13 pages.   Two test sites in the
Southern Great Plains, one centered around Lubbock, Texas, and one
around Hobbs, New Mexico were used in this resource inventory.   Using
supervised (training sets) and non-supervised (clustering) computer pro-
grams the scenes were separated spectrally and mapped into classes.

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Classification results were correlated with ground information and a
comparison was made between the results of the Hobbs subframe (where
no ground information was available) and the Lubbock Subframe (where
a considerable amount was available). Classes of surface features
which were successfully identified and mapped spectrally were crop-
lands, rangelands, surface water, broad soil patterns, urban areas,
drainage patterns, and major transportation arteries.

022774* Woodring, S.M. and T.R. West. Engineering Soils Map-
ping from Multispectral Remote Sensing Data Using Computer Assisted
Analysis. An analysis procedure for engineering soils mapping by
computer of multispectral remote sensing data was developed: 1.
Locate cultural features by visual examination of imagery. 2. Pro-
duce generalized bare soil-vegetation-water map using non-supervised
technique. 3. Outline significant soil fields for computer training
using supervised approach. 4. Computer-classify entire area based
on these fields.

031274 Phillips, T. and S. Schwingendorf. On the Access to an
Earth Resources Data Processing System. 22 pages. The Purdue/LARS
Earth Resources Data Processing System is briefly described. The con-
siderations to which an organization would want to give attention
before obtaining a remote terminal to this system are discussed. The
support of such a terminal which Purdue/LARS is willing to propose is
described.

032574* Stohr, C.J. and T.R. West. Delineation of Sinkholes
Using Thermal Infrared Imagery. Proceedings of the Third Annual Remote
Sensing of Earth Resources Conference, UTSI, Tullahoma, Tenn. March
25-27, 1974. 13 pages. The reported results of several authors con-
cerning the location of sinkholes using only thermal infrared imagery
is herein questioned, because of theoretical and empirical considerations.
Daytime and nighttime thermal infrared imagery collected in the spring
and fall of 1970 over an area near Staunton, Virginia is examined
using manual interpretation and computer-assisted analysis. None of
these procedures could be used successfully to delineate sinkholes using
only thermal imagery, and it is concluded that thermal imagery should
be used as a supplementary tool in conjunction with aerial photography.

032674 Hitchcock, H.C. and R.M. Hoffer. Mapping a Recent Forest
Fire with ERTS-1 MSS Data. Proceedings of the Third Annual Remote
Sensing of Earth Resources Conference, UTSI, Tullahoma, Tenn. March 25-
27, 1974. 13 pages. Accurate fire boundary delineation provides essen-
tial information to forest managers in allocating suppression costs and
planning regeneration efforts. The objective of this study was to test
the capability of computer-aided analysis of ERTS-1 MSS data to accur-
ately define the boundary of a recent forest fire and to discriminate
spectral classes within the perimeter. Two frames of ERTS-1 MSS data
were selected for analysis of the Moccasin Mesa Fire in Mesa Verde
National Park. Data sets were collected one-half growing season and one
full growing season after the fire. Results indicate that computer-aided
analysis of ERTS-1 MSS data has the capability for accurately delineating

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fire boundaries and determining acreage of the burned area. Distinct spectral classes may also be defined within the fire perimeter.

032774* Sinnock, S., W. Melhorn and O. Montgomery. Machine-Aided Analysis of Land Use-Land Form Relations from ERTS-1 Imagery, Sand Hills Region, Nebraska. Proceedings of the Third Annual Remote Sensing of Earth Resources Conference, UTSI, Tullahoma, Tenn. March 25-27, 1974. 24 pages. A computer-augmented analysis of ERTS-1 MSS data was performed on a test area in McPherson and Arthur counties in the Sand Hills region of Nebraska. Excellent correlation was obtained between available USDA Soils maps and ground photography, and the machine analysis of differences in soil types, conditions of rangelands, physiography, and location and extent of water bodies and marshlands.

032874 Guernsey, J.L., P.W. Mausel and R.H. Gilbert. Machine Processing ERTS-1 Data in Analyzing Land Use Conflicts in the Indianapolis Metropolitan Area. Land use changes around a water body, a large regional airport, several new subdivisions and an interstate beltline. Both supervised and unsupervised procedures were used to analyze spectral data, and seven land use classes were delineated. Overall accuracy of land use identification for state-wide planning was very encouraging.

032974*[1] Jurica, G.M. and C.L. Parsons. Atmospheric Correction of Remotely Sensed Spacecraft Data. Proceedings of the third Annual Remote Sensing of Earth Resources Conference, UTSI, Tullahoma, Tenn. March 25-27, 1974. 13p. This paper reports on application of an atmospheric model to the interpretation of ERTS MSS data. It is concluded that Band 4 (0.80 - 1.00 µm) data are to a high degree influenced by the water vapor content of the atmosphere. Knowledge of the meteorological conditions at the time of an ERTS overpass appears to be necessary in order to achieve maximum classification accuracy of surface features.

033174 Coggeshall, M.E., R. Hoffer and J. Berkebile. A Comparison Between Digitized Color Infrared Photography and Multispectral Scanner Data, Using ADP Techniques. Proceedings of the Fourth Biennial Workshop on the use of color IR photography in the plant sciences. Orono, Maine. July 10-12, 1973. 13p. Computer classification results derived from digitized color infrared photography were compared with similarly derived results for three corresponding wavelength bands of multispectral scanner data. Classification results for 158 test fields indicated 47.5 percent overall correct identification with the digitized color infrared photography as compared to 80.5 percent for the corresponding three channels of multispectral scanner data (and 95.1 percent where all of the available twelve multispectral scanner channels were utilized). Forest cover was particularly difficult to separate from agricultural cover types using the digitized photography, but good separation was obtained with the multispectral scanner data.

*Supported in conjunction with another contract.
[1]This presentation has not been published.

040174 Whitsitt, S.J. and Landgrebe, D.A. Simulation Techniques for Estimating Error in the Classification of Normal Patterns. 30 pages. Methods of efficiently generating and classifying samples with specified multivariate normal distributions are discussed. Conservative confidence tables for sample sizes are given for selective sampling. Simulation results are compared with classified training data. Techniques for comparing error and separability measures for two normal patterns are investigated and used to display the relationship between error and the Chernoff bound.

040474 Davis, S.M. and J. C. Lindenlaub. An Application of Personalized Instruction to Remote Sensing. This paper describes an application of personalized instruction to the training of people using a computer network dedicated to remote sensing technology. It describes the educational challenge posed by the kind of learner to be trained, the instructors available, the physical and administrative conditions, and the rapid evolution of the technology being taught. The LARSYS Educational Package, a 6-module, multi-media sequence developed to meet this challenge, is described in detail. An evaluation of its effectiveness is included.

041574 Davis, B.J. and P. H. Swain. An Automated and Repeatable Data Analysis Procedure for Remote Sensing Applications. Proceedings of the Ninth International Symposium on Remote Sensing of Environment. Ann Arbor, Mich. April 15-19, 1974. 4p. A new multispectral data analysis procedure, based on LARSYS, has been developed which substantially reduces the influence of the analyst. The analysis is automated, including the interpretation of clustering results. The classification results obtained are repeatable and not biased by analyst subjectivity during the analysis.

041674 Miller, W.L. The Economic Impact of Remotely Sensed Data as the Source of Nonpoint Pollution Monitoring and Control. The nonpoint pollution in streams and lakes is a problem. This can be corrected through changes in land use and management practices. These actions have economic costs and benefits. This research examines the costs and benefits of these actions when remotely sensed data is used as the source of part of this information required for the analysis.

041774 Kumar, Ravindra and LeRoy F. Silva. Statistical Separability of Agricultural Cover Types in Subsets of One to Twelve Spectral Channels. The purpose of this study was to determine the statistic separability of several agricultural cover types using multispectral scanner measurements. The data from visible, near, middle, and far infrared channels were studied using the transformed divergence as a quantitative analysis tool. Correlation of separability with classification accuracy on a cover type basis and channel array selection is made.

041874   Hall, F.G., Bauer, M.E. and W. A. Malila.   First Results
from the Crop Identification Technology Assessment for Remote Sensing
(CITARS).   This paper describes the objectives, experimental plan,
procedures and first results for a crop identification by remote
sensing technology assessment project being conducted by NASA, ERIM
and LARS.