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QUARTERLY REPORT

Reporting Period: June 1, 1976-August 31, 1976
Contract Number: NAS9-14970
Title of Investigation:

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

Principal Investigator:

D. A. Landgrebe
Laboratory for Applications of Remote Sensing
Purdue University
West Lafayette, Indiana 47906

Submitted to:

NASA Lyndon B. Johnson Space Center
Attn: Jon D. Erickson, Mail Code TF3
Houston, Texas 77058
Mark for: Contract NAS9-14970

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2.1 Test of Boundary Finding/Per Field Classification (ECHO)

Project Preparation. A detailed Implementation Plan for this task was delivered to NASA in early July. The staff involved in the project has been familiarized with the theory behind the ECHO classifier and with the documentation of that theory in the LARS Information Notes. The existing versions of the research software were located and examined. Some internal documentation was performed on the research software and the processing flow was roughed out. Both the supervied ECHO processor (utilizing the statistical information about the training classes in cell selection and annexation) and the unsupervised ECHO processor (utilizing statistical characteristics of the cells only for cell selection and annexation) were examined, modified in minor ways, and put in running order.

User Consultation. Members of the LARS staff having experience in using the research version of the supervised ECHO processor were consulted. Comments, suggestions and information about known flaws in the research software were solicited. Typical comments included:

a. It is not clearly understood what the annexation and cell selection parameters are, what they mean, or what happens when they are varied.

b. The intermediate results tape is inconvenient.

c. Having the final results on disk is inconvenient.

d. Both the processor speed and the lack of "noise" in the output are very nice.

e. The program aborts abnormally without explanation under certain input conditions.

These comments have aided greatly in the determination of experimental design, restructuring needs, program configuration and selection of input/output parameters for the supervised version of ECHO. Due to the value this input has already provided, an ECHO users meeting will be held at LARS in September for the purpose of further consultation and to make available the research version of the unsupervised ECHO software so that user comments may be solicited on that version as well.

Appropriate Delivery Versions. The versions of the ECHO processors which will be developed to satisfy the SR&T Task 2.1 objectives are:

a. The supervised ECHO processor utilizing a Chi-squared statistic for cell selection, a generalized likelihood ratio for the annexation criterion and a maximum likelihood sample classifier.

b. The unsupervised ECHO processor utilizing a ratio of standard deviation/mean for a cell selection statistic, a "multiple univariate" generalized likelihood ratio for annexation and a maximum likelihood classifier.

Rationale for the selection of these versions were:

a. Speed - Maximum likelihood sample classification is faster than minimum distance (Bhattacharyya) sample classification.

b. Compatibility - The same basic statistics can be used to perform chi-squared cell selection, generalized likelihood annexation and maximum likelihood classification. Such compatibility also contributes to overall classification speed.

c. Universality - Multi-univariate cell selection and annexation statistics were chosen over multivariate statistics for the unsupervised processor since multivariate tests require a larger number of pixels within a cell than the number of channels of data while multi-univariate statistics do not have this limitation.

Desired Program Configuration and Parameters. A tentative control card listing for the supervised processor appears on the following page. The supervised version currently functions in two phases. The first phase calculates the covariance matrix for each cell and the discriminant value associated with each class for each cell, does a Chi-squared test for cell homogeneity, and writes the result on an intermediate results tape. The second phase retrieves these data from the intermediate tape, runs through the annexation tests and produces a final results file on disk. This process flow will be altered so that all processing will be done in one processor, without requiring an intermediate tape, and the results will be optionally written to either disk or tape. Since having an intermediate tape does allow the analyst to produce classifications based on several different annexation parameters without repeating the fairly complex and time-consuming task of calculating covariance matrices and discriminant values for each cell, an intermediate tape may be used or produced as an option. Object (boundary) and classification maps will also be added as optional output products. The annexation algorithm will be altered so that a cell will be annexed to the neighboring field which has the highest likelihood ratio above the specified annexation threshold rather than the first field encountered which exceeds the annexation threshold.

The program configuration for the unsupervised ECHO processor has not been finalized yet and will not be finalized until more experience is gained with its use and suggestions have been obtained from users within LARS. No one currently at LARS has had extensive experience in the use of this processor. Although the final configuration has not been decided on as yet, the ability to produce an object map (without the benefit of a statistics deck) and a LARSYS multispectral image storage tape (containing the mean value for each channel for all the pixels of each object) will be added to the processor. This processor will also be restructured from a two-pass to a one-pass classifier with an optional intermediate storage tape. As more experience is gained in the uses and values of the unsupervised ECHO processor, additional restructuring and products may be incorporated.

Experimental Design. Experiments have been designed to:

REQ	KEY WORD	CONTROL PARAMETER	FUNCTION	DEFAULT
+	*SECHO	(NONE)	SELECT THE SUPERVISED ECHO CLASSIFIER.	(NONE)
	RESULTS	TAPE(TTT) FILE(FF) INITIALIZE	DESTINATION OF CLASSIFICATION RESULTS ON TAPE TTT, FILE FF. INITIALIZE FILE 1 OF A NEW RESULTS TAPE (REQUIRED WHEN USING A NEW TAPE).	CLASSIFICATION RESULTS STORED ON DISK
1 3	INTER-MEDIATE	TAPE(TTT) FILE(FF) INITIALIZE	PRODUCE OR USE INTERMEDIATE TAPE TTT FILE FF STORING MOST LIKELY CLASS AND CLASS LIKELIHOODS INITIALIZE FILE 1 IF WRITING ON A NEW RESULTS TAPE.	NO INTERMEDIATE RESULTS TAPE PRODUCED OR USED
2 3	CELL	SIZE (N)	PARTITION DATA INTO NXN CELLS & TEST THESE CELLS FOR HOMO-GENEITY BY COMPARING	(NONE)
		SELECTION(SS.S)	SS.S TO THE CHI-SQUARE STATISTIC FOR EACH CELL. (SEE NOTE 1 BELOW.)	SS.S=0 (per point classification)
1 2	ANNEXATION	THRESHOLD(T.T)	COMPARE 10**-T.T TO THE LIKELIHOOD RATIO FOR ANNEXATION. (SEE NOTE 2 BELOW.)	
	OPTIONS	INTERMEDIATE	START FROM THE INTERMEDIATE TAPE TO PRODUCE CLASSIFI-CATION.	START FROM MULTISPECTRAL IMAGE STORAGE TAPE
	PRINT	OBJECTS CLASSIFICATION	PRINT OBJECT MAP. PRINT CLASSIFICATION MAP. (SEE NOTE 4 BELOW.)	NO MAPS PRINTED
		STATS	PRINT STATISTICS TO BE USED.	NO STATISTICS PRINTED
	CLASSES	NAME (P1/C1,C2/)	POOL STATISTICS FOR TRAINING CLASSES C1,C2,... ASSIGN NAME AS POOL NAME AND P1 AS POOL NUMBER. (SEE NOTE 3 BELOW.)	INDIVIDUAL CLASSES USED
	SYMBOLS	S1,S2,S3,...	SYMBOLS USED TO PRODUCE OBJECT AND CLASSIFICATION MAPS. (SEE NOTE 4 BELOW.)	ARBITRARY SYMBOLS ASSIGNED
1 3	CHANNELS	I,J,K,...	CHANNELS I,J,K,... ARE SELECTED.	(NONE)

R E Q	KEY WORD	CONTROL PARAMETER	FUNCTION	DEFAULT
	CARDS	READSTATS	STATISTICS FILE ON CARDS. (SEE NOTE 6 BELOW.)	STATISTICS FILE EXPECTED FROM DISK.
	DATA	START OF DATA DECK		
			PUNCHED STATISTICS FILE FROM STATISTICS FUNCTION IF 'CARDS READSTATS' CONTROL CARD IS INCLUDED.	
2	DATA	START OF DATA DECK		
3			FIELD DESCRIPTION CARDS DESCRIBING AREAS TO BE CLASSIFIED (ALWAYS REQUIRED). EITHER FORM OF THE FIELD DESCRIPTION CARD MAY BE USED.	
+	END			

+ ALWAYS REQUIRED
1 REQUIRED IF CLASSIFYING FROM INTERMEDIATE TAPE
2 REQUIRED IF CLASSIFYING FROM RUN TAPE
3 REQUIRED TO PRODUCE INTERMEDIATE RESULTS TAPE

NOTE 1 . . . AS SS.S (VALUE OF CELL SELECTION PARAMETER) INCREASES, FIELD-AT-A-TIME CLASSIFICATION IS APPROACHED. AS SS.S DECREASES PER POINT CLASSIFICATION IS APPROACHED.

NOTE 2 . . . AS T.T INCREASES, THE TENDENCY TOWARDS ANNEXATION INCREASES. AS T.T APPROACHES ZERO, PER CELL CLASSIFICATION IS APPROACHED.

NOTE 3 . . . THE FORMAT C1,C2,...MAY BE USED FOR THE CLASSES AND TO INDICATE THAT ONLY A SUBSET OF THE CLASSES (C1,C2,...) IN THE STATISTICS FILE SHOULD BE CONSIDERED. IF A CLASSES CARD IS USED, ALL DESIRED CLASSES MUST BE EXPLICITLY REQUESTED. IF NO CLASSES CARD IS USED, ALL CLASSES ARE INCLUDED.

NOTE 4 . . . A CLASSIFICATION MAP MAY ONLY BE PRODUCED WHEN AN ANNEXATION CARD IS PRESENT IN THE CONTROL CARD DECK.

NOTE 5 . . . THE SYMBOLS CARD SHOULD ONLY BE USED WHEN PRINT MAP IS SPECIFIED. IF PRINT MAP IS SPECIFIED, BUT NO SYMBOLS CARD IS USED, ARBITRARY SYMBOLS WILL BE USED TO PRODUCE THE OBJECT AND CLASSIFICATION MAPS.

NOTE 6 . . . STATISTICS ARE REQUIRED FROM EITHER CARDS OR DISK EXCEPT WHEN CLASSIFYING FROM AN INTERMEDIATE TAPE.

a. Determine the classification accuracy, on a field-center-pixel basis, which results from varying cell selection and annexation parameters over selected areas.

b. Compare the classification accuracies of a pixel-at-a-time classifier and the two ECHO classifiers over selected areas.

c. Monitor the changes in classification accuracy over simulated Thematic Mapper sites at different resolutions and with different cell selection and annexation parameters.

d. Compare the computer time required to classify an area using the ECHO processor to the time required by a pixel-at-a-time processor. This will require some reprogramming of the pixel-at-a-time classifier in FORTRAN to secure comparative times.

e. Measure the amount of rapid class changes in ECHO results versus pixel-at-a-time classifications. Rapid class changes are often regarded as classification noise.

Select Test Data Sets. The above investigations will be performed primarily on the 1973 Kansas LACIE segments, the simulated Thematic Mapper data and the 24-channel aircraft data used to produce the Thematic Mapper simulations. Additional LANDSAT data in the LARS data library is being considered so that the effects of more complex ground scenes than the Kansas LACIE segments may be examined.

Work in Process. The classifications and field-center-pixel classification accuracies obtained in conjunction with the "stratification" task for the 1973 LACIE test sites have been located. The test fields and statistics decks used to produce these classifications have also been located so that these benchmark results may be compared to ECHO classifications of the same areas using the same test fields and the same class statistics decks. Results of classifications utilizing simulated Thematic Mapper data have also been secured. The 24-channel aircraft data has not yet been classified.

The possibility of converting the cell selection variable from a numerical threshold to a confidence level is being examined. There is some question as to the usefulness of this conversion as the data may fit neither the class normality assumption nor the assumption that all classes are truly represented by the statistics deck.

Implementation of restructured software has begun. The unsupervised ECHO processor now has the capability to produce an object map on the line printer. The annexation routine for the supervised version now unites a cell with the adjoining field having the greatest likelihood ratio above the annexation threshold rather than the first likelihood ratio encountered which exceeds the annexation threshold.

2.2 Stratification of Scene Characteristics

2.2a Stratification by Machine Clustering

The major activity in this quarter was the comilation of two sets of sample units which form the base for the correlation and regression analysis of the agronomic-meteorological and spectral data. The first of these two sets of data is the LACIE and SRS segments which were made available to LARS by NASA in CY76. The second of the two sets of samples is based on LANDSAT scene 1689-16382, which is the base data for Task 2.2b: Digitization and Registration of Ancillary Data. The ancillary data registered by Task 2.2b in CY76 and this quarter is being used to generate the physical factor observations for the second data set. This data set has more samples than the first; but the analysis will be restricted to one date: June 12, 1974; and a small geographic region, Central Kansas. The correlation and regression analysis of physical factor data is proceeding slower than anticipated, but results should be available by the end of September.

Additional effort in this quarter has focused on use of transformations such as the "Tasselled Cap" and the delta classifier transforms as a pre-processing step before machine stratification in order to "expand" the strata or minimize the effects of certain physical factors. Such transformations can now be applied before stratification, but new partitions of the Kansas data set have not yet been generated from preprocessed data.

2.2b Digitization and Registration of Ancillary Data

The major activity in this quarter was finishing the ancillary data registration processing which was started in CY76 and which was reported in detail in the June 1976 SR&T Final Report. The four variables being overlaid on LANDSAT frame 1689-16382 obtained June 12, 1974, are soils, land use, temperature and precipitation. Only soils was fully processed by June 1, 1976. Land use, temperature and precipitation registration have been completed and the data is currently being used in Task 2.2a. The following material describes the registered data files in detail.

The result of registering soil map, county map and land use map of Kansas onto LANDSAT data (run 74025100) is a full frame 13-channel file which is too large to be stored in one single tape. Therefore, the image is divided into three approximately equal portions.

The first four channels are original LANDSAT data. The next three channels are overlays of the soil map, county map and land use map respectively. Furthermore, single-channel full frame files for these overlays are available.

The last six channels are precipitation and temperature maps which are formed by assigning special codes to the county map. The complete list of the 13 channels is in Table 1.

TABLE 1: LIST OF 13 CHANNELS OF FINAL OVERLAY

Channel	Comment
1	Original data from channel 1 of 74025100
2	Original data from channel 2 of 74025100
3	Original data from channel 3 of 74025100
4	Original data from channel 4 of 74025100
5	Overlay of the soil map
6	Overlay of the county map
7	Overlay of the land use map
8	Total precipitation: Oct 1973 - June 1974
9	Total precipitation: Mar 1974 - June 1975
10	Mean minimum temperature: Oct 1973 - June 1974
11	Mean minimum temperature: Mar 1974 - June 1974
12	Mean maximum temperature: Oct 1973 - June 1974
13	Mean maximum temperature: Mar 1974 - June 1974

The calibration codes C_0, C_1, C_2 in the ID record and the calibration codes K_0, K_1, K_2 at the end of each channel are used to calibrate the data of channel 8 to 13 so that the original values of each quantity (e.g., inches for the precipitations, degrees Fahrenheit for the temperatures) can be retrieved by the LARSYS system. One may get the total precipitation values or total temperatures values by using calibration 5 (for more details, see LARSYS program abstract 005 on the GADLIN program), or he may get these values on monthly basis by using calibration 6. The channels 1 to 7 are not affected by these codes.

The creation of these tapes essentially completes the work planned for CY76. Work on the four tasks defined for Ancillary Data Registration has focused on the development of alternative methods for converting maps to digital format.

Existing methods of map digitization require tedious boundary tracing using table digitizers and detailed processing of coordinate data to achieve the desired digital representation. These processes are costly, time consuming and error-prone. Better, more automatic methods are needed to carry out this process.

Work has begun on one possible method of automatic map digitization. Image processing and pattern recognition techniques are being employed in the current effort. The process to be evaluated consists of these steps: 1) Map photo preparation; 2) densitometer scanning and digitizing; and 3) pattern recognition processing. These phases will be developed further as work proceeds. In this quarter the land use map which has well-defined color c ies for each category was converted to 4" x 5" color transparency and digit_zed on a rotating drum microdensitometer. Three files were generated using a blue, green, and red filter. Those files will be reformatted to a three band LARSYS data set and pattern recognition methods will be applied to extract the map classes during the next quarter.

2.2c Crop Inventory Using Full Frame Classification

The major activity in this area has been inproducing "full-frame" classifications in Kansas. The classifications are done on a county basis using every other line and every other column of data. The classifications will be completed by October 1.

2.3 Field Measurements for Remote Sensing of Wheat

Field measurements activities during this quarter have included: preparation of implementation plan, data acquisition, data processing and evaluation, management of data library, data analysis, and project leadership and coordination.

Preparation of Implementation Plan. The implementation plan that describes the activities for the current contract year was prepared and submitted to NASA/JSC.

Data Acquisition. Four two-week data acquisition missions were performed at Williston, North Dakota between May 25 and August 31. The missions covered the planting-pre emergence to mature-harvested stages of spring wheat development. Five missions had been planned, however, the wheat matured sooner than the previous year so one mission was deleted. Data were collected using the LARS spectroradiometer system for: 1) 60 spring wheat and other small grain plots, plus 8 plots of other crops and cover types, 2) a study of the reflective and emissive characteristics of wheat canopies as a function of view and solar angle, 3) a study of the polarization characteristics of wheat canopies as a function of view and solar angles, 3) measurement of the reflectance of canvas panels used for calibration of the FSS(S191-H) and eleven channel MSS data. In addition, data were periodically obtained with a tripod-mounted radiometer in support of LACIE/SR&T wheat canopy modeling studies.

Detailed agronomic data including leaf area index, dry matter production of leaves, stems, and heads, soil moisture, and grain yield were obtained. Supporting meteorological measurements included: cloud cover and type, barometric pressure, total irradiance, wind speed and direction, air temperature, and humidity.

Data Processing and Evaluation. Data processing activities included: processing 1975 FSS(S191-H) data collected over Williams County and processing 1976 Exotech 20C data. All of the 1975 NASA/ERL Exotech 20D data have been processed and partially evaluated. The panel calibration tables to calibrate the 1975 Finney County FSS data are being prepared. Nearly all of the 1975 Finney County FSS data have been processed. All of the 1975 Exotech 20C data have been processed. The panel calibration tables to calibrate the 1975 Williams County FSS data have been prepared. Processing is ready to begin on the 1975 Williams County FSS data using the Exotech 20C calibration tables. The 1976 Exotech 20C data are being digitized and the ground truth data are being keypunched.

All in-house LANDSAT data collected over the test sites have been processed. Work is presently under way to register the data to form multitemporal data sets over each of the sites.

In addition, work is under way to reformat the aircraft multispectral scanner data into LARSYS format from universal format to condense the data.

Data Library. The 1975-76 data received to date have been catalogued. All 1975-76 ancillary data received to date, including meteorological data, flight logs, field maps and data logs have been distributed to Texas A&M University and ERIM. Also, computer tapes with 1975 Finney County FSS, 60% of 1975 Exotech 20C, all available FSAS interferometer, and 3 dates of the ERL Exotech 20D data were distributed to researchers at Texas A&M University and ERIM.

Version 1 of the Field Measurement Data Library catalogue was prepared and distributed to personnel from NASA/JSC, ERIM, and Texas A&M University. Version 2 of the catalogue has been prepared incorporating suggesions made at a Field Measurements meeting held at Purdue on July 21-22.

Data Analysis. Analysis activities have included study of the Exotech 20C, Exotech 20D, and FSAS Interferometer data collected over the calibration panels. The data from the three instruments are in close agreement.

The 1976 Exotech 20C data are being analyzed to determine the best approach to reduce the uncertainty of the data caused by an instable power source.

The analysis of the relation of the geometric characteristics of reflectance characteristics of wheat canopies is nearing completion. The agronomic data analysis of the 1974-75 field measurements data is now under way. The objectives and approach for these analyses have previously been described in our implementation plan.

Project Leadership and Coordination. A meeting with major project participants was held in late July at Purdue to discuss data status and outline a presentation on the Field Measurements project. During June, a representative from LARS reviewed the FSAS data acquisition procedures in Finney County to determine comparability to data taken with FSAS and other instruments in the project. Activities have also included continued communication with personnel at JSC and other centers concerning the project.

Plans for Next Quarter. The processing of the 1974-75 FSS data will be completed and the data distributed. Also, the rest of the 1975 Exotech 20C data and the 1975 Exotech 20D data will be distributed. Processing will continue on the 1976 Exotech 20C data and processing will begin on the 1975-76 FSS data. Evaluation of the data will continue and information will be compiled summarizing the "quality" of the data. Version 2 of the Data Library Catalogue will be distributed.

2.4 Scanner Parameter Study

During the quarter work proceeded on 5 of the tasks defined in the implementation plan. These activities are defined in the following paragraphs.

Completion of Thematic Mapper Simulations (Subtask 10). During the quarter, work on finishing Kansas flightline classifications for July 6 was undertaken. The work accomplished can be broken down into three areas. The first area was to classify the LANDSAT 2 data over the flightline using four channel clustering and classification. In addition to the classification using the LARSYS *CLASSIFYPOINTS processor, the ECHO classifier was also run for comparison purposes. The classification of the LANDSAT 2 data was done in order to have a reference classification for the existing system to be used for comparisons with the simulated Thematic Mapper data set classifications. The second area of work was to classify the LANDSAT 2 data using only channels 2, 3, and 4 (.6 - .7, .7 - .8, 1.8 - 1.1 micrometers) and to classify the simulated LANDSAT 2 data using only channels 1, 2, and 3 (.59 - .69, .72 - .81, .82 - 1.04 micrometers). These channels were chosen since they have spectral bands which most nearly coincide. The purpose of this work was to gain some idea of how well the simulation process approximated the current system. The third area was to finally classify the simulated LANDSAT 2 data set using all four channels. The simulated channel 4 is a thermal channel (10.1 - 12.0). This classification can then be compared to the three channel classification using channels 1, 2, and 3 only to give some idea as to how effective a thermal channel is for this scene. Wrap-up of this activity is expected to be complete by the end of the second quarter.

Optimum Basis Function Study (Subtask 4). The goal of this task is to optimize the selection of wavebands in a multispectral scanner system. To accomplish this optimization, the stochastic process, consisting of an ensemble of spectra, is represented by a series expansion in terms of orthogonal basis functions with uncorrelated coefficients. These basis functions have the properties that they represent the process with minimum mean-square error and they carry maximum information with regard to discrimination of classes.

A software system is being developed to compute these basis functions, using the Karhunen-Loève expansion. The procedure is to estimate the covariance of the ensemble of sample functions which are representative of the spectra that will be observed. Using the covariance matrix the basis functions are obtained by solving an integral equation. The optimum vector for representing each sample function is then found by integrating the product of the basis functions and the sample function over the domain of interest. At present the sample functions are generated artificially with a random function generator. Data from the field spectroradiometer will be used in future work. This analysis will give an indication of where the information in the spectrum is present, providing important inputs to the design of scanner systems.

Multispectral Scanner Model (Subtask 7). During this quarter, work was directed toward the analytical study of multispectral scanner design. A theoretically optimum scanner model was considered; specifically, a signal model was studied, which should be valuable in reducing the computational complexity for the optimum scanner model. The signal studies utilized data obtained from field measurements experiments (EXOSYS). This data was used to reinforce the justification for considering the signal model used.

The scanner model is optimum in the sense of minimum probability of misclassification over any particular spectral band. However, at present an analytical technique for choosing a particular spectral band is not known. By this, it is meant that an efficient technique for band selection. Thus, it is proposed to pursue this problem in the coming quarter.

Analytical Methods of Error Prediction (Subtask 5). Work neared completion of an analytical model for classification error for the M class N dimension case for M > 2 and N of the order of 4 to 12. The subject was pursued to a sufficient extent to reveal the difficulties in evaluating closed form expressions for the expected classification error. Attention has been focused on the numerical solution of expressions for the error and this is the work defined in Subtask 6. Work on Subtask 5 will be essentially complete by the end of the second quarter and (6) is in progress and will continue through the next quarter.

Spectral Data Base Development (Subtask 2). A large number of field spectrometer spectra were added to those already on hand through the quarter through the SR&T Field Experiment Project. This data was processed and catalogued and this work continues. Sufficient spectral data now exists for conducting Subtask 4. Data preprocessing, cataloging and quality evaluation will continue through the next quarter until the data collected in Summer 1976, plus previous summers, has been placed in a data base. It is expected that the schedule will be kept and statistical modeling of this data base can begin in the third quarter.

2.5 Transfer of Computer Image Analysis Techniques

This task has been organized into four major subtasks: Support of the JSC remote terminal, evaluation of educational and training materials, instructor training, and development of education and training materials. These subtasks were described in some detail in the implementation plan drawn up during the first month of the contract period.

Support of the JSC Remote Terminal. Support of the JSC/LARS remote terminal includes maintaining at the LARS central computer site the necessary hardware and software required to support the JSC terminals, providing computer services and systems consultation, and developing concepts for an improved remote terminal system.

During the period July 1 - August 31, 1976 a problem arose with the modem at LARS which interrupted JSC terminal operations for several days. A faulty power supply was replaced in the modem. John Cornwell, Systems Specialist at JSC, has reported that the IBM 2780 at JSC frequently has problems and consideration should be given to replacing it. Hardware at JSC is a NASA-furnished item.

Currently the primary use of the terminal at JSC is for LACIE support with some use being made in support of the Field Measurements Project with LARS. There is little training activity going on at the present time, but as new projects begin to phase in at JSC training activities are expected to increase.

For some time LARS has been formulating the concept that the next logical step for improved hardware/software capabilities for processing earth resources remote sensing data should be a facility based around a minicomputer, supported by an array of special purpose and general purpose peripheral equipment and attached by communications lines to a high capability computer. Under this "intelligent terminal" concept, the large computer will cease to be the only tool for remote sensing data processing research, but will instead be used as a resource that is called upon only for the tasks it can do well. As a result of being able to purchase some hardware under the FY76 SR&T contract some initial steps have been taken to plan and implement this concept.

Implementation of the concept has been planned in three phases. Phase I is to be a developmental prototype and will utilize equipment already ordered which includes a PDP-11/34 Minicomputer, a Varian Electrostatic Printer/Plotter, a Table Digitizer, two CRT terminals and necessary modem and interface items. It is hoped after demonstration of Phase I capabilities, further phases will allow additional hardware and software to be added. Also, not to be overlooked is the expected capability to implement significantly less expensive subsets based on the Phase I system after it has been developed initially. For example, it is expected that hardware costing less than half as much as the Phase I system could be used to run software developed for Phase I and very significantly outperform current 2780-type terminals used for Earth Resources data processing.

Phase II will build on the Phase I experience and results to design and implement additional software so that the intelligent terminal itself becomes the system that the user interacts with. The crucial step is that now the large central processor, together with its data library and software (e.g. LARSYS), is logically treated as subordinate to the terminal. In other words, the large system and its capabilities become a resource that is called into play and controlled by the intelligent terminal in response to user needs and requests.

Phase III would further develop the intelligent terminal concept by adding additional hardware and further enhancing the system software.

Evaluation of Educational and Training Materials. The draft of the simulation exercise, "Determining Land Use Patterns Through Man-Machine Analysis of LANDSAT Data," reported on during the FY76 contract has been evaluated by five subject-matter specialists. Based on these evaluations the document has been rewritten and will be duplicated in limited quantities (approximately 30) for further evaluation by students taking remote sensing courses.

Instructor Training. One of the recommendations made in conjunction with the FY76 SR&T contract was that a one to two week training session be held for a group of JSC personnel to familiarize them with available education and training materials in the field of remote sensing. One of the purposes of this training session would be to prepare the participants to serve as instructors for training other JSC personnel. Training materials which are now available are described in Matrix of Education and Training Materials in Remote Sensing (LARS Information Note 052576). The availability of these materials and a cadre of on-site instructor-consultants could improve and simplify on-the-job training of JSC personnel.

Details of this effort were to be worked out in a planning meeting between Professor John Lindenlaub (317-749-2052) and the contract and/or task monitor. Due to overlapping vacation schedules and other factors the joint planning meeting has not taken place. The implementation plan suggested that this meeting take place before October 1, 1976. A more concerted effort to establish contact and schedule this meeting is now being made.

Development of Education and Training Materials. With the exception of the continued development of the simulation exercise mentioned above no new education and training materials development efforts were undertaken during the first quarter of the contract period. Plans have been made, however, to prepare different versions of Units III and IV of the LARSYS Educational Package to accommodate a Data 100 remote terminal. This effort will provide a second hardware option to remote terminal users and is a good preliminary step towards the development of training materials to support the intelligent terminal concept described above.

2.6 Large Area Crop Inventory Design

Major Activities. During the first quarter discussions were held with NASA/JSC and ERIM personnel on possible approaches to the project. Discussions have been started with LARS staff concerning experiments and research needing to be performed in order to develop a multi-crop inventory system. In addition, the LACIE system and results of phase 1 have been reviewed for their applicability to a multi-crop system.

2.7 Forestry Applications Project

Major Activities. The FAP activity at LARS is directed at developing inventory methods. These methods should investigate maximizing the use of remote sensing technology with application to forest and rangeland information needs. During the first years activity LARS will focus their efforts primarily in the area of identifying sampling strategies. Such strategies should be statistically valid and applicable to large area inventories.

The primary activities during this first reporting period have been: (a) developing an implementation plan, and (b) developing background reference data. The implementation plan was completed and submitted by the end of June. The remaining time on the project has been spent in reviewing the State-of-the-Art of Inventory Design.

A detailed reference list is being constructed for all pertinent inventory literature. This list will provide valuable guidance during the design phase of this program. The sources include publications acquired through the National Technical Information Center, Purdue University's Forestry and Natural Resources Library, and other professional literature (primarily articles appearing in professional Journals). Likewise, the staff is reviewing the resources planning act in hopes of understanding the information needs imposed by that legislation. These activities will broaden our base of knowledge regarding inventory design and also our understanding of the scope of the FAP activity. Both these tasks are necessary and important in providing insights to proposing meaningful design solutions.

Planned future activities will involve further search into the literature which may include tapping U.S. Forest Service sources and other libraries through the Interlibrary Loan Program.

2.8 Regional Applications Project (RAP)

Major Activities. The first portion of this quarter was spent in development of a RAP milestone schedule and implementation plan for CY77. However, the main effort of the work conducted during the first quarter of CY77 was directed toward reclassifying the Austwell quadrangle and determining the correlation between the spectral reflectance classes and the Spectral Environmental Classification provided by JSC/LEC.

A "modified" unsupervised approach was used during classification. The Spectral Environmental Overlay in conjunction with February 1975 CIR photography was used to choose training areas. The resulting classification contained 35 spectrally separable classes which appeared to characterize the scene completely.

Since the Spectral Environmental Overlay contained only 25 classes, (Austwell quadrangle) a one-to-one correspondence between the overlay classes and the 35 spectral classes could not be established. Preliminary comparisons show that some classes of the hierarchical classification are represented by more than one spectral class, and there are some hierarchical classes (e.g., TFi, WB) that are not represented in the spectral classification of the Austwell area. The absence of these classes can be explained either by there being so few data points available to use as training samples to represent the classes or the classes are not spectrally separable from other classes. It appears that the latter case may prevail. Grouping of certain members of the 35 spectral classes is being conducted to gain the maximum correlation between the spectral classes and the hierarchy classification.

The third area of activity this quarter has been in making a final decision on which method of change detection will be used to monitor alterations in the coastal environment. After reviewing CY76 procedures and results, it was decided to utilize the direct change method of change detection. The basis for this decision included the test performances of the four change detection methods, straightforwardness of the procedures, and the output products required by RAP for this project year.

The fourth area of involvement this quarter consisted of investigation of methods for improving the geometric accuracy of the registered coastal zone quadrangles. The current corrected Austwell and Port O'Connor quadrangle data was inspected to obtain all possible ground control point locations. The same points were located in the uncorrected data and on the USGS map used as a geometric reference. Alternative interpolation methods were used and compared to the least squares bi-quadratic method used in the original corrections. One method uses a linear transformation and shows promise where control points are not well distributed over the area to be corrected.

In the Port O'Connor quadrangle there are no control points in the lower right quarter since this is an offshore region. A one-to-two line geometric stretch error is observed and this is thought to be due to the effect of inaccurate quadratic terms caused by poor point distribution. This work is not yet complete and should be finished in the next quarter.

Technical Problems Encountered. The most serious difficulty met at this point has been the lack of data available for use in developing our procedures. Scheduling and atmospheric conditions have apparently prevented the necessary digital and photographic data from being collected over the study site by NASA, and subsequently transmitted to LARS.

2.9 Interpretation of Thermal Band Data

Major Activities. The implementation plan that describes the proposed activities for the contract year was prepared and submitted to NASA/JSC. This project is divided into three principal parts:

1. Data acquisition and preprocessing
2. Radiation model development
3. Radiation model testing

Essentially, all of the data for this project were acquired during the first quarterly reporting period. These data will be used to test and modify a theoretical model of radiant and convective heat transfer in plant canopies. The data were obtained at the North Dakota State University Agricultural Experiment Station located at Williston, North Dakota and at a commercial field located near the experiment station.

Data were acquired according to the following schedule:

June, 1976 - Temperature-profile and thermal-image data were acquired over a mature winter wheat canopy on the experiment farm at Williston.

July, 1976 - Thermal profile and thermal image data were acquired over ripe winter wheat and headed spring wheat canopies at the experiment station. Additionally, thermal-spectral and reflective-spectral data were obtained over the headed spring wheat canopies coincidentally with the acquisition of the thermal-image and thermal-profile data.

August, 1976 - Thermal-profile and thermal-image data were acquired over ripe spring wheat canopies on the experimental farm. Additionally, reflective-spectral and thermal-spectral were acquired coincidentally with thermal-image data on the spring wheat canopies. Thermal-image and thermal-profile data were obtained from a commercial field of ripe spring wheat located near the experimental farm.

Temperature profiles of the various wheat canopies were obtained in two basic fashions. An array of thermistors was attached to each of four stakes driven into the soil and located in the wheat canopy under test. The thermistors were positioned so that they measured the air temperature in and above the canopy as well as the soil surface temperature. The thermistors were positioned so as to be shaded from direct solar radiation. A fast scan thermal scanner (Dynarad Model 209A) was modified so that it could measure the radiant temperature profile looking into the edge of the canopy. All data were calibrated using blackbodies located in the field of view of the thermal scanner. The data from the thermal scanner were recorded on a video tape recorder for subsequent detailed analysis. Several experiments using blackbodies located in the canopy and a radiation thermometer were conducted to establish the role of canopy edge effects on the radiant temperature profiles obtained. It was determined that the edge effects can be fully accounted for in the processing of the data. The thermal scanner was then mounted in a cherry picker bucket and thermal-image data were obtained in a vertical view of the canopy. These data were correlated with radiant temperature and temperature profile data taken in the canopy. Again blackbody references were located in the field of view of the thermal scanner for calibration purposes. Thermal-image data were acquired in the edge of the canopy as well. Both horizontal and vertical temperature profiles were obtained from the canopy edge experiments.

The thermal scanner was mounted next to the short wavelength and long wavelength heads of the Exotech Model 20C spectroradiometer and reflective-spectral and thermal-spectra data were obtained along with thermal-image data. At the time of this data acquisition, radiant temperature measurements and air temperature profiles were obtained in the canopy under study. Reference blackbodies were located in the field of view of the thermal scanner for calibration purposes.

The data from the June and July missions have been annotated and pre-processed. Additionally, special photographic data were acquired in order to quantitatively establish the geometric characteristics of the canopies.

Meteorological data which were obtained in time coincidence with the thermal-spectral data, thermal-image data and temperature profile data will be correlated with these data. The most important correlations will involve wind velocity and total solar input energy data.

Technical Problems and Solutions. No significant technical problems have yet been encountered.

Plans for Next Quarter. Pre-processing and annotation of the August data will be completed. An experiment on a corn canopy for comparison purposes will be executed at the agronomy farm at Purdue University. Preliminary development of the radiation model will be completed and the analysis of geometric data that have been acquired as a part of the field measurements research project will be applied to the data sets described here.

2.10 Super Site Data Management

Major Activities. The implementation plan that describes the proposed activities for the contract year was prepared and submitted to NASA/JSC. The activities can be divided into four major sub-tasks.

1. Conduct study of data types collected in EOD field data gathering.
2. Selection of sites for data storage.
3. Devise catalogue and data flow procedures for the various data types; develop any needed software. Begin receiving data to be stored at LARS.
4. Develop a current catalogue of super site data.

The study of the data types collected by EOD field data gathering projects is in progress.

Technical Problems and Solutions. No significant technical problems have been encountered yet.

Plans for Next Quarter. During the next quarter, the study of the data types being collected will be completed and the sites for data storage will be selected through discussions including LARS, NASA/JSC, and other possible institutions.

2.11 Soil Classification and Survey

Major Activities. The objective of the research for this fiscal year is to develop the analytical methods and interpretive skills for effective use of satellite multispectral data in classifying and surveying soils. There are many reasons why this objective is particularly appropriate now. Four are suggested: (a) A world with serious food shortages today and more serious famines predicted in the decades ahead still depends upon its finite soils resources as the major medium for food production. (b) Although a very generalized map of the soils of the world has been recently completed at a scale of 1:6,000,000, a major portion of the soil resources of the world is yet to be mapped in sufficient detail for effective use in local and regional planning and management. (c) It has been demonstrated that digital analysis of LANDSAT data can be used to delineate and map soils differences and greatly accelerate the production of soils maps (at scales as large as 1:15,840); this capability is of critical need to the developing world. (d) With world soils resources subjected to increasing intensification for food production, there is a growing concern over the acceleration, water-logging, water erosion, wind erosion, and subsidence. Modern remote sensing should be used to map and monitor this deterioration.

Four specific activities designed to meet the objective of this project can be reported for the first quarter of FY77.

1. Implementation Plan

During the early part of this quarter an implementation plan was developed and submitted to NASA. The implementation plan provides details on how the Exotech Model 20 spectroradiometer will be used to provide detailed spectral data of soils in the laboratory and in the field under varying conditions. Soil samples are to be obtained from a wide range of parent material, climatic regions, and weathering regime and will be analyzed to determine the physical characteristics and chemical constituents. Statistical correlations between physical-chemical parameters and reflectance will be studied. Specific reflectance bands will be related to the various vibration modes within the molecular structures of specific constituents. The implementation also provides details on how spectral maps produced by computer-implemented analysis of LANDSAT data will be used as a base for field mapping of soils.

2. Preparation of Manuscripts

During this quarter work was initiated on manuscripts for two technical papers from the PhD thesis entitled "An Investigation of the Relationship between Spectral Reflectance and the Chemical, Physical and Genetic Characteristics of Soils" by Dr. Oscar Montgomery who completed his research at Purdue University in FY76. The titles of the two manuscripts which are in preparation are "Climatic Effects on the Relationships between Physico-Chemical Properties of Soils and Reflectance" by Montgomery and Baumgardner and "An Investigation of the Relationship between Spectral Reflectance and the Chemical, Physical and Genetic Characteristics of Soils" by Montgomery, Weismiller, and Baumgardner.

3. Recruitment

A graduate student was recruited to continue and extend the work already begun by Dr. Oscar Montgomery to study the contributions of various soil components to spectral reflectance and emittance. The graduate student is Mr. Eric Stoner who has enrolled for the fall semester at Purdue University and will pursue his studies for a PhD degree. His initial tasks are a literature search and training for the use of LARSYS in analyzing multispectral data for use in soil classification and survey.

4. Soil Survey

Work is continuing in the use of spectral maps produced at 1:15,840 for use by the soil surveyor. These spectral maps seem to provide certain advantages to the soil surveyor. First, a spectral map of a county provides an excellent base map for planning field operations. The spectral map delineates the homogeneous areas and the heterogeneous or complex areas. The soil surveyor can then make a rational decision on areas requiring minimum and maximum ground observation. Spectral maps also provide an excellect quality control too. On numerous occasions spectral maps have been used to compare with field sheets prepared by the soil surveyor by conventional means. The spectral maps have delineated complex areas and differences in drainage profiles which were not identified by conventional mapping techniques. Many times the spectral map provides a better location of the boundary between soils than can be done by conventional methods. This has been confirmed by ground checking in many places in Indiana.

The spectral maps also provide a method for speeding up soil mapping and perhaps even reducing the cost of producing a soil survey.

2.12 Improved Analysis Techniques for Multitemporal Data

Implementation Plan. A detailed implementation plan for this task was prepared and delivered to the technical monitor in early July. At this writing, no response has been received, but in order to maintain the proposed schedule of task milestones, work is proceeding as proposed.

Data Acquisition and Preparation. A number of multitemporal data sets are available at LARS for use under this task. Their suitability, especially with respect to adequacy of reference data, is being determined.

Research has been completed on techniques for registration of multitemporal multispectral scanner imagery (a technical report is in preparation). Several preprocessing techniques were evaluated to determine what methods provided the maximum improvement in image registration accuracy. It was determined that magnitude-of-the-gradient enhancement performed best. Several correlation measures were also evaluated, and although the correlation coefficient gave the best performance, the absolute difference method gave almost as good performance with much less computational cost. Thus this method is recommended.

Several other aspects of the registration problem were considered in this work. A theoretical method for estimating the variance of the registration error was developed. This result was used to derive a correlator which optimizes performance. An investigation of the effects of relative geometric distortion on registration accuracy was conducted using various signal and noise assumptions. Finally the statistical properties of temporal changes in LANDSAT data were evaluated. These studies support the advancement of the state of the art in image registration and are a part of a growing body of knowledge related to the image registration problem.

Layered Classifier Development. Documentation of the software for the Layered Classifier program, which implements any user-specified layered decision logic, is now about 75 percent complete. The prospects for the user documentation are uncertain at present due to unavailability of personnel. However, this phase of the two-phase layered classifier software (the other is the Optimal Tree Design program) is relatively easy to use, and the control card summary which is available will suffice until progress can be made with more formal user documentation.

No resources are currently available to pursue the optimal design research.

Future Plans. Personnel who will make major contributions to this task will become available approximately October 1, 1976. A number of key subtasks will be initiated by November 1. A multitemporal analysis workshop at LARS is planned for October or early November. This will involve all LARS staff who have attempted multitemporal analysis and is expected to produce an insightful assessment of existing approaches and promising avenues for pursuing further development.