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

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16. Abstract

This report provides tentative and preliminary results and summarizes progress for the current quarter on the four tasks of the subject contract which are:

2.1 Ag Scene Understanding
2.2 Processing Techniques Development
2.3 Crop Production Statistics
2.4 Computer Processing Support

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1. AGRICULTURAL SCENE UNDERSTANDING

A. Analysis of Spectral Data for Physical Understanding

I. Introduction

The spectral and agronomic measurements which have been acquired during the three years of the LACIE Field Measurements program are being analyzed to provide a quantitative understanding of the relationship of reflectance to the biological and physical characteristics of crops and soils.

The data acquired by truck- and helicopter-borne spectrometer systems are in narrow wavelength bands and permit simulation of the response in any specified wavelength band. Data were also acquired by a Landsat band radiometer which has the advantage of rapid data acquisition. All data were calibrated to permit valid comparisons among dates, locations, and sensors.

The knowledge which will be gained from these analyses of how important agronomic and physical factors affect reflectance is necessary for the optimal use of current Landsat MSS technology as well as for design and development of future remote sensing systems. Methods developed for analysis can be applied to the multicrop supporting field research task. Knowledge of relationships of agronomic variables to one another and to spectral reflectance and effects of sun and view angles on reflectance can be used to design better research for corn and soybeans.

II. Objectives

The overall objective of this task is to design and perform analyses of spectral data to enhance our understanding of the reflectance properties of agricultural crops, how these properties depend upon specific agronomic and other physical variables, and how changes in reflectance are affected by other "nuisance" parameters which are not ordinarily of interest. The results of these analyses will be interpreted to determine: spectral/temporal features of particular crops or crop conditions and predictive relationships between the crop identity, agronomic variables, physical variables, and the reflectance spectra.

III. Approach

The spectral data which have been used thus far in this analysis effort are:

(1) Truck-mounted spectrometer data acquired over experimental plots at the Williston, North Dakota, and Garden City, Kansas, experiment stations during 1975 and 1976.

(2) Helicopter-mounted spectrometer data acquired on the intensive test sites in Williams County, North Dakota, and Finney County, Kansas, during 1975 and 1976.

(3) Landsat band radiometer data acquired at the Williston AES in 1977 at several times during the day.

(4) Truck-mounted spectrometer data acquired at Williston in 1975 and 1976 at several sun and view angles.

Agronomic and meteorological data acquired at the experiment stations and intensive test sites are also being used.

The general approach has been to analyze band means for the Landsat MSS and proposed thematic mapper bands. In addition, the spectral data have been analyzed using several transformations of reflectance values including greenness, brightness, ratios, and the vegetation index.

The overall analysis approach is discussed here with specific details in the results section. Reflectance data were plotted to verify data quality and to qualitatively assess the information contained in the data. Regression and correlation are being used to relate biological and physical parameters such as leaf area index, biomass, percent ground cover, height, maturity stage, angles, and time of day to spectral response represented as band means or in basis function form. Analysis of variance and discriminant analysis are being used to determine the separability of wheat from other cover types and effects of experimental treatments.

IV. Accomplishments this Quarter

The progress which has been made through this past quarter is shown in the milestone chart attached. Some analyses have been delayed due to commitments to the summer field research program.

The study of basis functions for representing and discriminating crop spectra has been suspended. Support for writing computer programs to derive basis functions and their coefficients came from another task. Some problems in precision have been discovered with the programs which may cause meaningless results for some data sets.

Work has progressed on the analysis of 1975 and 1976 Williston and Garden City experiment stations data and on analysis of the sun angle-view angle experiment, but there are no significant results to report at this time. Results which will be discussed are: (1) changes in spectral reflectance during the day, (2) analysis results from the 1976 Williams County ITS including separability of cover types and relationship of agronomic variables to reflectance, and (3) analysis results of crop discriminability from the 1975 Finney County ITS.

a. Time of Day Effect on Reflectance of Spring Wheat

Analysis of data collected in 1975 and 1976 by the LACIE Field Measurements project indicated that there existed some effect due to the time of day that the spectra of the wheat canopies were obtained. This effect was apparent despite the fact that the spectra sampled were calibrated and corrected for changes in solar irradiance. An experiment was conducted at Williston in 1977 to assess time of day effects.

The data analyzed were acquired for 32 spring wheat plots on five dates during the 1977 growing season at Williston, North Dakota. The spectral measurements were made in the four Landsat MSS bands approximately every hour for four hours before and after solar noon. The bidirectional reflectance factor in the visible wavelengths varied as much as 100% during this time period.

Data analysis was aimed at separating the two time of day effects on reflectance: the changing sun angle and the changing scene. A regression model was formulated which was composed of a constant term, a linear term to account for the canopy changes, and a quadratic term to account for the sun angle effects. Effects due to changing sun angle were found to be symmetric with respect to solar noon while effects caused by canopy changes were asymmetric about solar noon.

The time of day effect can be minimized by measuring spectra at specific time intervals on days of data collection. The amount of variation in reflectance can be decreased to less than 20% if measurements are made within two hours of solar noon. This procedure would make results obtained on different dates and different times on the same date more valid for comparison.

The symmetric component, a pronounced effect of sun angle, was found to be the most important factor in explaining the variation in reflectance with time during the day. This component of the reflectance was found to be minimized in early July, the period of maximum biomass.

The asymmetric component of reflectance explained such effects as drying of the surface soil. However, the five dates and amount of supporting data (e.g., leaf wilting) were insufficient to characterize fully the asymmetric component of reflectance due to changes in the canopy. Thus, this study could not determine the effect of specific stresses on reflectance during the day.

A complete report describing the approach, analysis, and results of this experiment is being prepared.

b. Analysis of 1976 Williams County Intensive Test Site Data

To determine if wheat could be discriminated from pasture and fallow, analyses of variance were run for each date for each of the Landsat MSS and proposed reflective thematic mapper bands. Results indicated that there was a highly significant difference due to cover type for nearly all dates and wavelength bands.

Newman-Keuls range tests were run to determine which cover types were separable. On May 13, wheat was separable from both pasture and fallow in the visible and all three cover types were separable in the near infrared. On the May 28 and June 17 missions, wheat and pasture were confused with one another, but were both different from fallow in the visible wavelength bands. On these dates, patterns of recognition were not as clear in the near infrared. After this date until the wheat had matured, all three cover types were separable.

Analyses are in progress to determine the percent of each cover type which was correctly classified using different combinations of dates and to assess the utility of transformations in classification.

Studies of the relationships of agronomic variables with reflectance were also conducted with this data set. First, correlations of the spectral reflectance with the agronomic variables (height, maturity stage, and percent ground cover) were calculated. The reflectance was represented as band means for the Landsat MSS and proposed reflective thematic mapper bands and as transformations of band means. The linear (Pearson) correlation coefficients are given in Table 1A-1.

The improvement in correlation from band means to transformations is quite apparent here. While the .76 - .90 μm band was the band most highly correlated with percent cover ($r = .76$), six of the nine transformations had significantly higher correlation values. This result shows the strength of data transformations: if only one term is desired to relate reflectance to agronomic variables, transformations have the advantage of using more than one piece of information in a single term. In general, quadratic terms

Table 1A-1. Linear correlations of agronomic variables with band means and transformations of reflectance values (Williams County ITS, 1976).

Wavelength Band (μm)	Height	Maturity Stage	Percent Ground Cover
.5 - .6	0.490	0.152	0.129
.6 - .7	0.472	0.170	0.158
.7 - .8	0.331	0.531	0.676
.8 - 1.1	0.463	0.617	0.739
.45 - .52	0.507	0.240	0.247
.52 - .60	0.484	0.137	0.110
.63 - .69	0.458	0.146	0.130
.76 - .90	0.495	0.635	0.760
1.55 - 1.75	0.461	0.177	0.153
2.08 - 2.35	0.513	0.349	0.381
VIS/IR	0.631	0.710	0.871
IR/VIS	0.642	0.641	0.696
Vegetation Index (VI)	0.657	0.715	0.857
Transformed VI	0.648	0.714	0.864
VIS + IR	0.276	0.490	0.611
IR-VIS	0.606	0.690	0.807
1/VI	0.527	0.657	0.847
Brightness	0.232	0.460	0.585
Greenness	0.620	0.697	0.811

were not significant in the linear regression. Many transformations were more highly correlated with height and maturity stage if inverse relationships were considered.

Several types of models for prediction of agronomic variables by reflectance were investigated. Optimal models using a subset of linear, quadratic, and cubic band means were derived using the Landsat MSS and thematic mapper for each of the agronomic variables. Models using only linear and squared terms of transformations were considered and, finally, mixed models including both bands and transformations were included.

The best models were derived using the techniques of all possible regressions and C_p values as an indication of the bias. In general, the use of transformations alone or their use in conjunction with band means did not seem to provide substantial improvement in explaining the variability in agronomic variables. The strength, then, of transformations (as was illustrated earlier) is their use singly rather than in combination with other information.

c. Analysis of 1975 Finney County Intensive Test Site Data

Minimal analyses have been performed using this data set and no further analyses are planned at the current time. The 1975 data quality was not optimal and the location of the test site was not representative of conditions typically found in Kansas. As the site was moved after one year of data acquisition and analysis of the Williams County data indicated that 1976 data quality was superior, it was decided that resources would be more profitably spent in analysis of other data sets.

Preliminary analyses found unreliable data in the water absorption bands at 1.13 and 1.90 μm. No analysis was done using data from these wavelengths. Fields whose identities were questionable were omitted from the analysis.

Spectral plots of the data were done in two ways: (1) several crops on the same measurement date and (2) a single crop over several dates. The plots give indications of what crops may be separable at any given time and also show changes in a crop over the growing season. An extensive set of example plots can be found in the LACIE Field Measurements Data Examples (March, 1977).

Differentiability of crops on a specific date was assessed in several ways. First, univariate analysis of variance was performed on each wavelength band at each date to determine if a significant difference in reflectance existed due to crop type. For every band and for every date (except .7-.8 μm on June 17), there was a significant difference.

Discriminant analysis was used to discover which particular crops were different at each date. Two sets of wavelength bands were used for discrimination: the Landsat MSS bands and the proposed reflective thematic mapper bands. Discriminability was assessed by the classification performance on the training fields, judged sufficient in number to provide a reliable estimate of discriminability.

A summary of results of these analyses is presented in Table 1A-2. In November, it appears that wheat and alfalfa can be fairly well distinguished. Some confusion exists between these cover types and fallow, perhaps due to the small proportion of ground cover or insufficient statistics to define the spectral distribution of fallow.

In March and April, it appears that most wheat has reached a stage of greenness where it can be differentiated from fallow land and it remains separable on all following measurement dates. A few wheat fields are still being missed, but almost no fields are being falsely identified as wheat.

On May 14, alfalfa and wheat are quite distinctly differentiable and remain so on all following measurement dates. Corn, however, has not yet reached a growth stage where it is differentiable from fallow land. Corn and fallow are fairly differentiable by May 21 and then remain so. Beginning on June 9, sorghum can be correctly identified with the exception of some fallow being classified as sorghum. Fallow, which consists of bare soil and several degrees of stubble, is confused with other crop types early in the season.

Table IA-2. Summary of the separability of cover types at several times during the 1974-75 growing season for the Finney County, Kansas, Intensive Test Site.

DATE	CLASSES	OVERALL PERCENT CORRECT IDENTIFICATION		COMMENTS
		LANDSAT MSS	THEMATIC MAPPER	
Nov. 5	wheat,alfalfa, fallow,other	77	76	Some wheat was classified as alfalfa and fallow
March 20	wheat,alfalfa,fallow	87	88	Some wheat was missed.
April 8	wheat,alfalfa,fallow	88	87	
May 14	wheat,corn,fallow, alfalfa,other	77	76	Major problem is fallow being classified as another cover type.
May 21	wheat,corn,fallow, alfalfa,other	89	90	Same as May 14.
June 2	wheat,corn,fallow, alfalfa,sorghum, other	75	79	Wheat and alfalfa are correctly identified. All other cover types are confused.
June 9	wheat,corn,fallow, alfalfa,sorghum, other	67	88	Wheat and sorghum were correctly identified by the Landsat bands; alfalfa was also correct with thematic mapper.
June 17	wheat,corn,fallow, alfalfa,sorghum, other	78	83	All crops are separable from fallow; wheat and alfalfa separable; other crops confused.
June 26	wheat,corn,fallow, alfalfa,sorghum, other	88	90	Same as June 17.
July 6	wheat,corn,fallow, alfalfa,sorghum, other	84	92	Same as June 17 except more confusion of sorghum and fallow

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On June 9 and July 6, there is a noticeable difference in crop discriminability between performance of the Landsat MSS and proposed thematic mapper bands while they were close at all other measurement dates.

These results were obtained using field average data. These results provide a good indication of the separability of crops at any given time. Since there may be several spectral subclasses of a single cover type, a complete analysis should use single scan data and define subclasses before classifications are performed. LARS is working on development of software for definition of spectral subclasses by clustering.

V. Plans for Next Quarter

The analyses of 1975 and 1976 data from the Williston AES will be completed and preliminary analyses of the 1977 data will be done. The view angle-sun angle analysis will be completed. The 1976 helicopter spectrometer data from both North Dakota and Kansas will be evaluated for discriminability and relationships of agronomic variables with spectral reflectance.

Detailed Implementation Schedule

Analysis of Spectral Data for Physical Understanding

	DEC	JAN	FEB	MARCH	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV
Analysis of AES Data												
Williston												
1975												
1976												
1977												
Garden City												
1975												
1976												
1977												
Time of Day Expt.												
View Angle-Sun Angle Expt.												
Basis Function Study												
Analysis of ITS Data												
North Dakota												
1975												
1976												
1977												
Kansas												
1975												
1976												
1977												
Analysis of Combined Data Sets												
Crop Spectra Report												
Quarterly Progress Reports												
Contract Final Report												
Reports of Significant Results			Publication as significant technical results are obtained.									

B. Field Measurements Data Management

I. Introduction

The objective of this task is to complete the reformatting, verification and correlation of the data acquired during the 1975, 1976, and 1977 crop years at the three LACIE Field Measurements intensive test sites and continue the operation of the data library (prepare catalogs and distribute data). Activities during this quarter toward fullfillment of the objective include completion of the 1976-77 spectrometer data processing (FSS, FSAS, and Exotech 20C), distribution of the 1977 spectrometer data and ancillary data, preparation of catalog for the 1976-77 data, implementation of more powerful software for analysis and verification of spectrometer data (EXOSYSDV) and initial correlation analysis of 1977 spectrometer data.

II. Data Processing and Reformatting

a. Purdue/LARS Exotech 20C Field Spectrometer Data

The processing of the 1977 Exotech 20C data collected at the Williston, North Dakota Agriculture Experiment Station was completed; the data is ready for use by researchers. Also the processing of 1975 and 1976 sun angle-view angle data collected over a commercial field near the Williston Agriculture Experiment Station have been completed. In other words, all of the Purdue/LARS Exotech 20C Field Spectrometer data have been processed and are available for researchers.

The completion of the processing is in large part due to the new reformatting software and new analysis software developed during the previous two quarters. Nearly 2,500 observations were processed within three months; nine to twelve months would have been required with the old software systems.

b. NASA/JSC Field Spectrometer System (FSS)

All of the 1977 FSS data collected during the 1976-77 crop year have been processed and is available for researchers except for that collected on 7/17 and 8/04 for the Spectrometer Intercomparison Experiment. The data for this experiment had to be reprocessed at Johnson Space Center using a different calibration table than was originally used. We expect to receive the reprocessed data from JSC and complete the processing before the end of the quarter (May 31).

The FSS data yet to be processed includes that being collected at the Hand County, South Dakota site for the 1977-78 crop year. To date we have received the fall 1977 FSS data from NASA/JSC and will begin processing it during the next quarter.

c. NASA/JSC Field Signature Acquisition System (FSAS)

Processing of the 1977 FSAS data collected at the Garden City, Kansas Agriculture Experiment Station were completed; the data is available for researchers. The completion of 1977 data processing represents the completion of the processing of all the FSAS data collected for the LACIE Field Measurements program.

d. Landsat and Aircraft Multispectral Scanner Data

No Landsat data were received during this quarter. The task monitor will be notified to check if the NASA/Goddard order for Landsat data over Hand County, South Dakota during 1978 is in effect. All of the aircraft data have been received from NASA/JSC.

III. Maintenance of Data Library and Data Distribution

The LACIE Field Measurements catalog for the 1976-77 crop year is being updated. The update will be completed during the next quarter and the catalog sent to NASA/JSC (along with edited versions of the 1974-75 and 1975-76 catalogs) for duplication.

The 1977 Exotech 20C data were distributed to researchers at Texas A&M University and the Environmental Research Institute of Michigan along with the associated ancillary data. Also, the ancillary data (FSS flight logs, tape to film records, field maps, optical depth data and meteorological data) collected at the three intensive test sites during 1977 were distributed to researchers at the two above mentioned institutions. The 1977 FSS and FSAS spectrometer data will be sent, also, by the end of the quarter (May 31).

At the request of NASA/JSC, the FSS data collected on 4/18/76 and 5/6/76 at the Finney County, Kansas intensive test site were distributed to Craig Wiegand, USDA/SEA, Weslaco, Texas. The data included field maps, meteorological data, optical depth data, tape to film logs, FSS flight logs, data processing action requests (DPAR), ASCS period observation records and ASCS inventory records. The requested boresight photography will be sent when duplicates have been made. In association with this request, copies of the universal formatted FSS tapes for 4/18/76 and 5/6/76 were sent to Texas A&M University. NASA/Goddard has recently requested the 1976-77 Finney County, Kansas intensive test site data. Work is in process to fulfill the request.

IV. Software Development

During the LACIE Field Measurements Projects over 100,000 observations of spectrometer data have been collected. As the amounts of field measurements type data increased, the need for more powerful software tools to process, verify, and analyze the data efficiently and effectively also increased. The completion of the new Exotech 20C reformatting software system last quarter was a step toward providing more powerful tools. The original Exotech 20C reformatting system (pre LACIE Field Measurements) was designed for a few hundred observations per year compared to the two thousand observations per year collected for the field measurements project.

During this quarter, steps toward providing a more powerful analysis software were completed and made available for any researchers using the Purdue/LARS IBM 370/148 computer.

The software system (EXOSYSDV) provides the capability to review spectrometer data quickly on a CRT terminal, plot data on a line printer, or plot data on a high resolution Varian printer/plotter. The capability to review data on a CRT terminal speeds up the verification process. Moreover, researchers can also plot, print, and/or punch the ancillary data (leaf area index, fresh biomass, dry biomass, irradiance zenith angle, irradiance azimuth angle, etc.) along with the spectral data. The software system makes use of the Graphics Compatibility System (GCS) acquired from the U.S. Army Corps of Engineering Waterways Experiment Station, Vicksburg, Mississippi.

V. Documentation and Reporting

The analyses of the data collected for the Spectrometer Intercomparison Experiment were begun during the quarter. The initial analysis indicated that there was an error in processing the FSS data collected for the intercomparison experiment. The data is being corrected at NASA/JSC. The FSS data collected over the flightlines were satisfactory. The error involved the use of the 2° to 22° field of view transfer. The transfer was inadvertently used for the intercomparison data. All intercomparison data were collected in the 2° field of view mode, so no transfer was needed.

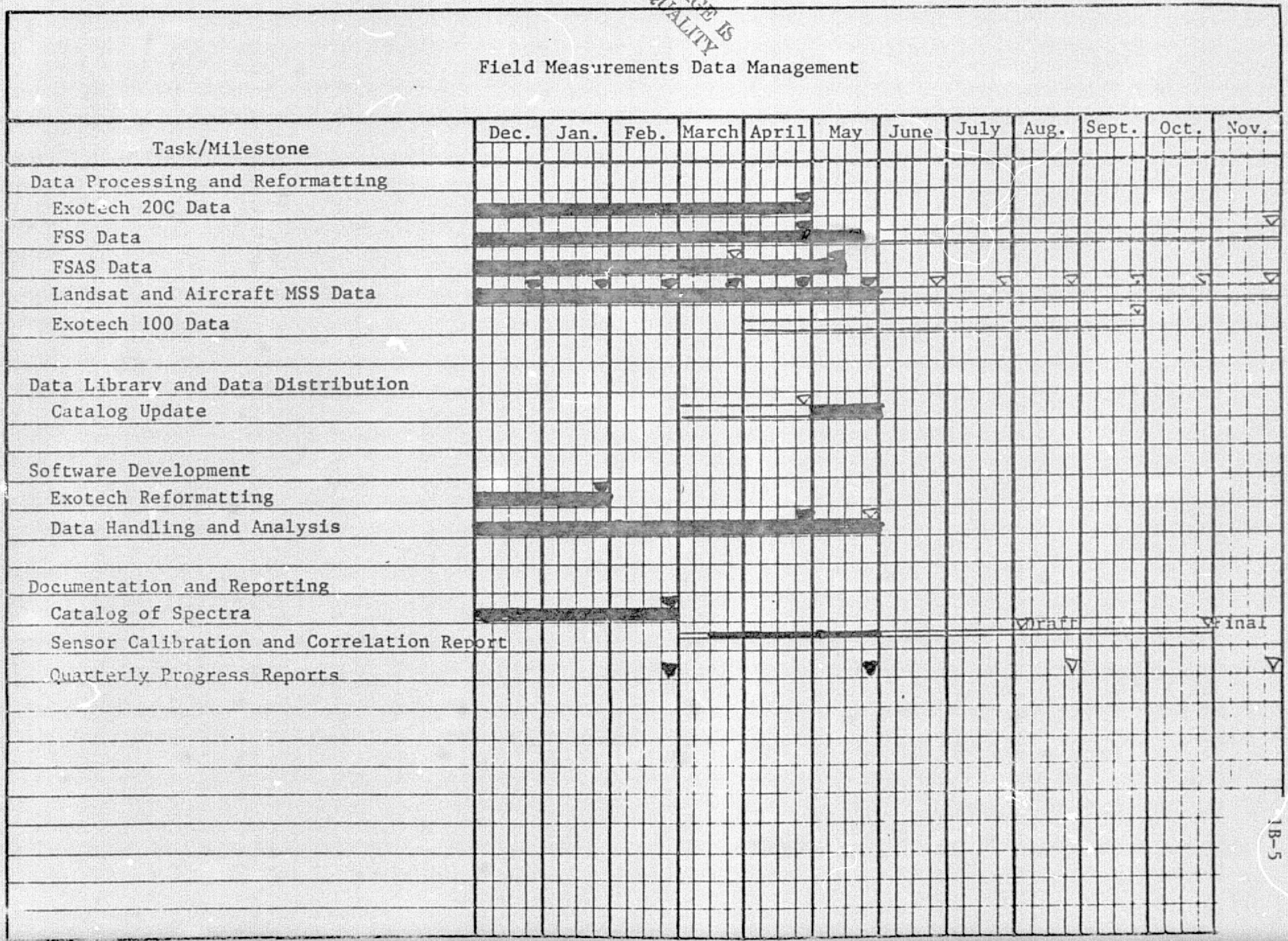
The initial analysis also confirmed the suspicion that the wrong calibration table had been provided to NASA/JSC to calibrate the summer 1977 FSAS data. The FSAS data were recalibrated at Purdue/LARS.

Once the reprocessed FSS intercomparison data have been received from NASA/JSC, the correlation analysis will continue and a report prepared summarizing the calibration and correlation of the LACIE Field Measurements spectral data.

VI. Next Quarter

During the next quarter, the updating of the three volumes of the catalog will be completed. The volumes will be sent to NASA/JSC for duplication. Also, as mentioned above, a technical report will be prepared summarizing the calibration and correlation of the LACIE Field Measurements spectral data.

Figure 1. Implementation Schedule



C. Determining the Climatic and Genetic Effects on the Relationships Between Multispectral Reflectance and Physical/Chemical Properties of Soil

I. Introduction

Modern soil classification systems emphasize the importance of information about the quantitative compositions of soils. In order to differentiate among soil groups, it is necessary to rely on laboratory measurements of selected soil properties. Physical, chemical, and engineering determinations of most soil properties follow well established procedures of laboratory analyses. Certain of these soil properties are selected as diagnostic criteria in the soil classification process, based on their importance in understanding the genesis of the soil. By a procedure of empirical correlation, critical limits between sets of soils are established, designed to reflect the influence of the soil forming factors of climate, parent material, relief, biological activity, and time.

Quantitative measurements of soil spectral properties have become available as a diagnostic tool for the soil scientist with the advent of such instruments as the Exotech Model 20C spectroradiometer. However, the climatic and genetic effects on the relationships between measured spectral properties and specific chemical, physical, and biological properties of the soil are not well understood. Whereas soil color is used as diagnostic criterion in the U.S. Soil Taxonomy (1), the determination of soil color by comparison with a color chart (2) continues to be a rather non-quantitative and subjective procedure. Spectral characterization of soil "color" by means of quantitative spectroradiometric measurements may add to the precision with which soils can be differentiated. With this increased precision of soil spectral characterization, the relationships with the more important diagnostic soil characteristics or qualities that are not so easily and accurately observed may be better understood.

a. Preparation of Soils for Analysis

All tests of agronomic properties are based on that portion of the soil sample that passes through a 2 mm (10 mesh) sieve while engineering determinations are based on the portion that passes a 0.425 mm (40 mesh) sieve. Spectroradiometric measurements will be taken on the portion of the soil that passes through a 2 mm (10 mesh) sieve.

Sample preparation includes drying the soil at air temperature and subsequent mixing and rolling with a heavy wooden rolling pin to break up the clods. The sample is alternately rolled and sieved until only the coarse fragments that do not slake in water remain on the sieve. The sieved soil is then subsampled and placed in separate cardboard containers for agronomic, spectrophotometric, and engineering determinations. Containers are marked to indicate the soil series, soil survey sampling number, and county where sampled.

b. Analytical Techniques

i. Physical Determinations

Particle Size Analysis (Mechanical Analysis). Eight particle size separates are recognized by the U.S. Department of Agriculture and are measured on a percentage basis: very coarse sand (2-1 mm), coarse sand (1-0.5 mm), medium sand (0.5-0.25 mm), fine sand (0.25-0.10 mm), very fine sand (0.10-0.05 mm), coarse silt (0.05-0.02 mm), fine silt (0.02-0.002 mm), and clay (<.002 mm). Total sand, silt, and clay percentages can be obtained by sum from these analyses.

The procedure followed by the Soil Conservation Service involves initial removal of organic matter with hydrogen peroxide and heat (3). This is followed by removal of the dissolved mineral matter by repeated washing and filtering through a Pasteur-Chamberlain filter. Sodium metaphosphate is then used as a dispersing agent. Sands are separated from silt and clay by washing the dispersed sample on a 300 mesh sieve. Clay and silt contents are determined by sedimentation-pipetting while sand fractions are determined by sieving.

Soil Moisture Parameters. Because of the need to provide an equipotential condition for spectrophotometric analysis of the prepared soil samples, a procedure was chosen which creates a one-tenth bar soil moisture tension on all the soil samples (4,5). Two asbestos tension tables will be used with a 100 cm column of water to create a one-tenth bar soil moisture tension for up to 50 sample holders at once. Sample holders consist of plastic rings 2 cm deep by 10 cm in diameter with 60 mesh brass strainer cloth attached to one end.

The one-tenth bar moisture percentage is used by some to designate the wet limit of the range of plant-available water under general field conditions (3), but the limitations of holding water at such a low tension in sieved samples are recognized (6,7). Principally, the sieved samples appear to hold more water than the given soil has pore space. The one-tenth bar moisture level is desirable mainly for the ease with which large numbers of samples can be prepared at equipotential moisture characteristics.

After overnight saturation and equilibration on the tension tables for 24 hours, the samples will be ready for spectral measurement, after which a portion of the sample will be transferred to moisture tins, weighed, dried at 105°C, weighed again, and moisture content reported as percentage of oven dry weight (3).

ii. Chemical Determinations

Cation Exchange Capacity. Ammonium acetate extraction is used for determination of the extractable cations (3). Extracted samples are analyzed by atomic absorption for calcium and magnesium and by emission spectroscopy for sodium and potassium. Extractable acidity is determined with a barium chloride and triethanolamine buffer solution by titration with hydrochloric aicd. Cation exchange capacity (CEC) is reported as the sum in millequivalents per 100 g of soil of the $Ca^{++} + Mg^{++} + K^{+} + Na^{+} + H^{+}$. Base saturation is calculated as:

$$\frac{CEC-H^{+}}{CEC} \times 100.$$

Organic Carbon. The modified Walkley-Black procedure of acid dichromate digestion with $FeSO_4$ titration will be used for determination of organic carbon (8).

pH Measurements. Potentiometric measurements will be made with the soil sample placed in deionized water as well as 1N KCl (3).

Available Phosphorus and Potassium. Available P and K are determined by NH_4OAc extraction for K and Bray 1 extraction for P and are reported as pounds per acre of the element, assuming an acre of topsoil weighs 2×10^6 lbs (9).

Free (Extractable) Iron, Aluminum, Silica, and Manganese. A dithionite-citrate-bicarbonate extraction is used with the desired elements being measured by atomic absorption (3).

Saturation Extract Conductivity. A saturated paste of soil is prepared and vacuum filtered to obtain a saturated extract which can be measured with a Wheatstone bridge-conductivity cell combination to determine the amount of soluble salts measured in units of mmho/cm at 25°C (3).

iii. Engineering Determinations

Introduction. A fine-grained soil can exist in any of several states; which state depends on the amount of water in the soil system. When water is added to a dry soil, each particle is covered with a film of absorbed water. If the addition of water is continued, the thickness of the water film on a particle increases. Increasing the thickness of the water films permits the particles to slide past one another more easily when, for example, the soil is sheared. Thus, the consistency behavior of the soil is related to the amount of water in the system.

Atterberg defined the boundaries of four physical states in terms of limits (10). The liquid limit (LL or W_ℓ) is the boundary between the liquid and plastic and semi-solid states. The shrinkage limit (SL) is the boundary between the semi-solid and solid states.

Casagrande (11) defined the liquid limit as the water content at which the soil has such a small shear strength that it flows to close a groove of standard size when the sample is jarred in a specified manner. The plastic limit is the water content at which the soil begins to crumble when rolled into threads of specified size. The shrinkage limit is the water content that is just sufficient to fill the pores when the soil is at the minimum volume attained by drying. The plasticity index (PI or I_p) is the amount of water added to change from the plastic limit to the liquid limit and is a measure of the soil's plasticity. Therefore, PI = LL - PL.

The consistency condition of an in situ soil is often partially revealed by the "water plasticity ratio" or liquidity index (I_ℓ) which is the ratio of the differences between the natural water content (W_n) and the plastic limit (W_p) to the plasticity index:

$$I_L = \frac{W_n - PL}{PI} = \frac{W_n - W_p}{W_\ell - W_p}$$

A high water-plasticity ratio means the natural water content is high relative to the liquid limit and indicates a very low remolded strength. If the ratio (I_L) $\geq$ 1, the soil's remolded strength is less than the small amount it has at the liquid limit ($\approx$20 g/cm^2).

The chemical and mineral composition, size, and shape of the soil particles influence the absorbed water films on the particles. Because such soil properties as compressibility, permeability, and strength, as well as the limits are dependent on water films, approximate relationships exist between these properties and the limits. Knowing the limits, predictions of the properties can be made. Such a procedure is helpful since the limits are more easily determined than compressibility, permeability, or strength (12, 13, 14).

Liquid Limit Determination.

1. Obtain the natural water content (W_n) of the soil sample.

a) Obtain weight of tare. (W_1)

b) Obtain weight of tare plus natural water and soil. (W_2)

c) Oven dry 24 hours @ 105°C.

d) Obtain weight of tare plus oven-dry soil. (W_3)

$$W_n = \frac{W_w}{W_s} = \frac{(W_2 - W_1) - (W_3 - W_1)}{(W_3 - W_1)}, \%$$

2. Sieve out material coarser than No. 40 sieve (<.425 mm). Caution: soil should not be oven or air dried in sieving process. The drying may alter natural behavior.

3. Take some moist soil and mix it thoroughly with distilled water in a small evaporating dish to form a uniform paste. For high plastic clays the mixture should have ample time for uniform water distribution.

4. Check equipment and adjust weight of drop. Grooving tools tend to wear on the tip. Standard tip width is 2 mm ± 0.1 mm. The pin on which the cam follower rests should not be worn sufficiently to permit sideplay. Screws connecting the cup to cam follower should be tight. A groove should not have been worn in the cup to the extent that it can be felt distinctly by the hand. The height of drop shall be adjusted by means of a gauge on the handle of grooving tool. (1 cm ± 0.2 mm)

5. Take 100 g of moist soil and place uniformly in brass cup. Avoid air bubbles, pits, holes, etc. Level soil off to a depth of approximately 1 cm. Divide the soil in the cup by drawing the grooving tool, beveled-edge forward, through the soil in one steady movement. The grooving tool should always be held perpendicular to the cup at the point of contact. This is easier to do if the cup is hand-held.

6. Connect the cup to the base and turn the crank at a rate of about 2 revolutions per second. Count the blows necessary to close the

groove in the soil for a distance of ½ inch. The number of blows should be between 10 and 40.

7. Remix the sample in the cup until 3 consistent blow counts are made. (number of blows ± 1 blow is acceptable)

8. When a consistent value is obtained, take 10 g of soil from groove and determine water content. At least 4 blow counts, 2 above 25 blows and 2 below 25 blows, are required.

9. Make a plot on single cycle semi-log paper of water content vs. log of blows. Such a plot is called the "flow curve" and it should be a straight line between 10-40 blows. The ordinate should be scaled appropriately. Definition: LL is the water content at 25 blows.

Plastic Limit Determination.

1. Prepare 15 g of soil as stated in 1, 2, 3 above except mix with distilled water to firmer consistency. It may be best to use a sample from the highest-blow liquid limit determination.

2. Roll the soil on a glass plate until it is 1/8 inch in diameter and breaks into lengths of 1/8 to 3/8 inch. Determine water content.

3. Obtain at least 4 determinations of the plastic limit which can be averaged.

Determination of Other Atterberg Indices and Additional Indices. Calculations are based on previous determinations as follows:

$$\text{Plasticity Index} = PI = LL - PI$$

$$\text{Liquidity Index} = LI = \frac{W_n - PL}{PI}$$

$$\text{Activity} = A = \frac{PI}{\% < .002\ \text{mm}}$$

The activity is a measure of the plasticity of the finest fraction which is largely clay minerals. Therefore, it expresses the water-holding ability of clay minerals. In general, for

Kaolinite	$A < 1$
Illite	$1 < A < 2$
Montmorillonite	$A > 2$

<u>Compression Index Calculation</u>. The compression index is of great practical importance because it permits one to compute the approximate settlement of a structure above a deposit of fairly insensitive normally loaded sedimented clay if only the liquid limit is known, and even if no consolidation tests have been performed. The compression index is calculated as:

$$\text{Compression Index} = C_c = .009\ (LL-10)$$

<u>Determination of Shrinkage Factors</u>.

1. Sieve out material coarser than No. 40 sieve.

2. Place a sample of about 30 g in an evaporating dish and thoroughly mix with distilled water in an amount sufficient to fill the soil voids completely and to make the soil pasty enough to be readily worked into the shrinkage dish without the inclusion of air bubbles.

3. Coat the inside of the shrinkage dish with a thin layer of petroleum jelly to prevent the adhesion of the soil to the dish.

4. Fill the shrinkage dish with soil until excess soil stands out about its edge.

5. Strike off the excess soil with a straight edge and wipe off all soil adhering to the outside of the dish.

6. Oven-dry the sample to constant mass at $110 \pm 5^{\circ}C$.

7. Determine the capacity of the dish in cubic centimeters, which is also the volume of the wet soil pat, by filling the dish to overflowing with mercury, removing the excess by pressing a glass plate firmly over the top of the dish, and measuring by means of a glass graduate the volume of mercury held in the dish.

8. Determine the volume of the dry soil pat by removing the pat from the shrinkage dish and immersing it in a glass cup full of mercury being careful not to trap any air under the soil pat.

9. Measure the volume of the mercury displaced with the glass graduate and record this as the volume of the dry soil pat.

Determination of Other Shrinkage Factors. These can be calculated from this procedure as follows:

$$\text{Shrinkage Limit} = SL = w - \{[(V-V_o)/W_o] \times 100\}$$

where:

w = moisture content of wet soil, in percentage of the oven-dried pat
V = volume of wet soil pat
V_o = volume of dry soil pat
W_o = mass of oven-dried soil pat

$$\text{Volumetric Shrinkage} = V_s = (w-SL)R$$

$$\text{Shrinkage Ratio} = R_s = \frac{W_o}{V_o}$$

$$\text{Linear Shrinkage} = L_s = 100[1-\sqrt[3]{100/(V_s + 100)}]$$

In addition, the specific gravity of the solids can be determined through the following formula:

$$\text{Specific Gravity} = G_s = 1/[(1/R) - (SL/100)]$$

C. Data Logging Procedure

An identification record has been prepared to be able to store all pertinent information that is being collected about the soils in this study and any future study involving laboratory or field soil experimentation. Data will be storea for each item listed in Table 1C-1, and it will be possible to call up given groups of soils by sorting on any of these items using EXOSYS subroutines (15).

Table 1C-1. Summary of items in soils identification record of EXOSYS.

Item

Soil Taxonomic Information:

Order
Suborder
Great Group
Subgroup Name
Particle Size Class
Contrasting Particle Size Class
Mineralogy Class
Other Modifiers
Temperature Regime

Moisture Zone
Drainage Class
Slope Class
Erosion Phase
Physiographic Position
Parent Material
Soil Series Name
Year Soil Sample Collected
State Abbreviation
County Code
Multiple Sampling Number
Consecutive Sampling Number
Horizon
Soil Testing Lab Number
Organic Carbon (%)
Water pH
Buffer pH

Extractable Bases:

Calcium (meg/100g)
Magnesium (meg/100g)
Sodium (meg/100g)
Potassium (meg/100g)
Extractable Acidity (meg/100g)

Cation Exchange Capacity
Base Saturation (%)
Iron Oxide (%)
Aluminum Oxide (%)
Manganese Dioxide (%)
Silicon Dioxide (%)
Available Phosphorus (lb/acre)
Available Potassium (lb/acre)

Item

Soil Moisture Tension (bars)
Water Content (percent)
Bulk Density (g/cm^3)
Munsell Color (moist)
Textural Class

USDA Particle Size Distribution:

Sand Content (percent)
Silt Content (percent)
Clay Content (percent)
Very Coarse Sand (percent)
Coarse Sand (percent)
Medium Sand (percent)
Fine Sand (percent)
Very Fine Sand (percent)
Coarse Silt (percent)
Fine Silt (percent)

Electrical Conductivity (mmhos/cm)
Erosion Factor (K)
Wind Erodibility Group
Engineering Lab Number
Sample Portion [(% < .425mm/% < 2mm) x 100]
Liquid Limit
Plastic Limit
Plasticity Index
Activity
Liquidity Index
Shrinkage Limit
Shrinkage Ratio
Volumetric Shrinkage
Linear Shrinkage
Compression Index

ASTM Particle Size Distribution:

Medium Sand (percent)
Fine Sand (percent)
Fines (percent)

Specific Gravity (g/cm^3)
AASHO Soil Classification
Unified Soil Classification
Soil Elevation
Other Experimentor Parameters (13 total)
Natural Vegetation or Crop
Surface Condition or Tillage-Planting System
Comments

References

1. Soil Survey Staff, "Soil Taxonomy-a Basic System of Soil Classification for Making and Interpreting Soil Surveys," Soil Conservation Service, U.S. Dept. of Agriculture, Agricultural Handbook No. 436, Washington, D.C. 1975.

2. Soil Survey Staff, Soil Survey Manual, U.S. Dept. of Agriculture Handbook 18, U.S. Govt. Printing Office, Washington, D.C. 1951.

3. SCS-USDA, Soil Survey Investigations Report No. 1, "Soil Survey Laboratory Methods and Procedures for Collecting Soil Samples," U.S. Govt. Printing Office, Washington, D.C. 1972.

4. Leamer, R. W. and B. Shaw, "A Simple Apparatus for Measuring Noncapillary Porosity on an Extensive Scale," Journal of American Society of Agronomy 33:1103-1008, 1941.

5. Jamison, V. C. and I. F. Reed, "Durable Asbestos Tension Tables," Soil Science 67:311-318, 1949.

6. Young, K. K. and J. D. Dixon, "Overestimation of Water Content at Field Capacity from Sieved Sample Data," Soil Science 101:104-107, 1966.

7. Elrick, D. E. and C. B. Tanner, "Influence of Sample Pretreatment on Soil Moisture Retention," Soil Science Society of America Proceedings 19:279-282, 1955.

8. Allison, L. E., "Wet combustion apparatus and procedure for organic and inorganic carbon in soil," Soil Sci. Soc. Am. Proc. 24:36-40, 1960.

9. North Central Region Soil Testing Committee, "Recommended Chemical Soil Test Procedures for the North Central Region," Bulletin No. 499, North Dakota State University, Fargo, North Dakota, p. 43, 1975.

10. Annual ASTM Standards, Part 19, ASTM, Philadelphia, Pennsylvania, pp. 80-85 and 89-91, 1976.

11. Casagrande, A., et. al., "Investigation of Stress-Deformation and Strength Characteristics of Compacted Clays," Harvard Soil Mechanics Series No. 70, Cambridge, Massachusetts, 1963.

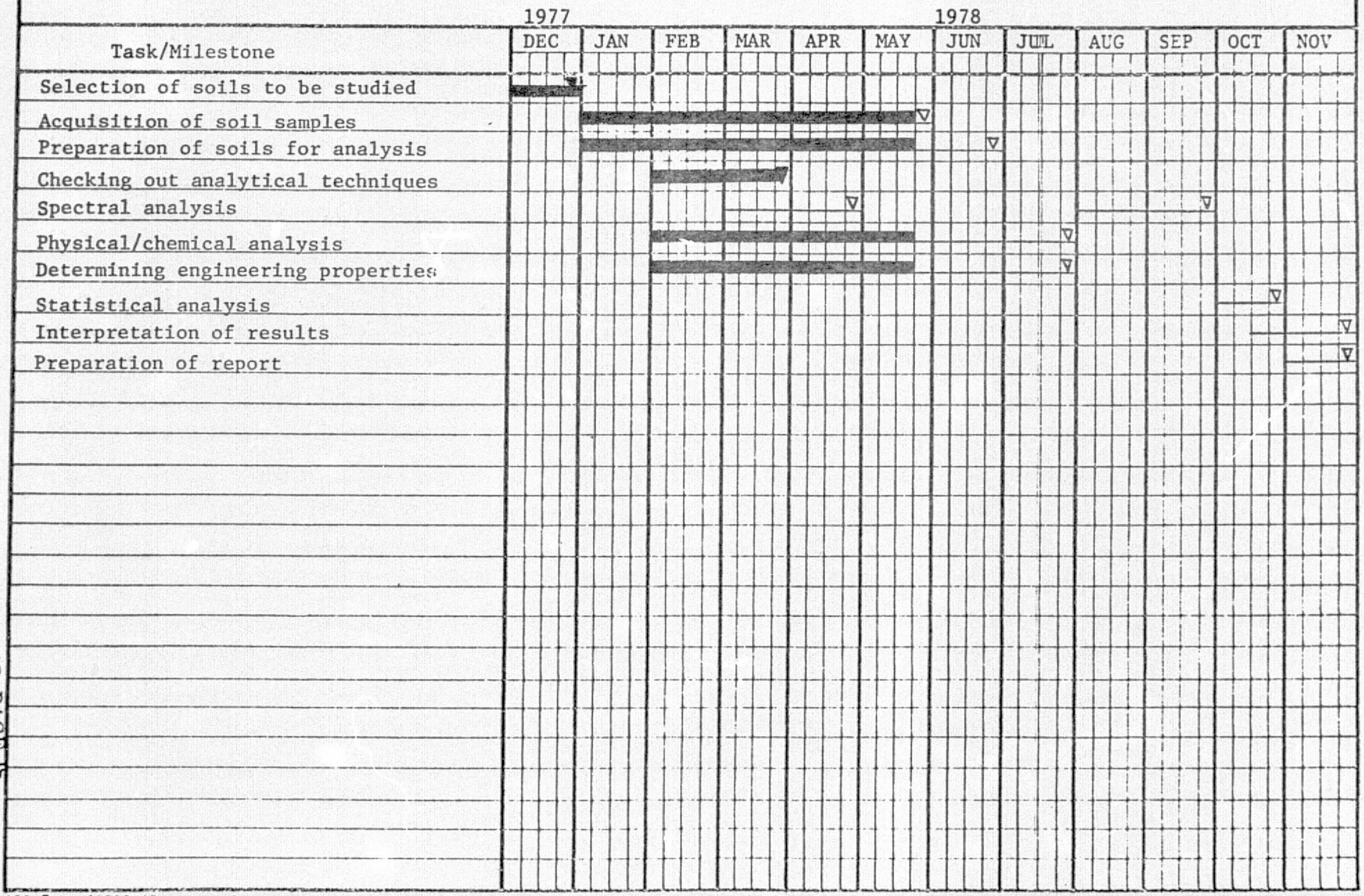
12. Lambe, William T., Soil Testingfor Engineers, Wiley, New York, pp. 22-28, 1951.

13. Peck, R., W. Hanson, and T. Thornburn, Foundation Engineering, Wiley, New York, p. 62, 1974.

14. Tergazhi, K. and R. Peck, Soil Mechanics in Engineering Practice, Wiley, New York, pp. 29-45, 1967.

15. Simmons, W. R., S. Wilkinson, W. C. Zurney, and J. L. Kast, "EXOSYS: Analysis Program for EXOTECH Model 20C Data," LARS Program Abstract 5000, Laboratory for Applications of Remote Sensing, Purdue University, West Lafayette, IN, 1975.

1C. Determining the Climatic and Genetic Effects on the Relationships between Multispectral Reflectance and Physical/Chemical Properties of Soil



A. Application of Statistical Pattern Recognition to Image Interpretation.

I. Introduction

This quarter has marked some upheavals in this task related to the transition phase of Multicrop. An effort to stratify the United States for corn and soybeans and an enlarged role in the preparation of the CITARS data for film production and for supplying copies to other sites caused delays in planned subtasks supporting the Image Interpretation task. The implementation plan has been revised to reflect these efforts in support of the Multicrop project.

II. Major Accomplishments

During this quarter, efforts were directed to (1) revise the implementation plan to support Multicrop tasks, (2) continue to apply the LIST method to data acquired over Kansas in the 1976 growing season, (3) assemble a data set to support the application of the LIST method to segments in North Dakota, South Dakota, Minnesota, and Montana, (4) work on quantitative analysis of the measurements produced by the LIST procedure, (5) stratify the U.S. corn and soybean production areas to support the Multicrop effort, (6) select segment locations for both low and high density Multicrop segments, and (7) prepare CITARS data in Universal format to facilitate the generation of film products and of digital data copies for the SR&T community.

Implementation Plan Revision. As a result of Multicrop meetings on March 16, the implementation plan for Task 2A Application of Statistical Pattern Recognition to Image Interpretation was revised and resubmitted for approval to reflect support for the FY78-79 Multicrop effort. The principal revisions relate to: (1) the stratification of the U.S. corn and soybeans areas based on corn production, soybeans production, and average farm size, (2) the selection of segments throughout the corn and soybeans producing areas of the U.S. for the acquisition of Landsat data in the 1978 growing season, and (3) an enlarged role in the conversion of CITARS data to Universal format. These additional efforts, of course, required resources of personnel and computer time and so forced a rearrangement of the originally planned tasks. The chief changes in the planned subtasks supporting Image Interpretation were a delay in the analysis of the Kansas data using the LIST method in order to accommodate the stratification effort and a resulting merging of the analyses of the blind sites in North Dakota and other states. The original and revised implementation schedules are included as Figures 2A-1 and 2A-2.

Analysis of LIST Method on Kansas Segments. The application of the LIST method to LACIE winter wheat segments in Kansas has been stretched out by the effort to stratify the corn and soybeans areas in the U.S. which took place in March and the subsequent segment locations selection in April. (See further description below and under Task 2B Application and Evaluation of Landsat Training, Classification, and Area Estimation Procedures for Crop Inventory).

The application of the LIST method on the Kansas segments has revealed a contradiction between the original LIST method developed by UCB/ERIM/LEC [1] and that described in technical memorandum LEC-10825 by M. D. Pore [2]. The LIST described in the technical memorandum has a contradiction in the logical flow of the questions. This was resolved by modifying the second set of questions to follow the flowchart from the original LIST.

Assembling the Data Required to Apply the LIST Method to North Dakota and Other States. The supporting data required to analyze segments 1633, 1637, 1660, and 1661 in North Dakota for the 1976 crop year has been assembled. Segments 1897, 1913, 1677, 1681, 1800, 1825, and 1811 in North Dakota, South Dakota, Montana, and Minnesota still await the receipt of digitized ground truth for the 1977 crop year from NASA/JSC. Full frame imagery covering these segments and segments 1652, 1927, and 1929 has been ordered from EROS Data Center, but has not been received.

In order to determine if the DO and DU areas could be automatically identified, the ERIM SCREEN procedure was applied to North Dakota segments 1633 and 1637 with the thresholds described in the documentation [3]. The results were judged by the analysts to be unsatisfactory due to the appearance of small scattered areas of "bad data" or "shadow" which did not agree with visual examination of the film products. The documentation included a warning that the algorithm is very sensitive to the threshold settings, so the areas where errors occurred were examined and the thresholds reset to eliminate these errors. With the new thresholds a different problem occurred; areas of actual shadow or water were not completely delineated. An examination of the data values in problem areas to determine optimal thresholds revealed that the thresholds which minimized the error on segment 1633 would not minimize the errors on segmenet 1637 and that the overall error occurrence for segment 1637 could never be as low as on segment 1633. It was judged that, at this time, the automatic SCREEN procedure would not produce a gain in accuracy or saving of analyst time in delineating the DO and DU areas.

Quantitative Analysis of LIST method. Some work has been done in analyzing the LIST method using linear discriminant functions [2]. This analysis has some pitfalls, involving the binary nature of many LIST answers and the high degree of structure in the LIST. A method to analyze the LIST data based on a tree structure and the calculation of transition probabilities at each node is being considered. This formulation would include a way to evaluate the importance of any question by determining superfluous nodes in the decision tree. Other methods, including sequential, nonparametric or categorical, are also being considered.

Stratification of the U.S. Corn and Soybeans Production Areas. At a Multicrop meeting in February, LARS was asked to work with A. Feiveson of NASA/JSC in constructing a stratification of the U.S. based on corn production, soybeans production, and average farm size as estimated by the Statistical Reporting Service of the USDA. This new task took longer than anticipated due to an unexpected need to verify the SRS data. The problems with the agricultural production data, the procedures used to obtain the stratification, and the strata constructed will be described in a separate report to be completed by the end of June, 1978.

Selection of Multicrop Segments. The stratification obtained in the previous task formed the basis for the selection of Multicrop segments for the 1978 crop year. Twenty counties were selected from each stratum. A set of programs developed for an SR&T sampling study in 1977 [3] was used to select segments within each county. A description of this procedure will also be included in the report on stratification.

Preparation of CITARS data in Universal Format. A copy of the geometrically corrected and registered Landsat data acquired in 1973 for the CITARS experiment was delivered to NASA/JSC at the March SR&T Quarterly Review. At that time EOD/JSC took the responsibility for constructing LACIE-size (117 lines and 196 columns) segments covering the CITARS data. However, due to some unexpected difficulty encountered at JSC, LARS subsequently accepted the responsibility to complete this task. By the end of May, the data shown in Tables 2A-1 and 2A-2 will be shipped to NASA/JSC. A copy of both the single acquisition and multiple acquisition runs will be available to NASA/EOD on the LARS computer system. A slight problem which is being tracked down is a difficulty in using a LARS tape on the PFC while a copy of the LARS tape made at JSC will run. This is inconvenient but is not preventing the completion of this task.

III. Technical Problems Encountered

To summarize the technical problems encountered in this quarter:

1. the inclusion of Multicrop stratification and sample selection efforts delayed the completion of the application of the LIST methods in Kansas;
2. digitized ground truth data for the 1977 crop year for segments 1861, 1897, 1913, 1677, 1681, 1800, 1811 and 1825 have not been received from JSC;
3. a potential problem in running a Universal format tape from LARS on the PFC must be resolved;
4. the agricultural production data gathered by the SRS and sent to LARS by NASA/JSC had such problems as missing data, duplicate cards, duplicate cards on which the yields were different by an order of magnitude, and nonexistent crop codes.

IV. Activities for Next Quarter

In the next quarter, June 1 through August 31, the application of the LIST method to Kansas data will be completed. The segments outside Kansas will be partially analyzed, starting with the segments in North Dakota. The report of the Multicrop stratification and segment selection effort will be available.

To support the development of a corn and soybeans labelling procedure, the CITARS data will be analyzed to provide a description of spectral response of both major crops and other cover types over the growing season. In addition to the Landsat bands, the first two components of the Tasselled cap or Kauth transformation [4], the visible/IR ratio [5,6], and vegetative index [7,8] will be examined and their variability at each acquisition described. The separability of the cover types over time will also be described.

The basis for this investigation will be a random sample of dots chosen from a grid over the ground truth areas of the CITARS data. Analysis of variance can be used to establish any effects due to local within CITARS segment variability, between CITARS segment variability, and between acquisition variability.

The random sample of pixels will allow this work to be more closely related to effects seen with a P1-type procedure than similar analyses based on fields or field center pixels. These analyses will support the development of a corn-soybeans procedure for image interpretation by providing for the quantitative descriptions of the spectral response of corn, soybeans and their confusion crops. It will also aid in choosing the most informative acquisitions for both image interpretation and for analysis.

Figure 2A-1 Implementation Schedule (as originally submitted)

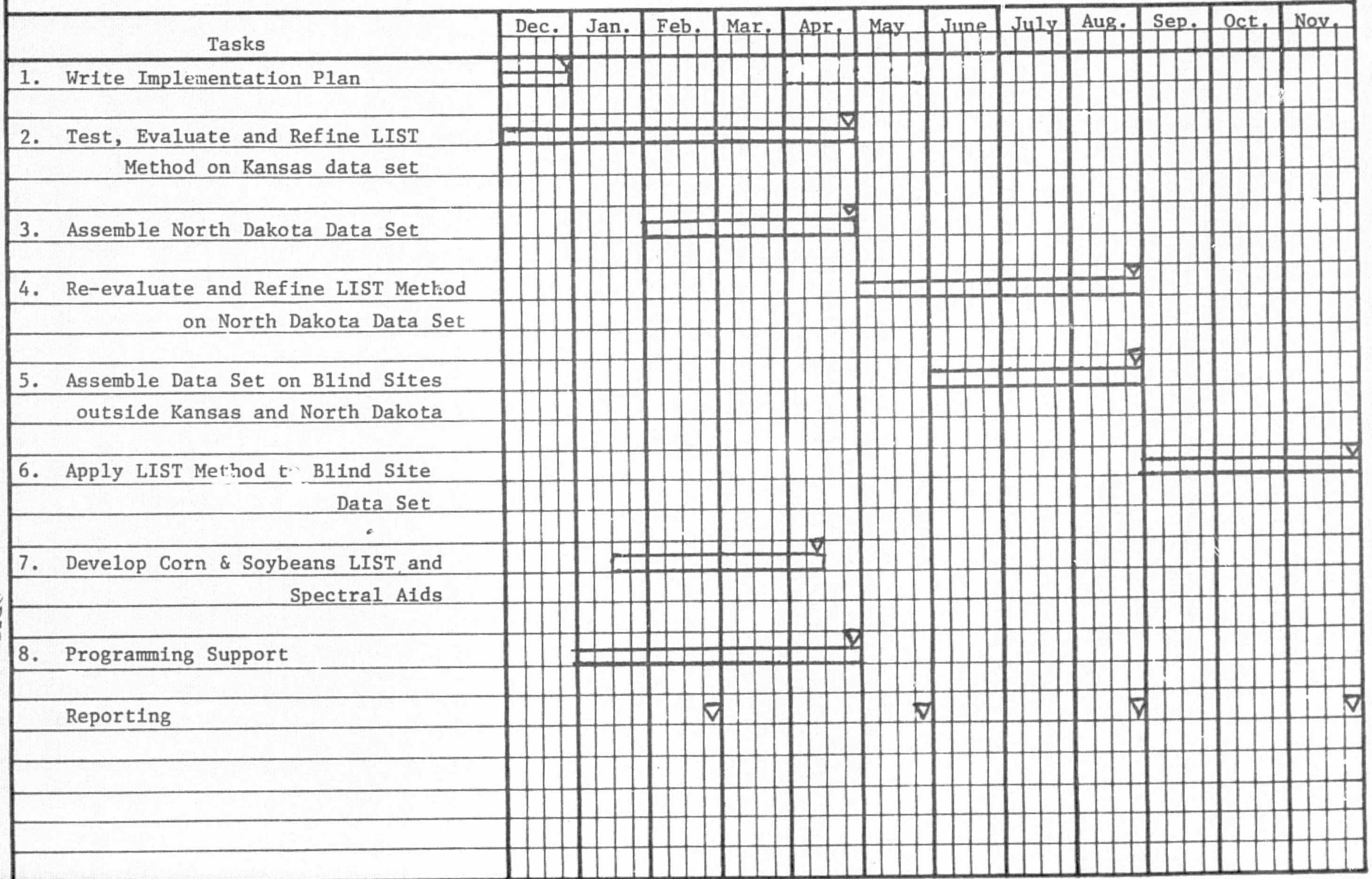


Figure 2A-2 Implementation Schedule (revised to reflect impact of Multicrop effort)

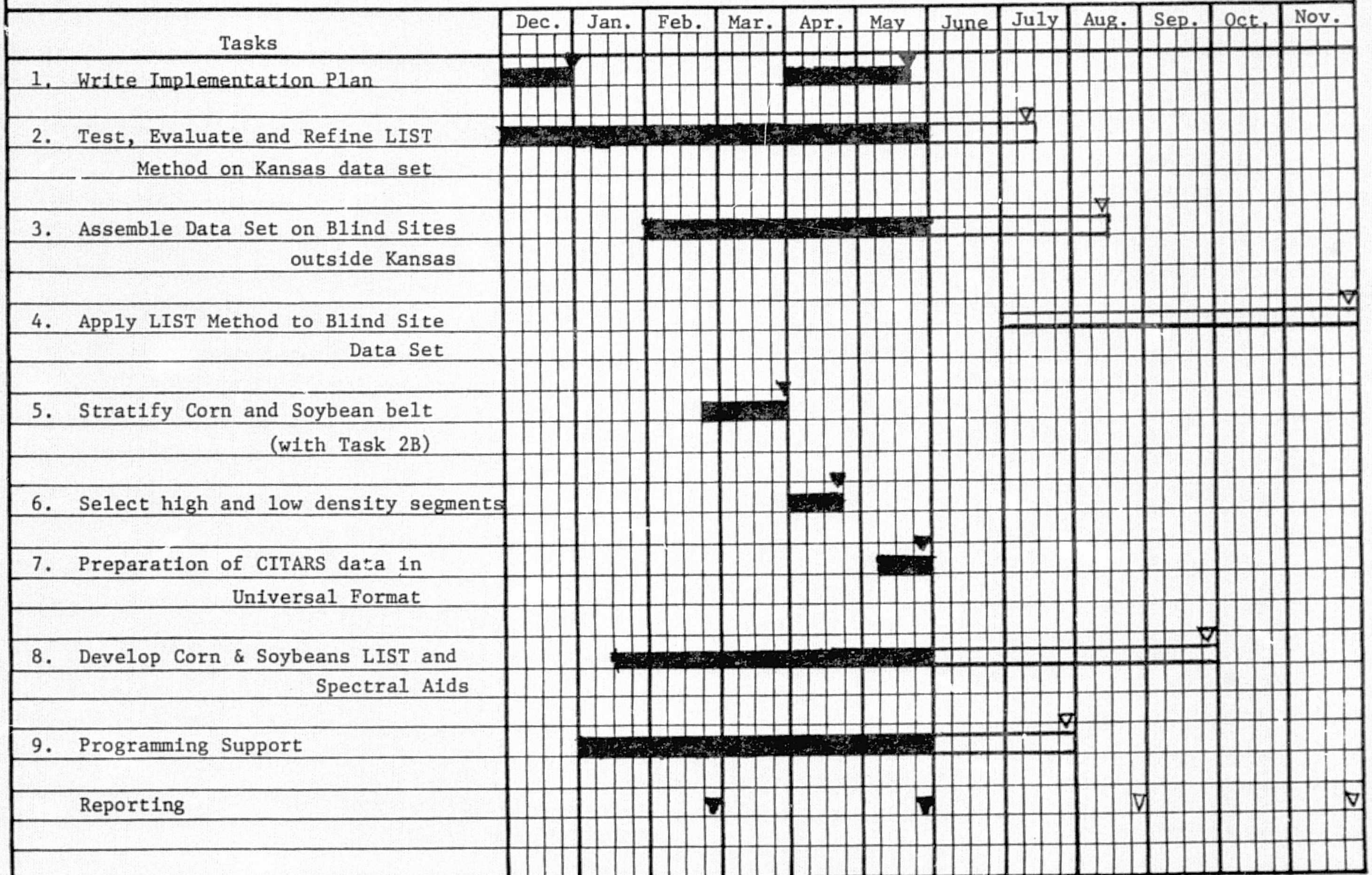


Table 2A-1. Single Acquisition (4 channel) 117 line and 196 column CITARS segments .

I. Huntington, Indiana (16 files)

A. Position of LACIE size segments in LARS run.

	Line		Column	
Segment	Start	End	Start	End
0101	50	166	23	218
0102	157	273	23	218
0103	264	380	23	218
0104	373	489	23	218

B. Acquisitions for each segment.

Landsat Scene ID	Date	LARS Run
1320-15534	6/8/73	73037601
1321-15593	6/9/73	73033707
1357-15590	7/15/73	73046407
1428-15520	9/24/73	73087602

II. Shelby, Indiana (16 files)

A. Position of LACIE size segments in LARS run.

	Line		Column	
Segment	Start	End	Start	End
0201	30	146	35	230
0202	134	250	35	230
0203	238	354	35	230
0204	344	460	35	230

B. Acquisitions for each segment.

Landsat Scene ID	Date	LARS Run
1320-15541	6/8/73	73037701
1393-15583	8/20/73	73061203
1411-15581	9/7/73	73067007
1428-15523	9/24/73	73087402

Table 2A-1 Continued

III. White, Indiana (12 files)

A. Position of LACIE size segments in LARS run.

Segment	Line Start	Line End	Column Start	Column End
0301	50	166	43	238
0302	157	273	43	238
0303	264	380	43	238
0304	371	487	43	238

B. Acquisitions for each segment.

Landsat Scene ID	Date	LARS Run
1321-15593	6/9/73	73033705
1394-16042	8/21/73	73060705
1411-15581	9/7/73	73067005

IV. Livingston, Illinois (20 files)

A. Position of LACIE size segments in LARS run.

Segment	Line Start	Line End	Column Start	Column End
0401	13	129	11	206
0402	119	235	11	206
0403	225	341	11	206
0404	331	447	11	206

B. Acquisitions for each segment.

Landsat Scene ID	Date	LARS Run
1322-16051	6/30/73	73033601
1341-16104	6/29/73	73047802
1358-16045	7/16/73	73047602
1376-16043	8/3/73	73052902
1394-16042	8/21/73	73060707

Table 2A-1 Continued

V. Fayette, Illinois (24 files)

A. Position of LACIE size segments in LARS run.

Segment	Line Start	Line End	Column Start	Column End
0501	57	173	11	206
0502	163	279	11	206
0503	270	386	11	206
0504	377	493	11	206

B. Acquisitions for each segment.

Landsat Scene ID	Date	LARS Run
1322-16054	6/10/73	73037402
1323-16112	6/11/73	73039101
1341-16111	6/29/73	73052002
1358-16051	7/16/73	73046502
1359-16105	7/17/73	73054202
1394-16044	8/21/73	73060802

VI. Lee, Illinois (12 files)

A. Position of LACIE size segments in LARS run.

Segment	Line Start	Line End	Column Start	Column End
0601	35	151	42	237
0602	141	258	42	237
0603	248	364	42	237
0604	354	470	42	237

B. Acquisitions for each segment.

Landsat Scene ID	Date	LARS Run
1359-16100	7/17/73	73052102
1360-16155	7/18/73	73066301
1378-16153	8/5/73	73120202

Table 2A-2. Multiple Acquisition (117 line by 196 column CITARS segments).

County	Segment*	No. of Acquisitions*	No. of Channels
Huntington	0101	4	16
Huntington	0102	4	16
Huntington	0103	4	16
Huntington	0104	4	16
Shelby	0201	4	16
Shelby	0202	4	16
Shelby	0203	4	16
Shelby	0204	4	16
White	0301	3	12
White	0302	3	12
White	0303	3	12
White	0304	3	12
Livingston	0401	5	20
Livingston	0402	5	20
Livingston	0403	5	20
Livingston	0404	5	20
Fayette	0501	6	24
Fayette	0502	6	24
Fayette	0503	6	24
Fayette	0504	6	24
Lee	0601	3	12
Lee	0602	3	12
Lee	0603	3	12
Lee	0604	3	12

*Segment definitions and acquisitions given in Table 2A-1

References

1. "Plan for Defining Dot Labelling Procedures for Procedure 1, The LIST Method", March 7, 1977.

2. "Label Identification from Statistical Tabulation (LIST)," Technical Memorandum LEC-10825, October 1977.

3. Landgrebe, D.A., "Crop Inventory Using Full-Frame Classification," Final Technical Report, NASA Contract NAS9-14970, T-1314/4, MA-129TA, Volume 2, Laboratory for Applications of Remote Sensing, Purdue University, West Lafayette, Indiana, June 1977.

4. Kauth, R.J. and G.S. Thomas, "The Tasselled Cap - A Graphic Description of the Spectral-Temporal Development of Agricultural Crops as seen by Landsat," Proc. Symposium on Machine Processing of Remotely Sensed Data, June 29, 1976.

5. Colwell, J.E., "Bidirectional Spectral Reflectance of Grass Canopies for Determination of Above Ground Standing Biomass," Ph.D. thesis, University of Michigan, University Microfilm 75-15, 693, 1973.

6. Colwell, J.E., "Vegetation Canopy Reflectance," RSE 3:175-183, 1974.

7. Rouse, J.W., R.H. Haas, J.A. Schell, and D.W. Deering, "Monitoring Vegetation Systems in the Great Plains with ERTS," Third ERTS Symposium, NASA SP-351 I:309-317, 1973.

8. Rouse, J.W., R.H. Haas, J.A. Schell, D.W. Deering, and J.C. Harlan, "Monitoring the Vernal Advancement and Retrogradation (greenwave effect) of Natural Vegetation", NASA/GSFC Type III Final Report, Greenbelt, Md, 1974.

B. Application and Evaluation of Landsat Training, Classification, and Area Estimation Procedures for Crop Inventory

I. Introduction

The Large Area Crop Inventory Experiment (LACIE) which was initiated in 1974 has sought to estimate wheat production in important wheat growing regions of the world. Recently there has been increasing emphasis on making production estimates for crops other than wheat; in particular, corn and soybeans are the two crops of immediate interest.

The procedures which were used by LACIE for wheat area estimation (in particular, the LACIE Procedure 1) need to be tested and extended for corn and soybeans. Recent developments in scene stratification, training sample selection, classification algorithms, and area estimation methods need to be considered in the development of a large area crop inventory system for corn and soybeans. In addressing these issues, this task supports the classification and sampling and aggregation components of the multicrop research effort.

II. Objectives

This task is the first part of a two year effort to advance the development of large area crop inventory systems for multicrop regions by applying and evaluating recently developed techniques. The investigation is divided into two phases: a pilot study and a major study. The primary objectives during year one are to develop the experiment design and approach, define data requirements, acquire data, and prepare data for analysis. An extensive data set covering several types of agricultural scenes in the Corn Belt is planned. Secondary objectives include a pilot study which will analyze currently available data to develop and refine multicrop inventory techniques for the major study.

The pilot study supports the major study by addressing some objectives with currently available data. The specific objectives of the pilot study are:

- Evaluate the LACIE P-1 procedure (with minimal changes) for a corn, soybeans, and "other" crop identification problem.

- Investigate parameter changes which may improve the performance of P-1 on corn and soybeans.

- Evaluate and refine procedures for obtaining class statistics from multiple training areas.

The objectives of the major study include training area selection and training, classification, and area estimation procedures. Specific objectives are:

1. Stratification and Sample Selection

   - To define strata in the corn and soybean belts which sample the range of production and farm (field) size.

   - To select segments (low density samples) spread throughout these strata to sample the conditions present.

   - To select segments (high density samples) in four homogeneous regions of the Corn Belt for intensive study.

2. Data Acquisition

   - To define data requirements and to design experiments for assessing choices of training, classification, and area estimation procedures.

   - To correlate and document Landsat data and imagery, aerial photography, and ground observations acquired for the major study.

3. Training

   - To evaluate and extend procedures for training area selection including factors such as size, number, and geographic location of the training areas.

- To refine procedures for obtaining class statistics from multiple training areas. Training methods include ISOCLS, multi-block clustering, and ECHO.

4. Classification

- To assess the accuracy of the area estimates of corn and soybeans obtained by different classification algorithms: per point maximum likelihood, ECHO, and sum of densities.

- To assess the accuracy of multitemporal classification (including P-1) as compared to the unitemporal classifications.

5. Area Estimation

- To compare the accuracy and precision of area estimates for corn and soybeans obtained by different estimation methods; specifically, to compare estimates obtained by classification and aggregation of a systematic sample of pixels with estimates made from a sample segment approach.

- To compare methods of obtaining unbiased estimates such as stratified area estimates and the regression approach.

III. Approach

a. Pilot Study

The pilot study will use data on corn and soybeans which was acquired during the CITARS project. Assessment of the accuracy and variability of P-1 will be done with minimal changes to work the three class problem. A key aspect of the approach is that ground truth or photointerpreted areas will be used rather than analyst-labeled dots. This will permit evaluation of the analysis procedure itself rather than the image interpretation accuracy. Each CITARS segment will be analyzed as four 5x5 mile blocks because this is as close to the LACIE segment size as possible using only the segment data. Dot grids will be laid over ground truth or photointerpreted areas and the proportion between dots and total area to be classified will be approximately the same as in LACIE. Both classification and area estimation accuracy will be assessed and the variability in the analysis procedure induced by the choice of type 1 and type 2 dots will be estimated.

In the assessment of LACIE P-1, default parameters, primarily for ISOCLS, will be used. It is probable that these settings are not optimal for the corn, soybeans, and "other" crop identification problem due to differences in spectral distribution of the crops of interest from that of wheat, more confusion crops, differences in crop calendar, and other factors. A sequential decision procedure or response surface design will be used to study improvements in accuracy due to parameter changes.

Training procedures will be addressed by comparing the accuracy of area estimates obtained by "extending" training statistics and by using multisegment training procedures.

b. Major Study

Four high density test areas have been located in eastern Indiana, west central Indiana/east central Illinois, north central Iowa, and west central Iowa. About 20 LACIE segments are located in each area. Both full frame and segment data will be acquired. Ground identifications and periodic observations of crop growth and condition will be made on the 80 segments. Aerial photography will be acquired on three to four flightlines in each of the four test areas.

In the training study, the size, number, and location of training areas will be addressed. Training data can be taken from other areas and can be of different size and numbers if aerial photography flightlines are acquired. Photointerpretation accuracy can be assessed by checking the high density segments which are covered by both the LACIE segments and the aerial photography. The photography can then be used to extend the "ground truth" areas from which training can be selected.

Analyses to be performed on the high density data set to investigate the optimal selection of training areas include:

1. Assess the variability in the county estimate due to the selection of a single 5x6 nm segment for training.

2. Assess the variability in the county estimate due to selection of one training segment smaller than 5x6 nm.

3. Assess the variability in the county estimate when using more smaller segments, but keeping the total amount of training data about the same as with one 5x6 nm segment.

The area estimates should be made using a systematic sample of data throughout the county for each of these methods to permit comparison of changes in training method.

Use of different algorithms in training and classification will also be investigated. The training methods which will be considered are the ISOCLS clustering method using dots to label the clusters, a multi-block clustering approach, and ECHO. The sum of densities, maximum likelihood per point, and ECHO classifiers will be considered. In addition, multitemporal classifiers, such as the layered or cascade classifier, will be considered.

Area estimation will be done by both a segment approach and a systematic sample approach. The stratified area estimate (SAE) will be computed on the basis of the training segments and an independent sample of segments and the results compared. A systematic sample of pixels distributed throughout the area to be classified will also be considered as a basis for area estimation.

IV. Accomplishments this Quarter

The activities during this quarter have supported both the pilot study and the major study. A revised implementation plan was written at the request of NASA/JSC and was forwarded in mid-May. Detailed analysis procedures for each of the specific objectives of the pilot study were documented in the revised implementation plan.

Acquaintance with the P-1 computer programs was a major activity during the quarter. Personnel from this task attended a course on P-1 given by Lockheed personnel at LARS on March 6-8. The programs did not work completely on the LARS computer system at that time. Lockheed was notified of the problems found in pursuing our research. Some problems were corrected by Lockheed; some corrections were made by LARS personnel to the LINERD, TAPHDR, and MONTOR routines to permit the programs to access LARSYS formatted tapes.

P-1 has been run on LARS system for one CITARS segment using four channels on one date. Time estimates were made for use in planning future work. Default parameters used in LACIE have been received from Lockheed. Currently in progress are investigation of a P-1 batch machine and generation of dot files from the CITARS ground truth.

In support of the FY 78-79 Multicrop Experiments, LARS performed a stratification of the U.S. corn and soybean production area based upon historical production of corn and soybeans and average farm size. Eight strata were defined and 20 5x6 nm sample segments were located in each stratum. The segments were submitted to JSC for checking non-agricultural areas and were then finalized. The procedures and results of the stratification and segment selection are currently being documented.

The four high density test sites to be analyzed in the major study were selected based on the stratifications. The four test sites selected are located in eastern Indiana, west central Indiana/east central Illinois, north central Iowa, and west central Iowa. Each site is relatively homogeneous, but the sites together sample different climates, soils, and cultural practices for corn and soybeans. Each test site contains about 10 counties with generally two 5x6 nm segments per county. The high density segments were located, submitted to NASA/JSC for checking non-agricultural areas, and were then finalized.

A recommendation was made to NASA/JSC concerning location of flightlines and acquisition of aerial photography for the major study. The aerial photography will permit objectives to be addressed concerning the location, number, and size of areas for training. The photointerpretation process will provide more segments for study than can be acquired as high density segments. LARS is currently awaiting response concerning the acquisition of photography by NASA aircraft. In addition, recommendations concerning the acquisition of inventory data ("wall-to-wall" crop identifications) and periodic observations of crop growth and condition for the segments was submitted.

V. Plans for Next Quarter

During the next quarter, evaluation of P-1 on the CITARS data will be pursued and a study of changes for improved performance on corn and soybeans will begin. The data acquisition for the major study will be in progress and receipt of data at LARS should begin.

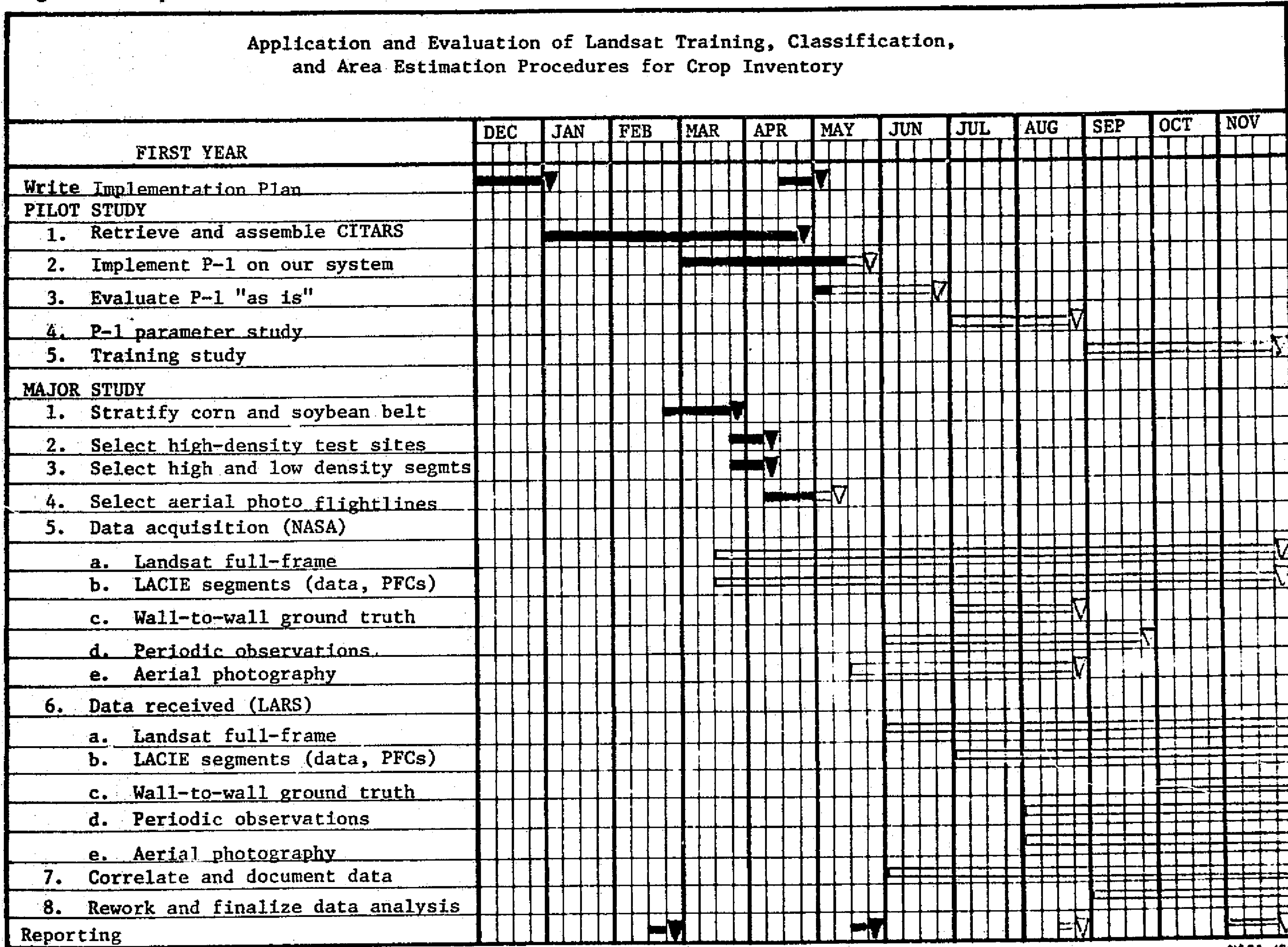
VI. Critical Issues

LARS is proceeding under the hypothesis that the revised implementation plan will be approved. Feedback is requested.

An issue which should be resolved as soon as possible is the acquisition of aerial photography. If NASA/JSC can acquire these data, more experiments can be conducted on other aspects of the Multicrop program. If LARS must acquire these data, this fact needs to be verified so that scheduling arrangements may be made.

Support of the LACIE P-1 programs needs to be continued. Only default parameters and four channels have been tested on our system. Any problems which may arise in the future will need support from Lockheed personnel.

Figure 1. Implementation Schedule.



2C MULTISENSOR RADIOMETRIC CORRECTION CORRELATION AND APPLICATIONS ANALYSIS

The objective of this subtask is to develop and evaluate data preprocessing techniques, procedures, and software systems for producing radiometrically corrected and spatially correlated multisensor data sets for applications information extraction.

The project is divided into two activities: one to investigate methods of modeling sensor characteristics and the other to develop methods of merging multisensor data to form data sets which will enable enhanced resource mapping potential.

2C1. Multisensor Parametric Evaluation and Radiometric Correction Model

This project included scanner sensor representation model development and testing. Several aspects of these models have been reported previously. Two tasks were active in the quarter, one addressing the class spectral modeling problem and the other extensions to microwave wavelengths.

I. Develop and Test K-L (Karhunen Loéve) and I-T (Information Theory) Spectral Models

The representation of class spectral characteristics between the wavelengths of .4 and 2.4 micrometers by K-L and I-T models progressed during the quarter and a complete report describing the I-T work was generated. This report will be printed as a LARS Technical Report and forwarded to NASA as soon as possible.

a. K-L Model Development

A software system has been developed to design an optimal sensor based on the Karhunen-Loéve representation technique and to evaluate practical systems. The criterion for optimality is the average mean-square representation error. The development of this system as well as the results from some preliminary testing have been reported previously.

During the past quarter further testing of the system has demonstrated that some difficulties will occur if consideration is not given to the choice of certain parameters. Two parameters which are used in the procedure are the size of the data set which consists of a set of functions of wavelength and the sample rate at which each function is sampled. As one would expect, increasing the number of sample points will improve the accuracy of representing each waveform. However, our purpose is to represent the random process from which the set of waveforms has been taken. Experimentation has indicated that for a fixed data set size, increasing the number of sample points may deteriorate the representation performance.

b. I-T Model Development

Information theory techniques have been developed for the study of some parameters of multispectral scanner systems. Previous quarterly reports have outlined the development of these techniques.

Average information techniques have been used to select a subset of spectral bands. One use for a selected subset of spectral bands is scene classification. Evaluation of classification accuracy with a subset of spectral bands is a useful area of investigation. An initial attempt was made to evaluate the potential classification accuracy on a typical subset of spectral bands. The estimation technique used was developed by Fu and Lissask [1]. Unfortunately, the empirical data used has a tendency to produce estimated covariance matrices that were singular to computer accuracy. Since the classification error estimation technique requires the inversion of the estimated covariance matrices, the singularity of the covariance matrices produces rather inconclusive results with respect to estimation of classification accuracy. Hence this topic is left for further exploration.

II. Develop and Test Spatial Model

Although work on this activity was completed by the end of the first quarter, documentation has continued and a detailed report covering the spatial model and the classification accuracy prediction algorithm completed in November 1977 has been completed. This report will be published and submitted as soon as possible. Further discussion of the results of the spatial modeling activity is included here.

In the previous reports the building blocks of the MSS performance evaluation process, i.e., the classification error estimator, MSS and multispectral data spatial model were identified and validated. The integration of these units in a parametric processing package provides the necessary techniques for investigating the following interactive relationships:

1. Effect of data spatial correlation on the classification accuracy.
2. Effect of signal-to-noise ratio (SNR) on classification accuracy.
3. Trade off between spatial resolution and SNR.

4. Effect of spatial resolution on classification accuracy.
5. The interactive relationships between IFOV, spatial correlation, class statistics, SNR and classification accuracy.

The block diagram of the entire simulation and evaluation process is shown in Fig. 2C1-1.

The variation of the probability of correct classification at the scanner output vs. IFOV and noise level is of particular interest. As a test case, three populations with three features were selected. The spectral correlation matrices are given by

$$\underline{S}_1 = \begin{bmatrix} 1.0 & 0.75 & 0.15 \\ & 1.0 & 0.45 \\ & & 1.0 \end{bmatrix}, \qquad \underline{S}_2 = \begin{bmatrix} 1.0 & 0.8 & 0 \\ & 1.0 & 0.1 \\ & & 1.0 \end{bmatrix}$$

$$\underline{S}_3 = \begin{bmatrix} 1.0 & 0.94 & 0.15 \\ & 1.0 & 0.05 \\ & & 1.0 \end{bmatrix}$$

The mean vectors are arranged in a simplex with their nonzero component at 0.70 on each axis where σ is the common channel variance. Two of the three features represent the visible and the third the infrared band. At the scanner input, the classification accuracies associated with these three populations are

$$\hat{P}_{c|\omega_1} = 68.6\%$$

$$\hat{P}_{c|\omega_2} = 74.3\%$$

$$\hat{P}_{c|\omega_3} = 75.9\%$$

$$\hat{P}_{c} = 72.9\%$$

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where $\hat{P}_{c|\omega_i}$ and $\hat{P}_c$ are the class conditional and overall probabilities of correct classification.

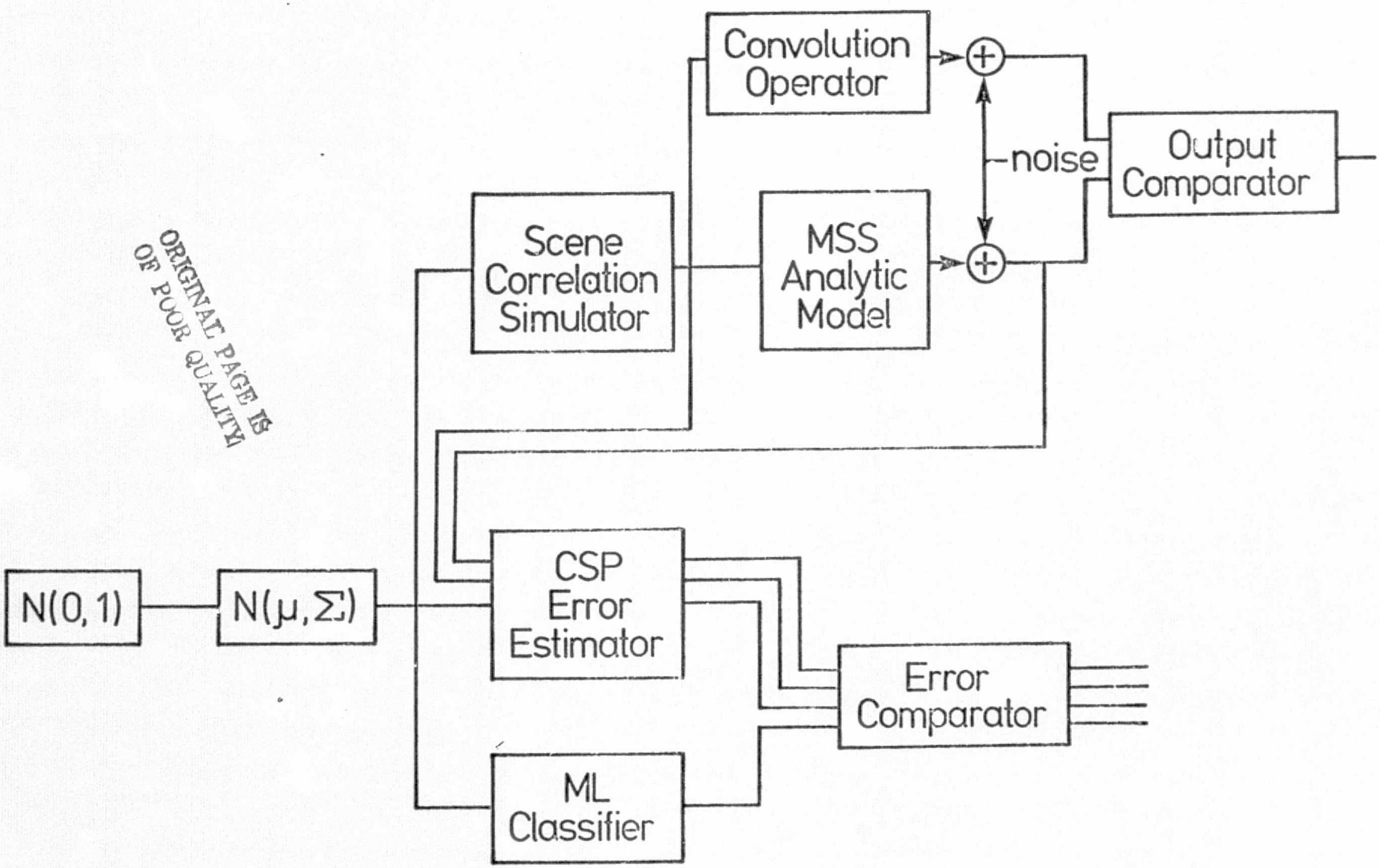


Fig. 2C1-1 The Block Diagram of the entire MSS Simulation Procedure.

The MSS is modeled by a Gaussian point spread function. In order to compute a set of classification accuracies at the output, the transformed class statistics in the form of mean vectors and covariance matrices is required. This task is accomplished by the scanner characteristic function, a spectral and spatial transfer function that determines the output statistics in terms of the corresponding input quantity. For three selected scene correlation structures simulating a highly uncorrelated to highly correlated, scanner IFOV was varied from 1 to 8 high resolution pixels. The variation of the output classification accuracies vs. IFOV and scene correlation are shown in Figure 2C1-2 thru 2C1-4.

The results are generally as expected. The output classification accuracy tends to rise with increasing IFOV. The rate of increase is strongly related to the degree of spatial correlation of the ground scene. This is due to the fact that a process with small spatial correlation emerges with a smaller variance than an otherwise identical process with a high spatial correlation. This is particularly evident in Figure 2C1-4 where the improvement in the output classification accuracies is much smaller than Figure 2C1-2. In the extreme case, the classification accuracies associated with M random processes with only a DC value is identical at the scanner input and output regardless of the IFOV (unity gain assumed).

In order to investigate the effects of random noise, three SNR's of 10, 20 and 30dB were selected and for each IFOV noise power was adjusted to keep the SNR at the prescribed level. Figure 2C1-5 shows the variation of the overall output classification accuracy vs. IFOV with SNR as a running parameter. A fixed spatial correlation with adjacent sample and line correlation of 0.85 and 0.79 was selected. Figure 2C1-5 indicates the available operating states of a MSS and associated tradeoffs between $\hat{P}_c$, SNR and IFOV. For example, if it is required that min $\{\hat{P}_c\}$ = 70%, the IFOV must satisfy the following inequalities

$$\text{IFOV} \geq 6 \qquad \text{SNR} = 10\text{dB}$$
$$\text{IFOV} \geq 3.8 \qquad \text{SNR} = 20\text{dB}$$
$$\text{IFOV} \geq 3.5 \qquad \text{SNR} = 30\text{dB}$$

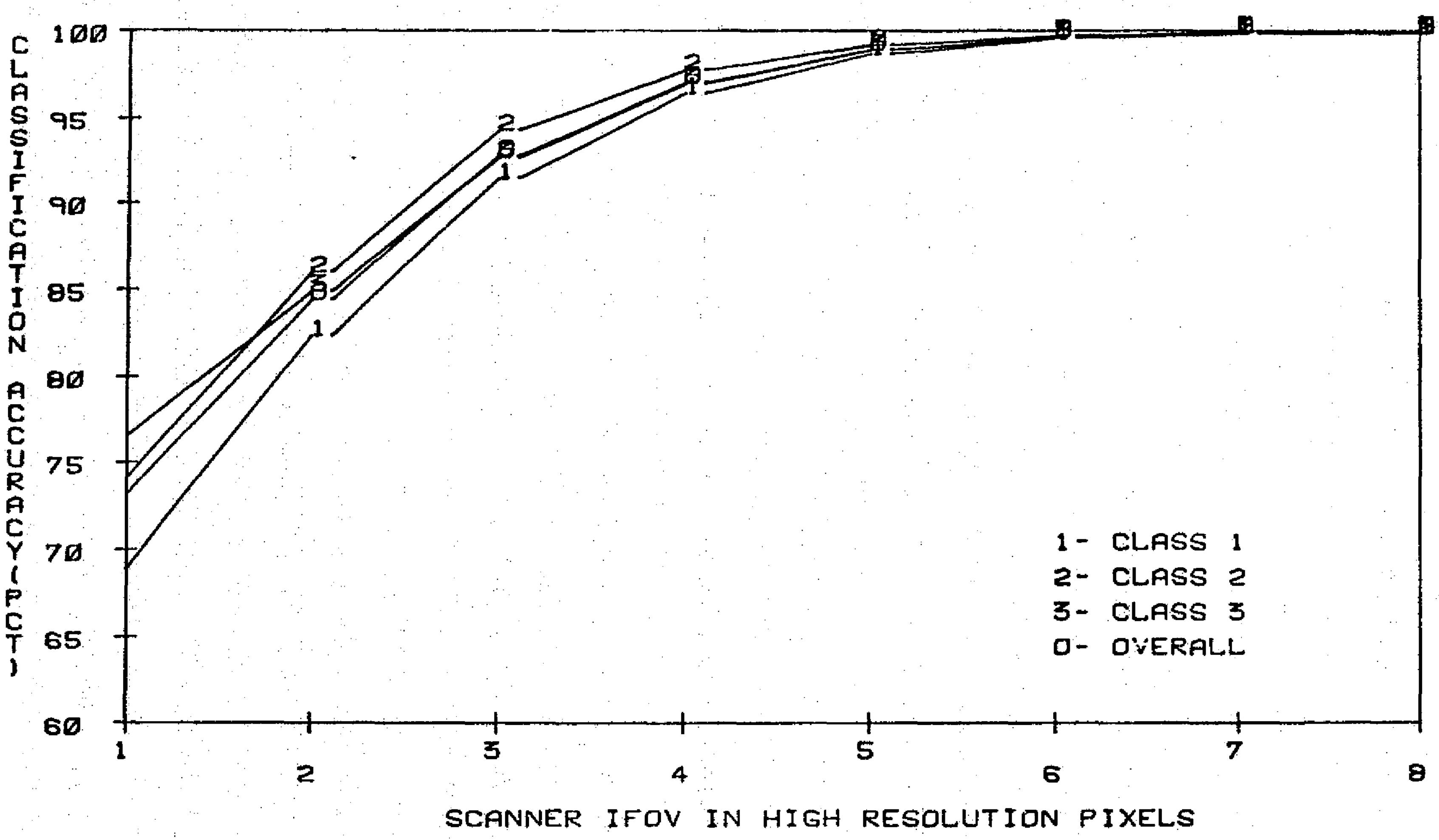


Fig. 2C1-2 SCANNER OUTPUT CLASSIFICATION ACCURACY VS. IFOV
ADJACENT SAMPLE CORRELATION= .5

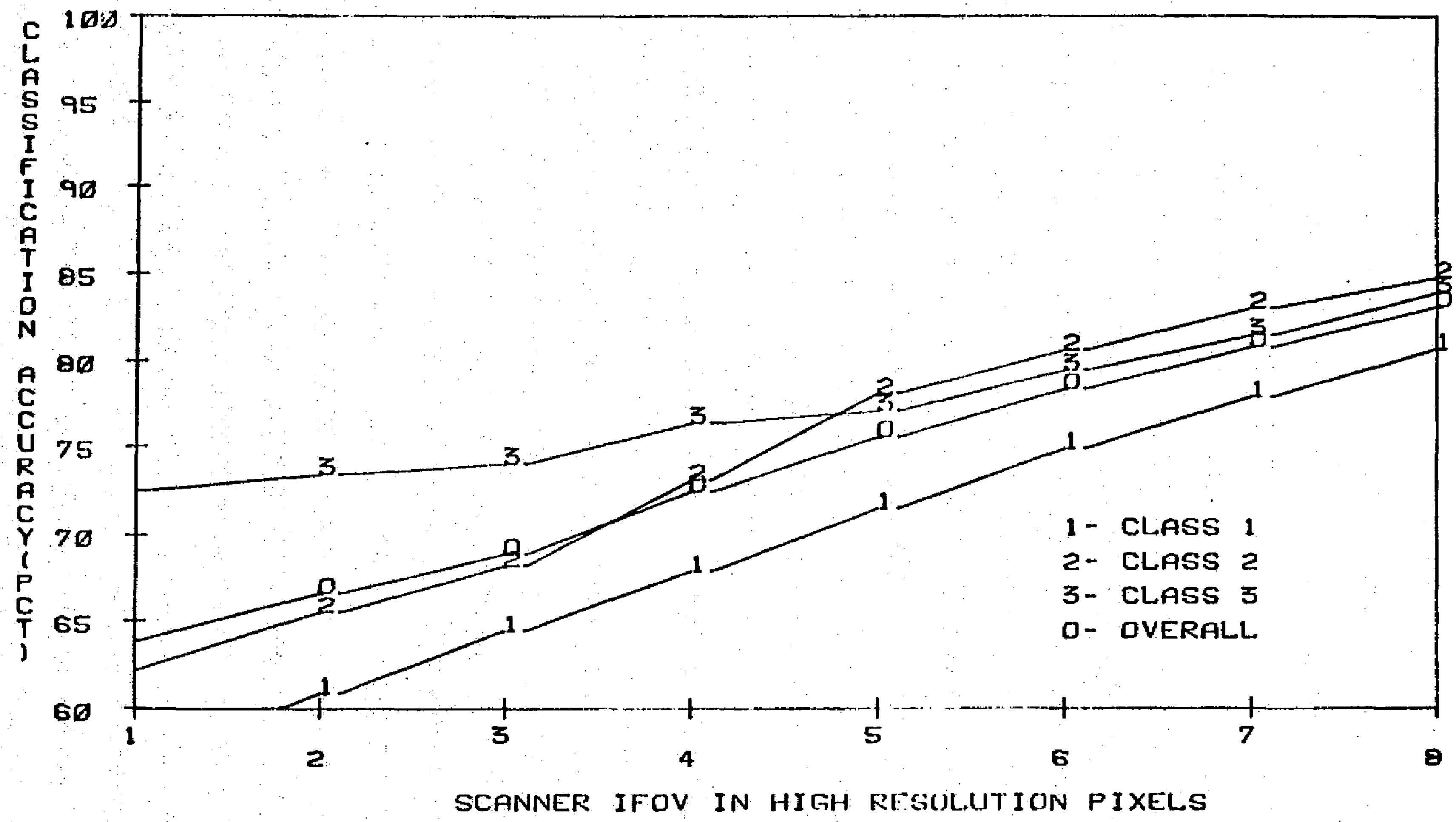


Fig. 2C1-3 SCANNER OUTPUT CLASSIFICATION ACCURACY VS. IFOV
ADJACENT SAMPLE CORRELATION= .85

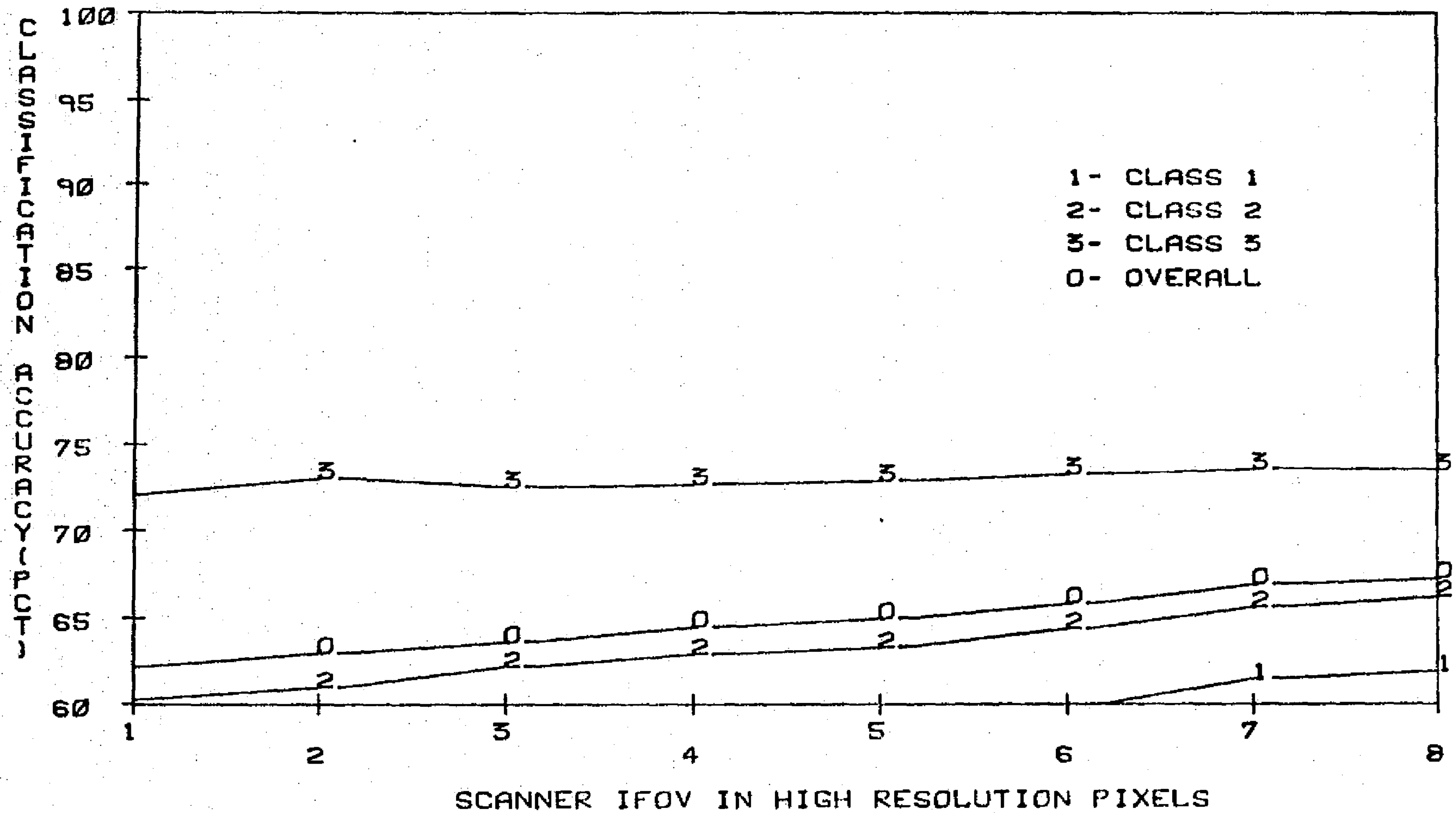


Fig. 2C1-4 SCANNER OUTPUT CLASSIFICATION ACCURACY VS. IFOV
ADJACENT SAMPLE CORRELATION= .95

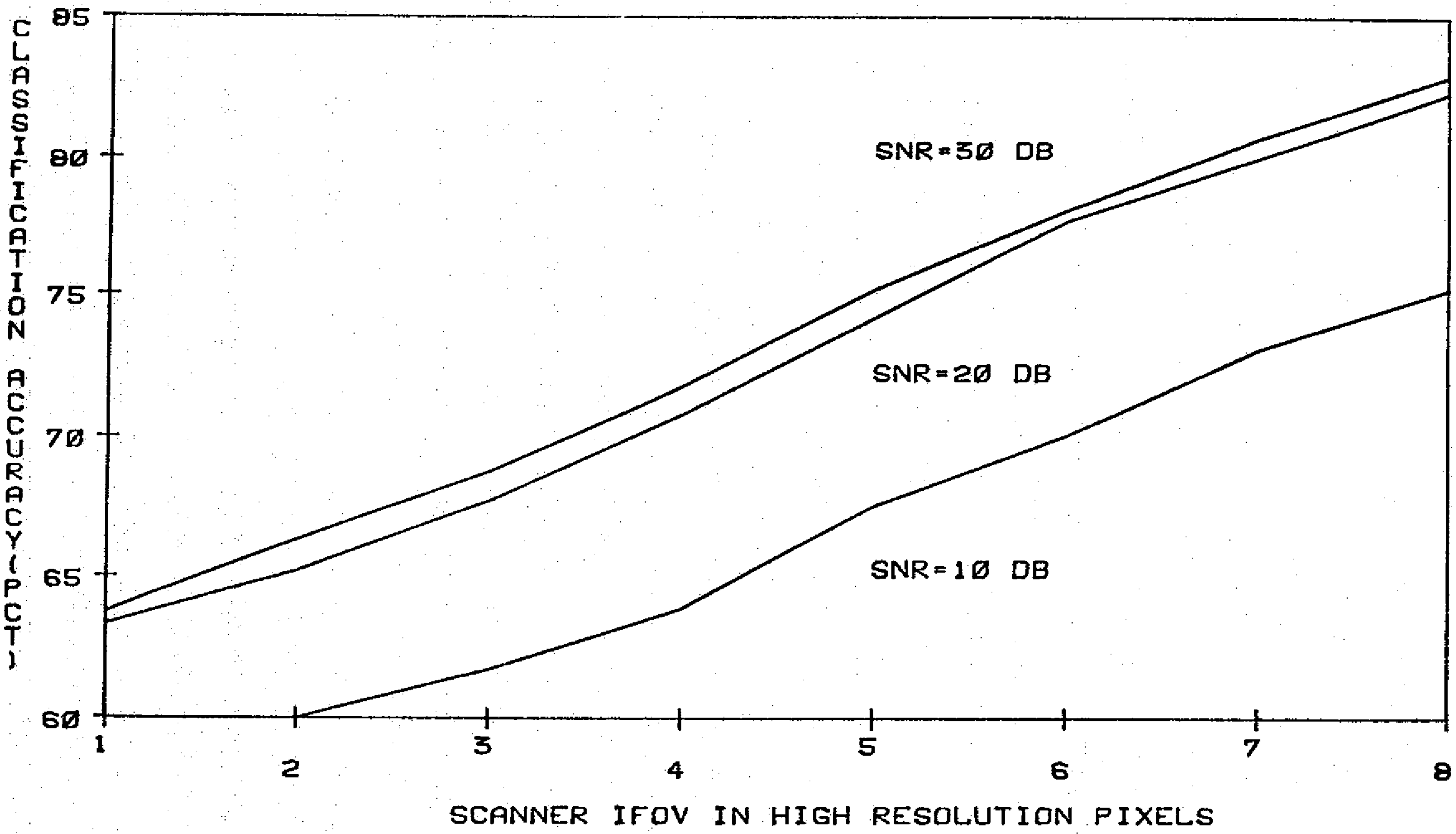


Fig. 2C1-5 OVERALL OUTPUT CLASSIFICATION ACCURACY VARIATION WITH NOISE AND IFOV

REFERENCES

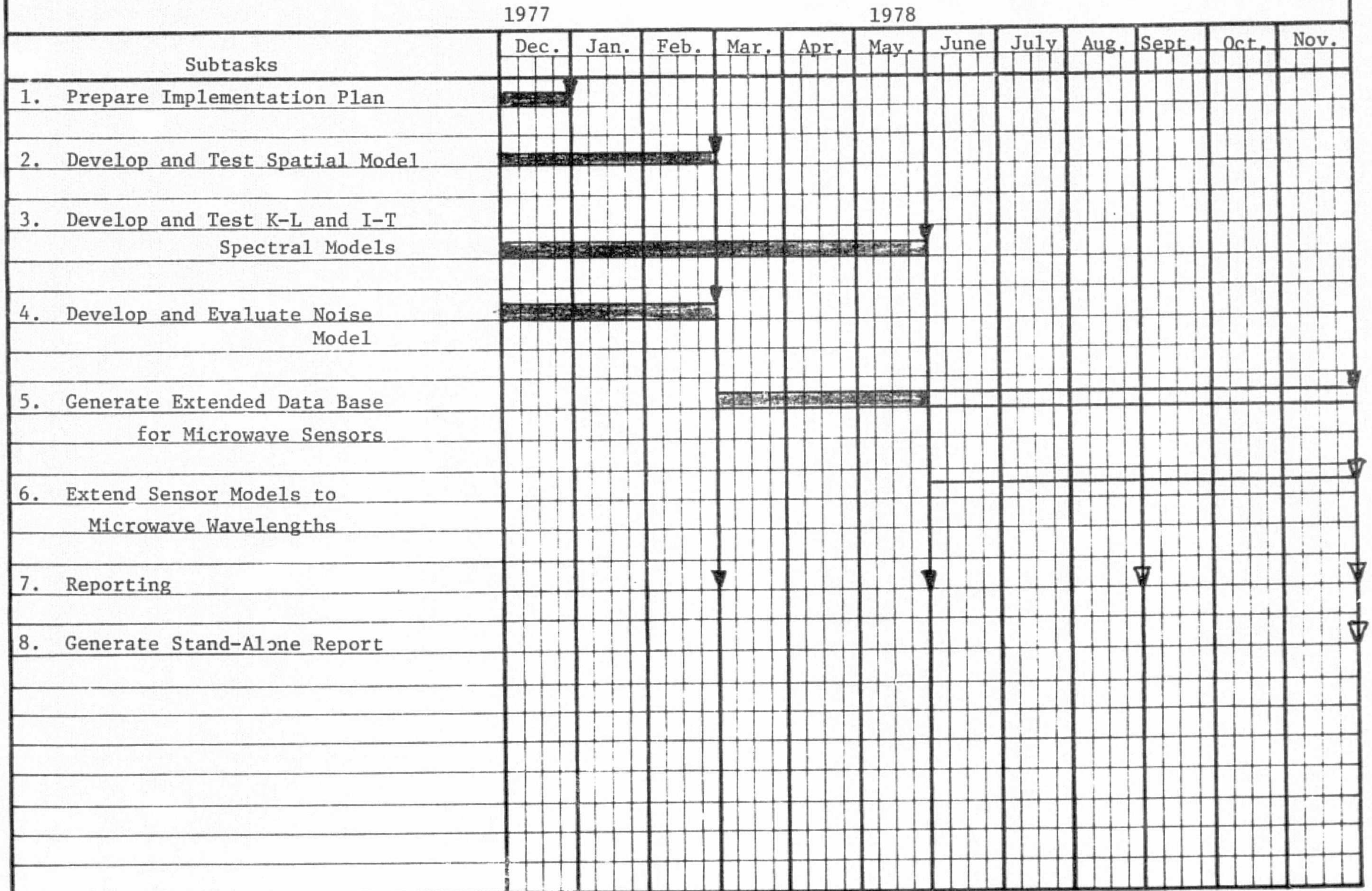
1. T. Lissask and K. S. Fu, "Error Estimation in Pattern Recognition via L^{α} - Distance Between Posterior Density Functions", IEEE Transactions on Information Theory, Vol. IT-22, No. 1, January 1976, p. 34-45.

III. Generate Extended Data Base for Microwave Sensors

Work on this task was limited to acquiring experiments conducted by the University of Kansas. Contact was made with Dr. Fawwaz Ulaby of the University of Kansas Center for Research regarding acquisition of microwave data. Requests and acquisition of some test data is expected in the third quarter.

A milestone chart is included as Figure 2C-1 and all subtasks are on schedule. Acquisiton and utilization of microwave data in the spectral modeling activity is planned for the last two quarters. Work on generating a stand-alone report describing all the models and their use will also be pursued through the remainder of the task. Completion and termination of the task is expected on Nov. 30, 1978.

Figure 2C-1 Multisensor Parametric Evaluation and Radiometric Correction Model



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2C2. Multisensor Multidate Spatial Feature Matching, Correlation, Registering, Resampling and Information Extraction

This activity is considering the specific case of synthetic aperture radar (SAR) imagery and inclusion of other sensor types will follow as the program progresses. Synthetic aperture radar imagery is of interest as an additional feature in pattern recognition analysis for resource mapping. Technology is being developed to combine SAR imagery and Landsat imagery to enable classification using both types of data. Three tasks were scheduled during the quarter and progress and problems are discussed here.

I. Data Set Survey and Acquisition

The goal of this activity is to acquire example SAR data sets for use in the research. Three data sets have been identified for the study and progress was made in acquiring the data. The first is a SAR aircraft flight in Maryland, August, 1976 which was optically correlated and recorded on film as part of another project. This data was scanned and digitized and the tape was received and reformatted into LARSYS format. Landsat data is available for the site and the SAR Landsat data will be registered during the third quarter. Ground truth is on hand for this data. Primary covers are corn, soybeans, and forest.

The second data set is from the Phoenix, Arizona area on June 17, 1977 and extensive ground truth data were obtained for the area covered during the quarter. The primary crops in the study site are cotton, alfalfa, barley, and wheat. The SAR data was in film form and was scanned and digitized during the quarter. A good quality Landsat frame on June 19, 1977 was located and the CCT's were ordered on March 1977. The data was not received during the quarter. Registration of this SAR and Landsat data is expected during the third quarter.

The third data set is an expected ERL SAR flight in the south-central states area. This data has not yet been gathered due to equipment problems and the flight is currently expected in May or June 1978. These three data sets are expected to be acquired and registered by the end of the third quarter.

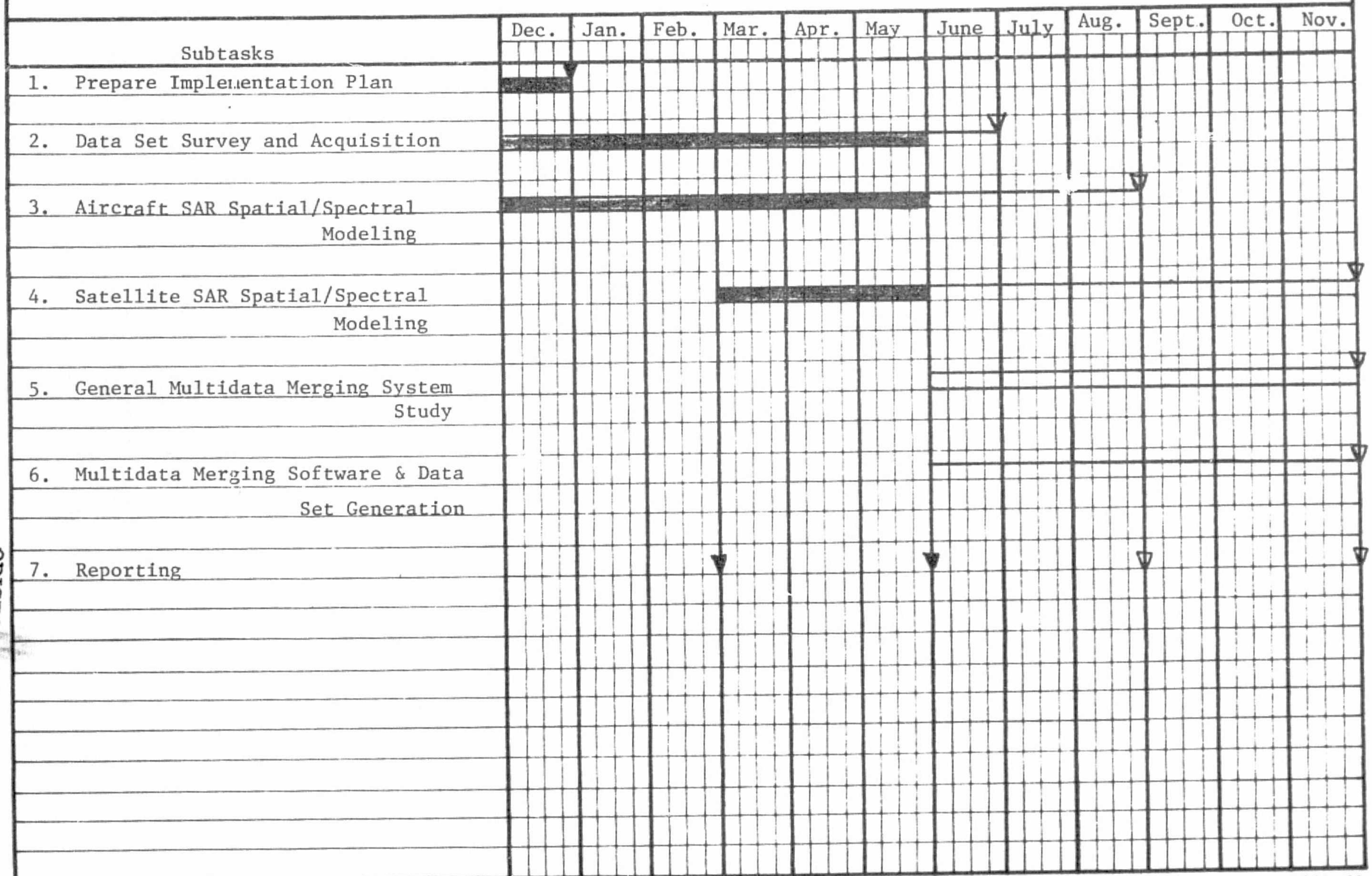
II. Aircraft SAR Spatial/Spectral Modeling

Preliminary considerations have been made relative to radiometric (spectral) and geometric (spatial) problems in registration and analysis of SAR and Landsat data. The two key items of interest are 1.) the form of the mathematical model to represent geometric distortion in aircraft SAR imagery and 2.) methods of removing brightness variations in SAR imagery due to sensor system variations. Systematic and affine geometric models are being studied. Testing will begin when the digital data sets are received.

III. Satellite SAR Spatial/Spectral Modeling

Consideration of the satellite case has been briefly made. Due to delays in getting the aircraft SAR data and lack of information availability on the SEASAT system work has not progressed as rapidly as desired. SEASAT L band SAR system and data information was obtained during the quarter; however, modeling activity has not yet made use of this information. It is expected that basic requirements for registering SEASAT L band SAR with Landsat will be defined in the third quarter.

Figure 2C-2 Multisensor Multidate Spatial Feature Matching, Correlation, Registering, Resampling and Information Extraction



2-3. ASSESSMENT OF METHODS OF ACQUIRING, ANALYZING, AND REPORTING CROP PRODUCTION STATISTICS

I. Introduction

During this quarter efforts were continued in documentation of methodology for acquiring, analyzing and reporting wheat production statistics for five of the major wheat producing countries: Argentina, Canada, India, the Soviet Union and the United States. The description of current statistical methodologies focused on collection and subsequent analysis of production statistics and any agricultural and economic influences.

II. Activity During Quarter

a. Primary Objective

The primary objectives during this quarter were to complete the U.S., India and Soviet Union portion of the task and to begin work on the Canadian portion of the study. In addition, formal contacts with representatives of the Ministry of Agriculture of Argentina were to be established to initiate a working relationship for the second phase of the project.

b. Approach

Information gathering activities consisted of travel and a continuing review of literature. During March, trips were made to Washington, D.C., Buenos Aires, Argentina and Houston.

While in Washington more detailed information was obtained on the objective yield analysis procedures, and the March meeting of the Crop Reporting Board was attended. Specifically, discussions were held with Richard Allen, Bill Wigton and Galen Hart of the Statistics Research Division of the U.S. Department of Agriculture. Topics discussed included paper strata replacing crop reporting districts, refusal rates for the enumerative survey, objective yield models, and a new technique featuring within year growth models for wheat yield. This information will be elaborated upon in the final report.

Dr. Anderson spent four days in Buenos Aires and met with officials of the Ministry of Agriculture responsible for estimating crop production. In addition to conversations concerning current statistical methodology used, Dr. Anderson was taken on a tour of the major agricultural experiment stations and the surrounding wheat area. A formal invitation has been issued to Osvaldo Stepancich, Chief of the Methodology Section of the Ministry of Agriculture to spend six to eight weeks at LARS as an internal consultant.

A good portion of the project activity has been devoted to a continuing review of pertinent literature on area estimation and yield prediction for the countries mentioned. Included in Section V is an updated bibliography.

The U.S. segment of the study has concentrated on understanding specific aspects of the design of sampling plans for the enumerative survey such as effects of refusal rates and respondent burden. Both academic and government reports from India were reviewed to determine details of their system of estimates. Materials from the CIA and the Economic Research Service provided the basis for the report on the Soviet Union's system. In addition, a thorough survey on the state-of-the-art in modeling and predicting crop yield was conducted. Important relationships between agronomic and meteorological factors were reviewed. Technical reports for each of these topics will be included in the final report.

III. Progress

Overall progress of the study has been satisfactory. Study of the U.S. and the Soviet Union has nearly been completed with drafts in the process of being edited. Contacts have been established with officials of Statistics Canada and appointments have been made. The second phase of the task has been planned and an invitation has been issued for the visiting scientist from Argentina.

IV. Plans for Next Quarter

Due to the revised budget, the activities of the next quarter will focus upon final editing of the technical reports and completion of the Argentina-U.S. cooperative study on Argentine statistical methods. A trip to Ottawa has been scheduled and will be the source of extensive information in Canadian methods. At the end of the quarter technical reports for each of the countries involved in the study will be compiled in the final report together with a substantial summary indicating differences, advantages and applicability.

V. Bibliography

a. Global

Agricultural Research Policy Advisory Committee. 1975. Research to meet U.S. and world food needs, Vol. I and II. Report of a Working Conference held in Kansas City, MO. (July 9-11).

Arthur, H. B. and G. L. Cramer. 1976. Brighter forecast for the world's food supply. Harvard Business Review 54:161-166.

Economic Research Service, USDA. 1977. Western hemisphere agricultural situation: review of 1976 and outlook for 1977. For. Agr. Econ. Report #136.

---------------. 1977. Western Europe agricultural situation: review of 1976 and outlook for 1977. For. Agr. Econ. Report #135.

---------------. 1977. World agricultural situation. WAS #14.

Food and Agricultural Organization, United Nations. 1965. Estimation of areas in agricultural statistics. (ed., S.S. Zackovich). Rome, Italy.

---------------. 1976. National grain policies, 1975. Rome, Italy.

---------------. 1974. National methods of collecting agricultural statistics: Asia, Far East, European and North American regions, Vol. I. Rome, Italy.

---------------. 1975. National methods of collecting agricultural statistics: African, Latin American and Near East regions, Vol. II. Rome, Italy.

---------------. 1966. World crop statistics, area production and yield 1948-1964.

International Food Policy and Research Institute. 1977. Food needs of developing countries: projections of production and consumption to 1990. Research Report 3.

Paarlberg, D. 1975. The world food situation: a consensus view. Vital Speeches 41:583-586.

---------------. 1976. The world food situation: myth and reality. Vital Speeches 42:624-628.

Panse, V. G. 1954. Estimation of crop yields. Food and Agricultural Organization, United Nations. Rome, Italy.

United Nations. 1967. International Wheat Conference. New York, NY.

---------------. 1974. Report of the World Food Conference. Rome, Italy.

---------------. 1972. A short manual on sampling, Vol. I: elements of sample survey theory. Rome, Italy.

---------------. 1972. A short manual on sampling, Vol. II: computer programmes for sample designs. Rome, Italy.

Warren, Fred. 1977. Forecast errors of USDA: wheat estimates for six foreign countries. Foreign Agricultural Service, U.S. Department of Agriculture.

Europa Publication Limited. 1977. The Europa Yearbook. A World Survey, Vol. I and Vol. II. Australia.

Hammond, Inc. 1971. Hammond Medallion World Atlas. Maplewood, NJ.

b. Argentina

Hill, R. C. 1977. Argentina today: human rights and foreign policy. Vital Speeches 43:612-615.

Papadakis, J. 1970. Agricultural research: principles, methodology, suggestions

c. Canada

Canada Department of Agriculture. 1974. Guide to federal agricultural services. Publ. #1262.

-------------. 1974. Winter wheat production in western Canada. Information Division, Ottawa, Canada.

Canadian Grain Commission. 1977. Canadian red spring wheat 1977 crop. Crop Bulletin #134.

-------------. 1977. Canadian amber durum wheat 1977 crop. Crop Bulletin #135.

-------------. 1978. Canadian flax and rope 1977. Crop Bulletin #137.

-------------. 1978. Canadian wheat cargoes 1977. Quarterly Bulletin #169.

-------------. 1978. Canadian durum cargoes. Quarterly Bulletin #170.

Information Division of Canada. 1970. Organization and activities of the Canada Department of Agriculture. Publ. #1123. Department of Agriculture, Ottawa, Canada.

Statistics Canada. 1978. Field crop reporting calendar.

-------------. 1977. Field crop reporting series #19: September forecast of principal field crops.

d. India

Bureau for Agricultural Statistics, Kerala. Kerala--Collection on agricultural statistics 1976-1977--instructions for field work.

Bureau of Economics and Statistics, Kerala. 1977. Instructions for field staff on area and yield estimation surveys. SGP Govt. Press Trivandrum.

---------------. 1975. Report on the crop cutting survey on winter and summer crop of paddy 1974.

---------------. 1975. Report on the crop cutting survey on winter and summer crop of paddy 1975.

---------------. 1977. Report on crop cutting survey on autumn crop of paddy 1976.

---------------. 1977. Report of the timely reporting survey of agricultural statistics, Kerala State, 1975-76.

---------------. 1976. Season and crop report for Kerala State 1974-75.

Chandraskhar, S. A. 1973. Population growth and agricultural development in India. Journal of the Indian Soc. of Agric. Statistics 25(1).

Chetty, R. K. Shanmukham. 1948. Symposium on statistical organisation for India with special reference to agriculture. Journal of the Indian Soc. of Agric. Statistics 1:8-11.

Directorate of Economics and Statistics. Crop forecasts in India. Ministry of Agriculture and Irrigation.

Economics Research Service, USDA. 1973. Agricultural development and employment in India. Report #84.

Mellor, John W. 1976. The agriculture of India. Scientific American 235:155-163.

Mokashi, V. K. 1953. Investigation of sampling for estimation of crop acreages-I. Journal of the Indian Soc. of Agric. Statistics 5:127-143.

Mokashi, V. K. 1954. Investigations of sampling for estimation of crop acreages-II. Journal of the Indian Soc. of Agric. Statistics 6:115-126.

Mokashi, V. K. 1950. A note on interpenetrating samples. Journal of the Indian Soc. of Agric. Statistics 2:189-195.

National Sample Survey Organization. 1975. Consolidated results of crop estimation surveys on principal crops 1970-71. A-1, No. 23.

---------------. 1975. Consolidated results of crop estimation surveys on principal crops 1971-72. A-1, No. 24.

---------------. 1975. Consolidated results of crop estimation on principal crops 1972-73. A-1, No. 25.

---------------. 1964. Crop estimation surveys (State Series): Report on type-2 study on maize in Bihan. A-3, No. 11.

---------------. 1966. Crop estimation surveys (State Series): Report on type-2 study on Jowar. A-3, No. 18.

Panse, V. G. 1961. The national sample survey, agricultural statistics and planning in India. Journal of the Indian Soc. of Agric. Statistics 13:41-63.

---------------. 1963. Plot size again. Journal of the Indian Soc. of Agric. Statistics 15:151-159.

---------------. 1948. Statistical organisation for India. Journal of the Indian Soc. of Agric. Statistics 1:12-33.

Panse, V. G. and P. V. Sukhatme. 1948. Crop surveys on India-I. Journal of the Indian Soc. of Agric. Statistics 1:34-58.

---------------. 1957. Statistical methods for agricultural workers. Indian Council of Agricultural Research, New Delhi, India.

Rao, J. N. K. 1971. Some thoughts on the foundations of survey sampling. Journal of the Indian Soc. of Agric. Statistics 23(2):69-82.

Rao, V. K. R. V. 1974. New challenges before the Indian agriculture. Journal of Indian Soc. of Agric. Statistics 26(1):33-56.

Subramaniam, C. 1971. The story of the green revolution in India. Journal of Indian Soc. of Agric. Statistics 23(1):1-10.

Sukhatme, P. V. and V. G. Panse. 1951. Crop surveys in India-II. Journal of Indian Soc. of Agric. Statistics 3:98-168.

e. Union of Soviet Socialists Republic

Central Intelligence Agency. 1974. USSR Agriculture Atlas

Economic Research Service, USDA. 1977. Agricultural in the U.S. and the Soviet Union. Econ. Report #92.

---------------. 1975. Collecting agricultural statistics in the Soviet Union. Econ. Report #112.

---------------. 1977. USSR agricultural situation review of 1976 and outlook for 1977. Econ. Report #132.

---------------. 1977. USSR grain statistics: national and regional 1955-1975. Statistical Bulletin #564.

Joint Economic Committee, U.S. Congress. 1976. Soviet economy in a new perspective, A Compendium of Papers.

---------------. 1973. Soviet economic prospects for the seventies, A Compendium of Papers.

Office of Economic Research, CIA. 1975. Research aid--the Soviet grain balance 1960-1973.

Schoonover, D. M. 1976. Agricultural trade implications of the 1976-80 Soviet economic plan. Economic Research Service, USDA. Presented at Annual Meeting of Washington Chapter of the Amer. Assoc. for Advancement of Slavic Studies.

f. United States

Agricultural Stabilization and Conservation Service, USDA. 1978. Wheat and feed grain programs: questions and answers.

Agricultural Research Service. 1976. Wheat in the United States. Agricultural Information Bulletin #386

Arrends, W. L., R. L. Addison, R. W. Young and R. R. Bosecker. 1973. An evaluation of enumeration techniques and associated response errors and biases. Statistical Research Service, USDA.

Buse, R. C. 1973. Increasing responses in mailed questionnaires. Amer. Journal of Ag. Econ. 55:503-508.

Caudill, Charles E. 1976. Current methods and policies of the SRS. Statical Research Service, USDA. LARS Symposium on Machine Processing of Remotely Sensed Data, Purdue University, West Lafayette, IN.

Ciancio, N. J. and R. D. Tortora. 1976. On unbiased estimation in the area and list frame. Presented at 136th Annual Meeting of the American Statistical Association, Boston Massachussetts.

Ciancio, N. J., N. J. Rockwell and R. D. Tortora. 1977. An empirical study of the area frame stratification. Statistical Research Service, USDA.

Dunn, D. M. and J. M. Landweher. 1976. Graphical displays for analyzing aggregation effects from clustering time periods. Proceedings American Statistical Association. Statistical Computing Section.

Econ, Incorporated. 1975. U.S. benefits of improved worldwide wheat crop information from a Landsat system, overview. Princeton, NJ.

---------------. 1975. The value of domestic production information in consumption rate determination for wheat, soubeans and small grains. Princeton, NJ.

---------------. 1975. The value of information for crop forecasting in a market system. Princeton, NJ.

---------------. 1977. Studies of Landsat benefits: an overview. Princeton, NJ.

Economic Research Service, USDA. 1977. 1977 Handbook of Agricultural Charts #524.

---------------. 1977. Wheat situation WS-242.

---------------. 1975. Periodicals-1975.

---------------. 1977. The U.S. cash grain trade in 1974: participants, transactions and information sources. Agr. Econ. Report #386.

Ford, B. L. Replication of samples from a finite population. Statistical Research Service, USDA.

---------------. 1975. Rotation group effects in SRS surveys--Nebraska and Missouri 1975--June enumerative survey. Statistical Research Service, USDA.

Gunnelson, G., W. D. Doleson, and S. Pamperin. 1972. Analysis of the accuracy of USDA crop forecasts. American Journal of Agr. Econ. 54(4): 639-645.

Hammond. A. L. 1975. Crop forecasting from space: toward a global food watch. Science 188:434-436.

Hanuschak, G. A. and K. M. Morrissey. 1977. Pilot study of the potential contributions of Landsat data in the construction of area sampling frames. Statistical Research Service, USDA.

Heady, E. O. 1976. The agriculture of the U.S. Scientific American 235(3): 107-127.

Houck, J. P. and D. Pearson. 1976. Minnesota Agricultural Economist--Official production estimates for corn and soybeans: Preparation and accuracy. Ag. Ext. Service, University of Minnesota #578.

Houseman, E. E. 1975. Area frame sampling in agriculture. Statistical Research Service, USDA. SRS #20.

---------------. 1974. Expected value of sample estimate. Statistical Research Service, USDA. SRS #19.

Huddleston, H. F. 1965. A new area sampling frame and its uses. Journal of Farm Economics 47:1524-33.

Kelley, B. W. 1963. Probability sampling in collecting farm data. Journal of Farm Economics 45:1515-21.

Kibler, W. E. 1967. Sampling for collection of agricultural information. Presented at Commodity Club of Chicago.

Kirkbride, J. W. 1977. Domestic agricultural information systems. Economic Research Service, USDA. Presented at Workshop on Global Information Systems for Food and Fiber, Purdue University, West Lafayette, IN.

LACIE Economic Evaluation Team. 1977. LACIE Economic Evaluation 1977--Interim Report.

Miller, T. A. 1977. Observations on the 1978 economic evaluation of LACIE. Economic Research Service, USDA.

National Academy of Science. 1976. Setting statistical priorities. Report of the Panel on Methodology for Statistical Priorities. Committee on National Statistics, Assembly of Mathematical and Physical Sciences.

Osterhoudt, F. H. 1977. Cost of current USDA foreign crop production estimation system. Foreign Agricultural Service, USDA.

Pratt, W. L. 1974. Use of interpenetrating-sampling in area frames. Statistical Research Service, USDA.

Shapley, D. 1976. Crops and climatic change: USDA's forecasts criticized. Science 193:1222-1225.

Sigman, R. G., C. P. Gleason, G. A. Hanuschak and R. R. Starbuck. 1977. Stratified acreage estimates in the Illinois crop-acreage experiment. Presented at 1977 Machine Processing of Remotely Sensed Data Symposium at the Laboratory for Applications of Remote Sensing, West Lafayette, IN.

Spielman, H. and E. E. Weeks. 1975. Inventory and critique of U.S. agricultural capacity. American Journal of Agr. Econ. 52(5):922-927.

Statistical Research Service, USDA. 1977. Primary agency concerns entering 1977 as related to activities of the sampling studies section.

----------------. Replication of samples from finite populations.

----------------. 1975. Scope and methods of the SRS. Misc. Publication #1308.

----------------. Status report on recommendations made by the sampling studies section.

----------------. 1977. Wheat forecasting and estimating models. In Objective Yield Survey--Supervising and Editing Manual.

----------------. 1977. Wheat objective yield survey: enumerator's manual. Crop Reporting Board, USDA.

Thomasson, L. 1977. Agricultural information systems in the U.S. Paper presented at Workshop on Global Information Systems for Food and Fiber, Purdue University, West Lafayette, IN.

Tortora, R. D. 1977. Reducing respondent burden for repeated samples. Ag. Econ. Research: A Journal of the USDA, AERS 29(2):41-44.

U.S. Department of Agriculture. 1977. Overview of U.S. wheat industry with emphasis on decision making and information sources--Part I.

----------------. 1977. Brief overview of wheat industry of Argentina, Australia and Canada--Part II.

Vermeer, J. 1976. A summary of the study: the use and value of foreign wheat production information to USDA programs and activities.

Warren, F. 1977. Accuracy of USDA/SRS forecasts of wheat acreage, yield, and production 1966-1975 crop years. Foreign Agricultural Service, USDA.

Wigton, W. H. World Food Survey. U.S. Department of Agriculture.

g. Indiana

Bureau of Census, U.S. Department of Commerce. 1977. 1974 Census of agriculture--Indiana. Vol. 1.

Indiana Department of Commerce. 1970-71. Indiana economic report and forecast. Economic Research Division.

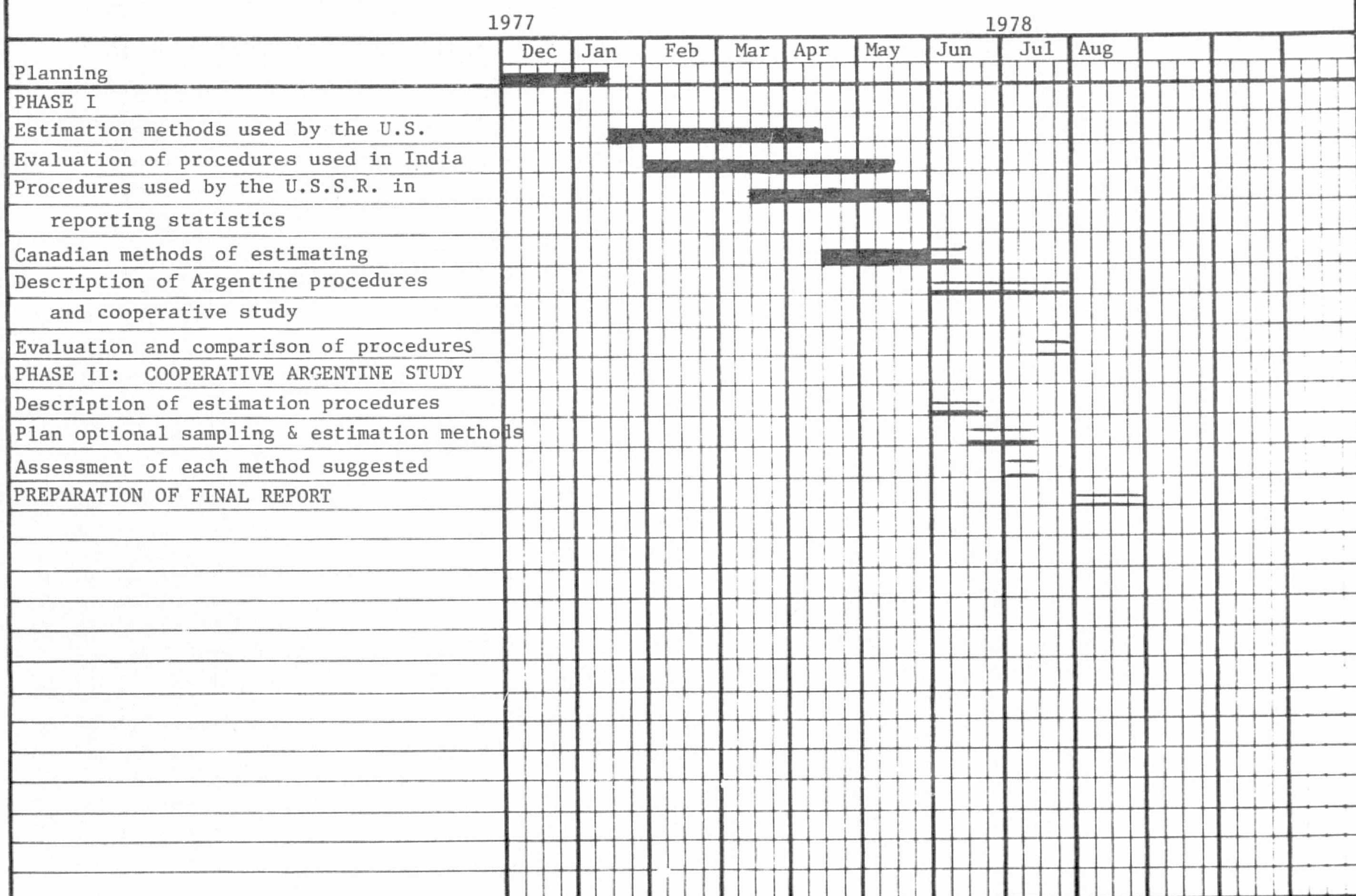
Indiana Crop and Livestock Reporting Service. 1977. Monthly crop statistics--Indiana: Small grain summary 1977. #M77-9. Purdue University, West Lafayette, Indiana.

Indiana Crop and Livestock Reporting Service. 1977. Field crops. Agricultural Experiment Station, Dept. of Agricultural Statistics, Purdue University, West Lafayette, Indiana.

Kreider, L. E. 1972. Indiana economic trends of national policy. State of Indiana Economic Research Division.

State Planning Services Agency. Indiana Facts Book 1976: Planning Information System #1.

3. Assessment of Methods of Acquiring, Analyzing and Reporting Crop Production Statistics



2.4 COMPUTER PROCESSING SUPPORT

1. Introduction

a. Background

The Laboratory for Applications of Remote Sensing at Purdue University (Purdue/LARS) has developed and maintained an Earth Resources Data Processing System which is used by LARS personnel and remote users at Johnson Space Center's Earth Observations Division (JSC/EOD) and other locations. The implementation of LARSYS on a general purpose computer with time sharing and remote terminal capabilities increases the system's value for a large group of users. The resulting system potentially provides:

* User access, at the user's location, to data and the processing capabilities,
* Centralization and sharing of expensive portions of processing hardware at a cost advantage,
* Centralization of software allowing flexibility in software maintenance, addition, and updating at a cost advantage over independent systems, and
* Ease of training users and sharing experiences through standard data formats, terminology, and shared communication channels.

The Earth Observations Division is planning to install hardware for an Earth Resources Data System (ERDS) in the early 1980's timeframe. The ERDS system must be designed to support world wide coverage for the multi-crop food and fiber program while allowing the processing flexibility necessary for a research and development environment. In addition, the system must be conceptualized and tested over a period expected to have a very limited earth resources budget.

Both hardware and software for the ERDS system must be modular for development and expansion purposes. Subsystems should execute independently where possible. The most advanced, proven technology must be employed. The system should be effective and flexible with an easy to use, readily available, user interface.

The LARS data processing facilities provide JSC with a test bed for ERDS techniques development:

* Examples of modular software systems exist in the forms of LARSYS, LARSYSDV, LARSYSXP, EXOSYS, etc.
* The capability for independent software subsystems has been developed.
* EOD and LARS both possess proven and advanced processing techniques; drawing from the best techniques available at both organizations should allow the formation of optimal processing software for ERDS.

The decision has been made to upgrade the LARS software/hardware facilities at JSC to provide Procedure 1 processing capabilities and increased terminal support. This upgrade will:

* Improve the capability for techniques exchange (such as P1 or ECHO) between the two organizations,
* Relieve RT&E computational constraints by supplanting or augmenting on-site computing as JSC processing capabilities are implemented at LARS,
* Reduce total costs by improving the efficiency of computer operations,
* Maintain valuable computational capabilities supporting LARS and JSC research and development, and
* Increase for both organizations' access to useful resources (data, technology, processing systems, hardware, etc.)

Work toward providing a capability to mutually exchange remote sensing data processing techniques between NASA/JSC and Purdue/LARS had begun prior to this contract year. The state of the exchange efforts as of December 1, 1977 was documented in the "Final Report on Processing Techniques Development" of NASA Contract NAS9-14970, dated November 1977. This report included a "Plan for the Installation of a Data 100 Remote Terminal" which is being pursued during this contract period.

b. Objective

The objective of this task is to provide to EOD and LARS a shared data processing environment designed for the support of remote sensing technology through a facility including computer and related hardware, software, data, personnel, and procedures.

During this contract period, LARS will continue to support JSC's 2780 terminal while it continues to be used. LARS will provide support to the JSC software conversion and hardware implementation tasks and will provide computer support for the conversion and testing of programs. Subtasks which are to be pursued include:

* Hardware installation
* Software support
* Systems consulting
* Techniques exchange
* Software conversion support
* RT&E data base support

Additional subtasks may be defined and pursued at some future date including:

* CMS/370 support
* LARSYSP1/LARSYS integration
* Statistical package support
* Ancillary LARS Systems capability transfer (LARSYSDV, LARSYSXP, Registration System, etc.)
* ERDS design and concept testing

c. Review of First Quarter Accomplishments

During the first quarter, an implementation plan was written and transmitted to JSC. The tasks outlined in that plan were categorized into four general areas, responsibilities were assigned for those areas and the areas were prioritized:

Priority	Area
1	Hardware Installation
2	Software Support
3	Systems Consulting
4	Techniques Exchange

The thrust of the work performed during the first quarter was to provide JSC with the hardware, software, and knowledge necessary for greatly expanded usage of the LARS computer by JSC personnel.

i. Hardware Installation

During the first quarter, an order for a voice grade phone line with D1 conditioning was placed for eventual support of the JSC Data 100. Six ports to the IBM 3705 communication controller at LARS were ordered to support the JSC Data 100 and five additional keyboard terminals to be located at JSC. An order was also placed for a tape rack to house the SR&T data base.

ii. Software Support

During the first quarter, ground work was done in support of Tape Transfer Software and IMSL installation. IMSL was contacted and the systems and programming considerations for its installation on an IBM 370/148 were discussed. Documentation of the Data 100 tape transfer protocol was secured and a plan for the implementation of a tape transfer capability was drafted and distributed.

iii. Systems Consulting

Computer ID's, tapes, and disks were added and altered during the first quarter and consulting advice on the use of the statistical packages and several LARS EXEC files was provided.

iv. Techniques Exchange

During the first quarter, two short courses were designed and scheduled. The first, covering the use of the LARS computer system, was presented at JSC during the first quarter.

II. Status Report for the Second Quarter

During the second quarter, a fifth general area of work, RT&E Data Base, was added to the four areas pursued in the first quarter (Hardware Installation, Software Support, Systems Consulting, and Techniques Exchange).

a. Hardware Installation

The objective of this subtask is to provide the computer and related hardware necessary for the support of JSC terminal facilities and users.

i. Work Completed

Phone Line. The 4-wire, full-duplex, voice grade channel AT&T type 3002, with D1 conditioning and a 9600 baud modem were installed at JSC and LARS during early March to support the Data 100 terminal at JSC.

IBM 3705 Communications Controller. Cables, line sets, and a new line interface base are scheduled for installation in time to support the new multiplexor and five additional keyboard terminal ports scheduled for installation at JSC by June 15.

Tape Rack. During the second quarter, a new tape rack was installed to house the RT&E data base.

Data 100 Installation. The JSC Data 100 terminal and the Modem Selection Switching System have been installed and tested at both sites. The Data 100's punch, printer and reader are performing successfully in IBM 2780 emulator mode. The tape drive, however, is not performing to the Data 100 documentation in 2780 emulator mode. This has caused a delay in the implementation of the tape transfer software.

ii. Work in Progress

Disk Space. Disk space remains a major unresolved hardware issue. During the second quarter some breathing room was created by the conversion of the EOD LARSYS routines to CMS370 and the subsequent shift of some JSC ID's to the 3350 disk drives. The shift of these ID's to 3350 disk space helped reduce another disk problem, the shortage of temporary disks. During April, three 2314 temporary disks were added to the system. These disks are required to support both LARSYS and EOD LARSYS processing. Demand for disk space continues to increase, however, and it appears that soon demand will exceed the combined space available on the 3350's and the 2314's. To gather the information necessary to evaluate alternative disk options, Purdue's Purchasing Department has been requested to secure quotations on the costs of IBM 2314, 3330 and 3350 equivalent disk drives. In addition, a plan has been formulated to release some currently used disk space as demand for additional disk storage increases. The extent of additional demand for disk space will largely be determined by the amount of work JSC and other terminal sites choose to do on the LARS computer.

iii. Future Work

The installation of cables, multiplexor and 3705 ports should take place during June when JSC receives the new multiplexor. Additional disk storage and other hardware modifications may become necessary during the third or fourth quarter.

b. Software Support

The objective of this subtask is to provide the EOD user community with system and other software support, necessary maintenance and implementation of earth resources processing capabilities.

During the second quarter, a large proportion of the LARS effort has been concentrated on the software support subtask. Much of that work is continuing into the third quarter where it should be completed.

i. Work Completed

To run the Accuracy Assessment group's Atmospheric Transmission Program on the IBM 370/148 required the conversion of the program and the data used by the program. The data tape was generated to be used on a UNIVAC 1108 and contained the UNIVAC binary representation of both integers and floating point numbers. The software to convert the data tape to IBM's representation has been written and the data tape successfully converted.

ii. Work in Process

The software support work we are currently performing is aimed at supporting tape transfers, supporting the development and implementation of the EOD LARSYS software, and the development of CMS370 batch machines to allow the tape transfer and the LARSYSP1 software to be run in a batch environment.

System Software Modifications. A large effort was directed toward modification of system software during the past quarter. The Control Program (CP), Conversational Monitoring System (CMS), and the Remote Spooling Communications Subsystem (RSCS) operating systems were modified to obtain support for a CMS370 batch machine and operation of the JSC Data 100 in IBM 360/20 emulation mode.

RSCS

To support the Data 100 in IBM 360/20 emulator mode (HASP) the Simultaneous Multi-Leaving line driver (DMTSML or SML), the RSCS system initialization routine (DMTREX), and the RSCS link definitions (AXSLINKS) have to be modified. The major reason for operating JSCTEXAS in HASP mode is to allow tape transfers between EOD and LARS. The 2780 Emulator Program as supplied by Data 100 produced an output file that would be extremely difficult to reconstruct a tape from. The output from the 360/20 Data 100 emulator program is in a much better defined and more usable format. Operation of the Data 100 in HASP mode also allows the JSC Data 100 operator to send messages and commands from the Data 100 operator's console and to receive messages at his operator's console. The SML line driver also supports the simultaneous sending and receiving of data. When data that contains duplicate character strings is being transmitted or received, less information is transmitted over the line due to data packing techniques employed in the HASP protocol. This allows quicker transmission of data.

There is presently a software "bug" in the SML line driver which prevents it from being used in an operational mode. Much effort is being spent to isolate and correct the error. The cooperation and assistance of Glen Prow in this matter has been greatly appreciated.

CMS 370 BATCH MACHINE

Support for a CMS370 batch machine necessitated making changes to CP, CMS, and the batch programs. (The changes made to CP will also, with a little effort, make it possible to IPL LARSYSP1).

The 370 batch machine capability was desired so that LARSYSP1 could be run in a batch mode. The advantages of running batch are better utilization of system resources and lower cost. There are several advantages to running CMS370 as opposed to CMS360. When running CMS370 on the occurrence of an I/O error, the error condition and status information from the device which caused the error are recorded. This data, which is not recorded by CMS360, aids in the detection, diagnosis, and correction of hardware problems. CMS370 makes use of a diagnose interface to CP to do all of its I/O operations. The CMS370 interface requires less handling by CP than CMS360, resulting in faster I/O response and less total CPU time used.

Tape Transfer Software. Initial programming has been completed and testing is in progress of the tapecopy routines which allow the transfer of specified tape files from a tape at either site to a tape at the other site. Difficulty was experienced in the implementation of the tape transfer software when the Data 100 was emulating an IBM 2780. The documentation provided by Data 100 on the Data 100 IBM 2780 tape data transmission protocol was vague and insufficient. After several discussions with Data 100 during March and April, it became apparent that it would be much faster and more efficient to implement the tapecopy software to function when the Data 100 was emulating an IBM 360/20 rather than a 2780. The software is in the testing mode currently and should be ready for general use sometime in June.

In normal operation a tape transfer job will be run in batch mode. When the tape transfer batch machine is initiated, if it has any jobs in its queue, it will instruct the operators at both sites how to proceed. To run a tape transfer job, as it will initially be implemented, a card deck consisting of batch header cards and tape transfer control cards will be input.

BATCH HEADER CARDS:

```
C       C
O       O
L       L
        1
1       0
-       -
ID      BATCH
BATCH MACHINE TAPTRAN
BATCH ID userid name
BATCH OUTPUT site COMPUTER
EXEC TRANSFER
```

userid = Valid userid on the IBM 370/148 to which the tape transfer is to be charged.

name = Name of the user requesting the tape transfer.

site = Site at which printer output is to be received e.g., JSCTEXAS

TAPE TRANSFER CONTROL CARDS:

```
*TAPE TRANSFER
FROM(site1), TAPE(mmmm), FILE(ii,hh)
TO(site2), TAPE(nnnn), FILE(jj)
END
```

site1 = Site of input tape i.e., HOUSTON or LARS.

site2 = Site of output tape i.e., HOUSTON or LARS.

mmmm = Input tape description e.g. 1267.

hh = First input file number to be copied.

ll = Last input file number to be copied (If only one file is to be copied, this parameter should be omitted).

nnnn = Output tape descriptor e.g. A1308

jj = First output file to receive data

NOTE...

Up to ten sets of tape transfer control cards may be included in a job.

EXAMPLE 1. Jeanne Etheridge wishes to copy files 3 and 4 of a tape she has at LARS to file 1 and 2 of a tape at HOUSTON, so she reads in the following cards:

```
ID     BATCH
BATCH MACHINE TAPTRAN
BATCH ID CLAKE ETHERIDGE
BATCH OUTPUT FLEXLAB2 COMPUTER
EXEC TRANSFER
*TAPE TRANSFER
FROM(LARS), TAPE(667), FILE(3,4)
TO(HOUSTON), TAPE(9637), FILE(1)
END
```

EXAMPLE 2. Glen Prow wishes to copy the first file of two tapes he has at HOUSTON to files 1 and 2 of a tape at LARS, so he reads in the following cards:

```
ID     BATCH
BATCH MACHINE TAPTRAN
BATCH ID JSC102 GLEN PROW
BATCH OUTPUT JSCTEXAS COMPUTER
EXEC TRANSFER
*TAPE TRANSFER
FROM(HOUSTON), TAPE(6897), FILE(1)
TO(LARS), TAPE(134), FILE(1)
END
```

```
*TAPE TRANSFER
FROM(HOUSTON), TAPE(6898), FILE(1)
TO(LARS), TAPE(134), FILE(2)
END
```

LARSYSP1 Software Support.

PROMPTING EXEC

Since it is desirable that EOD LARSYS be easy to access, we have been working in conjunction with NASA and LEC to create a CMS EXEC prompting routine. To run LARSYSP1 with the prompting routine, the user needs only to answer a few simple questions rather than gain a working knowledge of CMS370 commands. The questions are:

1. Are the LARSYSP1 cards in the card reader, on disk or do you wish to create or modify them? (READER, DISK, EDIT)
2. Do you wish to run interactively (at the terminal) or have your LARSYSP1 job sent to a batch machine? (INTER or BATCH)
3. At which site do you wish to receive output? (HOUSTON, JSCTEXAS, etc.)
4. Will your LARSYSP1 job require a data tape? (YES or NO)
5. Do you wish to save any intermediate results produced by LARSYSP1 or use any previously saved results? (YES or NO)

If the answer to question 5 is YES, the user will then be asked which data files he wishes to use and/or save. Classification maps or class statistics are examples of data files an analyst may wish to save on disk or tape. If the answer to question 4 is YES, the user will be asked what the desired tape number is. The number of questions has been kept to a minimum. The prompting routine is currently being tested and debugged at LARS.

Setting up an IPL system for LARSYSP1 has been discussed. If this were to be done, a user would then type 'I LARSYSP1' or 'IPL LARSYSP1' instead of 'I CMS370' and additional CMS370 commands. In order to have an IPL system, a system monitoring EXEC routine must exist. The prompting EXEC being developed will serve as a basis for the LARSYSP1 system monitoring EXEC.

UNIVERSAL HEADER LISTINGS

A program to list the header information from either a Universal formatted data tape or a LARSYS formatted data tape is currently being implemented at LARS. The program will be implemented in a form which will allow its inclusion in the LARSYSP1 System. When completed, a copy of the program listing and documentation will be forwarded to JSC for consideration as a portion of LARSYSP1.

iii. Future Work

LARSYSP1 IPL System. During the third quarter, a LARSYSP1 IPL system should be implemented to allow a user to quickly and easily analyze data using the EOD LARSYS routines. The IPL system will also greatly simplify the process of running LARSYSP1 routines in a batch environment.

LARSYSP1 Prompting Software. When the prompting routine has been completely tested, we will consider ways to easily produce LARSYSP1 control card decks. For instance, standard decks could be available so that the user, instead of creating the entire deck, would only need to alter one or two cards from the standard deck to run his specific job. For this example, the standard decks would reside on the LARSYSP1 System disk and question 1 would be changed so that the user could easily access and alter them. Another possibility would be to create a standard set of default options and a front end control card processor which would generate the LARSYSP1 control cards by accepting user input and augmenting it with the standard control card defaults where the user has failed to supply parameters.

Tape Transfer Software. The tape transfer software must be tested, documented, and knowledge of its use transferred to JSC. After an initial capability is on-line, refined and expanded tapecopy procedures may be developed to make access of tapes at JSC more transparent to the JSC users and the Data 100 operator. Completion of the tape transfer software is highly sensitive to the debugging of the systems software which recognizes the JSC Data 100 as a HASP work station.

IMSL. The IMSL source tapes have just been received at the date of this writing. We anticipate that installation will be completed during the first week of June. There are no test procedures supplied on the library tape. Testing will be accomplished with the assistance of JSC.

Software support for additional conversion or development efforts may be of value. These efforts must first be identified and plans devised, however. Certain candidate conversion or development efforts have been discussed as possibilities:

* Additional statistical package implementations,
* Implementation of Building 30 processing on the LARS computer,
* Development of an integrated EOD-LARS processing system as an ERDS prototype,
* Implementing a registration system useful to both sites.

c. System Consulting

The objective of the systems consulting subtask is to provide assistance in the use of any software facilities available at LARS and to obtain computer resources, preprocessing products or programming support as required for JSC remote terminal users.

i. Work Accomplished

Computer ID's. During this quarter a total of 28 computer ID's were added to the Purdue/LARS system; 22 for use by people at JSC and 6 for LARS support of activities on this project. In addition, approximately 30 requests to alter the status of existing ID's were handled during this period, including moving disk space for 8 ID's to the 3350 disks.

This temporarily alleviated the disk space problem. There are no outstanding ID requests at this time.

Glen Prow Visit. On March 14th and 15th, Glen Prow (LEC) was at LARS to complete the installation and testing of a Codex LSI 9600 modem, a backup Codex 4800 modem, and a 7200/4800 modem switch panel.

Statistical Program Support. LARS personnel have been answering questions pertaining to the use of CMS360 SPSS, CMS370 SPSS and the BMD programs. Some questions arise because the user has an enormous amount of data.

The BMDX85 routines for regression analysis required a fix in order to allow the user to supply Fortran statements as part of his input deck. This work has been completed and documented in the LARS SCANLINES. Sue Schwingendorf should be contacted with questions on the use of these routines.

Visiting Consultant. A portion of both the techniques exchange and the systems consulting subtasks is to provide assistance in the use of software facilities available at LARS and programming support required by JSC terminal users. To facilitate the effectiveness with which this may be done, a visiting consultant program has been initiated. In this manner, LARS personnel may more directly interface with JSC personnel.

To start the program, Bill Shelley served as a visiting consultant at JSC from March 15 to March 22. The JSC personnel were well prepared for such a visit with many questions and needs for assistance well in mind. The type of consulting done ranged from discussing output products to implementing an interim batch machine and other programming tasks.

SR&T Community Support. During his visiting consultant trip to JSC, Bill Shelley aided Jack Bryant of Texas A&M University in the implementation of a spatial clustering algorithm on the LARS computer. During May, CMS370 documentation was sent to Texas A&M in anticipation of expanded use of the LARS system by researchers there.

ii. Work in Progress

Statistical Program Support. There is still an outstanding problem in CMS370 SPSS that was reported by Mike Pore. The discriminant analysis routines do not work properly. We have been consulting with Mike and he has been running them on CMS360 SPSS until the 370 version is working. The problem is being worked on and should be resolved soon by Jeanne Etheridge.

Sue Schwingendorf has recently received the IMSL package and will soon be putting it on the system so that the routines can be accessed from CMS370.

Visiting Consultant. Sue Schwingendorf is scheduled to be at JSC during the end of May. She will be demonstrating the use of batch machines and tapecopy software if it has been successfully tested by the time of her trip.

iii. Future Work

Purdue/LARS will continue to provide consultants to respond to requests and questions from the JSC remote site specialists about system use and access to computer resources. We will try to make the communications as efficient and effective as possible by encouraging users at JSC to consult their site specialists before calling LARS.

d. Techniques Exchange

The objective of this subtask is to mutually exchange the experience and expertise resident at JSC and LARS.

Installation of JSC software on the LARS computer system has created a unique opportunity for both LARS and JSC to share and gain insight and experience related to data processing, data analysis, and software design. In response to this opportunity, the need for a formally administered activity to insure orderly exchange of information continues. As a result, steps toward development of an ongoing technique interchange have been taken.

i. Work Accomplished

During this quarter, a short course on Procedure I and EOD LARSYS was presented at LARS. An outline of that course is reproduced below. In addition, one LARS staff member spent one week at JSC as a consultant, one JSC staff member visited LARS to install a modem and obtain first hand knowledge of our hardware configuration, and numerous reciprocal telephone communications have occurred in support of establishing a global understanding of our mutual hardware/software systems.

MONDAY, MARCH 6

9:00	Introduction
9:30	Overview of Procedure I (rationale, background)
12:00	Lunch
1:30	Overview of EOD LARSYS
3:00	Break
3:15	Operating System for EOD LARSYS

TUESDAY, March 7

9:00	I/O of EOD LARSYS
10:30	Control card formats and run procedures
12:00	Lunch
1:30	LARSYS/P1 Example

WEDNESDAY, March 8

8:00 - 10:00	Optional time Q/A or Demonstration

ii. Future Work

An interchange session on use of tapecopy software developed at LARS is anticipated pending finalization of such software. LARS requests a set of interchange specifications/objectives be transmitted in connection with this activity.

Additional reciprocal workshops and/or visits remain excellent possibilities, as suggested in the first quarterly report. Demonstration of interest on the part of JSC is prerequisite, however.

Attempts by LARS staff members to utilize the LARSYSP1 software have been somewhat frustrated by the lack of user oriented documentation. Although personal communications have usually resolved these difficulties, some upgrading of the documentation would greatly enhance its understandability. If the EOD LARSYS software is to be efficiently used by LARS or other sites remote to JSC, some documentation activity seems in order. This could take the form of describing the system at some point in time followed by monthly updates or addenda. Reciprocally, this activity could be undertaken for some component of the LARS system if interest is communicated.

e. RT&E Data Base

During the second quarter work was begun on the building of an RT&E data base at LARS. This task may eventually lead to a centralization of research software and a standardized data base located at Purdue and available to the SR&T user community via remote terminals.

i. Work Completed

The 1977 Universal formatted Phase III data base consisting of 222 tapes arrived at LARS the last week of March and was subsequently placed in the Purdue/LARS Tape Library.

ii. Work in Process

Data Base Format. Information has been exchanged between LARS and JSC personnel concerning the eventual format of the RT&E data base to be located at LARS. Because of disk space limitations and because of the virtual machine characteristics of the LARS computer, use of tapes as a medium for data base storage has been tentatively agreed to. Other format considerations include whether the data base should be stored in composed or single-acquisition data files, how multiple dates should be handled, etc. Issues which will influence the selection of the data base format include:

* the cost of formatting the data base,
* the cost of running an analysis on the data,
* the ease of access to the data base,
* turnaround time for the analysis, and
* the system resources required to perform an analysis.

Segment Catalog. Regardless of the data base format, the quality and quantity of research which may be conducted utilizing the data base will be greatly enhanced if a data catalog is devised and maintained.

At least six separate data bases are associated with the Multicrop Experiment:

* Data base of acquisitions of Landsat data,
* Data base of wall-to-wall ground observations for each segment,
* Data base of labels and label information for each segment,
* Data base of agronomic observations data,
* Data base of crop calendar data, and
* Data base of meterological data.

All of these data bases should be organized on a segment-by-segment basis and at least 3 of these data bases (the Landsat data, the ground observation data, and the dot label data) are primarily digital in nature and should be stored in a computer-compatible, computer-indexed form.

Computer indices pointing to the location of various elements of the various data bases associated with each segment, together with the value of certain specific variables for each segment, will compose a Segment Catalog.

A preliminary design of such a data catalog is presented in Appendix 4A.

iii. Future Work

Data Base. The 1976 LACIE Phase II data base is expected to arrive soon. This data base will join the 1977 Phase III data base in the LARS Tape Library.

Segment Catalog. The design of the Segment Catalog should soon be finalized so that work may begin on its implementation. It is recommended that software be designed to:

1. Update the segment catalog
2. To interface the segment catalog with the LARSYSP1 Processing System
3. Search the data base to locate data with unions and intersections of user defined characteristics.

In addition, access and use of those programs should be well documented in a user-oriented manner.

C-2

III Technical Problems Encountered

This section of the report is a concentration of the major unresolved technical problems encountered to this point on the project. Where reasonable alternative approaches exist, they will be discussed.

a. Hardware Problems

The major unresolved hardware problem is that of disk space. At the present time, virtually all available disk space on both the IBM 3350 and the IBM 2314 drives is either reserved for system use or assigned to users. The problem we are facing is to give good service to, and provide for expanding use of the LARS computer by JSC users in light of this disk situation. We are in the process of examining the following options:

* Purchasing or renting more disk space,
* Reducing the disk space available to users at LARS to make more space available to JSC, and
* Reducing the disk space used by the system to make more space available to JSC.

Securing more disk hardware would be the least painful alternative from the point of view of the LARS users because neither the system usage nor the users' private disk requirements would be impacted. On the other hand, this option would increase the cost of running the computer facility at a time when funds are short. The actions taken to gain information about the option consist of requesting Purdue's purchasing department to secure quotations for IBM 3330, 3350 and/or 2314 equivalent disk drives.

Reducing the disk space available to users at LARS will reduce, to some extent, the effectiveness of the LARS users. If only a small amount of disk space is needed, this solution will only require some personnel time for unused disk space to be identified and eliminated. However, as more and more disk space is required, actual LARS use of the computer will be impacted under this option. To this point, only the LARS users in the computer facility have been asked to look for and release any unused disks they may control.

Upon a preliminary examination of the disk space assigned to the system for spooling and paging, it appeared that a reduction in the spooling and paging areas might result in as much as 140 additional megabytes available to systems users. This option is being examined more carefully at the present time. What effects such a reduction might have on system loading, tape transfers, number of users the system can handle concurrently, etc., must be weighed against the needs for increased disk space.

In the short run, we will attempt to satisfy JSC's need for additional disk space through the latter two solutions. An estimate of eventual disk requirements by JSC is necessary, however, to determine whether or not it will be reasonable or even possible to supply sufficient disk space without purchasing additional drives. On the basis of some preliminary discussions with disk suppliers, wait times for disk equipment range from three months to in excess of one year.

b. Software Problems

There are two major software problems which we are currently attempting to deal with. Both are related to the tape transfer software.

i. SML

To operate the Data 100 terminals in IBM 360/20 emulator mode (HASP), the Simultaneous Multi-Leaving (SML) line driver software must function properly. Because the output of the Data 100 functioning in 370/20 emulator mode is better documented and both easier and more efficient to use than Data 100 output in 2780 mode, the tape transfer software requires a properly working SML. We have encountered several "bugs" in the SML software and, since IBM has recently released a new version of the operating system which we have not yet received, IBM is no longer supporting our current version of the SML software.

We have the following options with respect to operating the Data 100 in IBM 360/20 emulator mode.

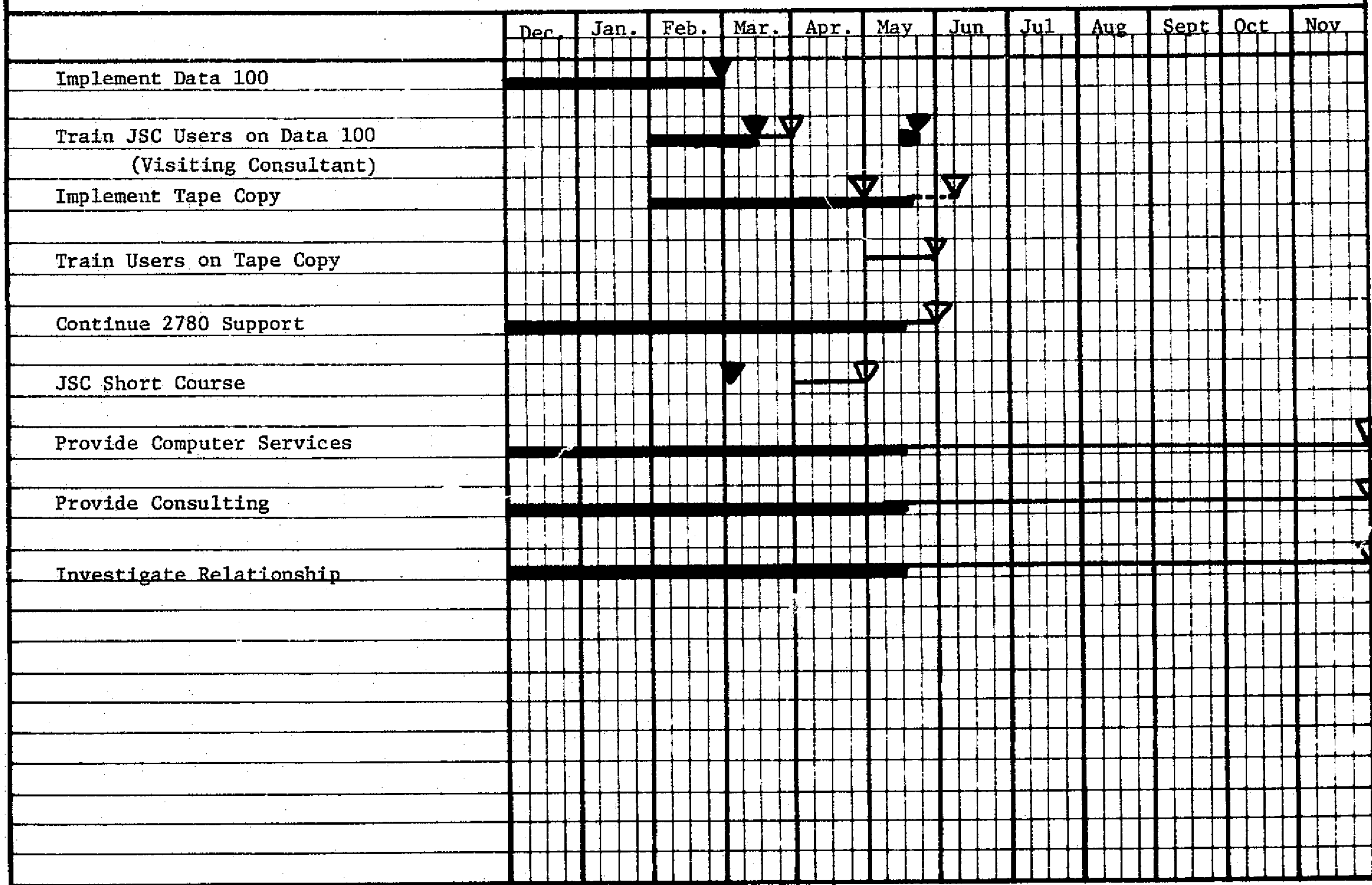
* Debug the current version of SML
* Wait for release five of the operating system to be installed before operationally transferring tapes
* Secure RASP from SHARE, the IBM users' group

We are currently working to debug SML since we have not yet received Release 5 of the operating system and it is quite possible that the new release will still have problems in the SML software. At the same time, we are attempting to secure a copy of RASP. RASP was written by the SHARE group as a replacement for RSCS and SML. It is documented as having superior characteristics to RSCS.

b. Tape Transfer Software

Although the format and the documentation of the data from/to the Data 100 tape drive is superior for the IBM 360/20 emulator, it is far from complete. We currently have been able to successfully transfer tapes from JSC to LARS. We have not, however, been able to successfully reverse the process. Documentation for both the format of the data stream to be sent to the Data 100 and for the commands which must be entered by the Data 100 operator is needed. In addition, it would be helpful if Data 100 would examine the data stream we are sending to their machine and identify what, if anything, is wrong with it, since the tape transfer capability is necessary to justify the continued rental of their tape equipment.

TASK 2.4 COMPUTER PROCESSING SUPPORT



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APPENDIX 4A

SEGMENT CATALOG

There are at least 6 separate data bases associated with the Multicrop Experiment:

* Data base of acquisitions of Landsat data,
* Data base of wall-to-wall ground observations for each segment,
* Data base of labels and label information for each segment,
* Data base of agronomic observations data,
* Data base of crop calendar data, and
* Data base of meterological data.

All of these data bases should be organized on a segment-by-segment basis and at least 3 of these data bases (the Landsat data, the ground observation data, and the dot label data) are primarily digital in nature. and should be stored in a computer-compatible, computer-indexed form.

Computer indices pointing to the location of various elements of the various data bases associated with each segment, together with the value of certain specific variables for each segment, will compose a Segment Catalog. This document is a first cut design at that Segment Catalog.

The Segment Catalog (See Figure 1) will itself be composed of six separate data files:

1) the Segment Index,
2) the Acquisition List,
3) the Dot Label Table,
4) the Ground Observations Index,
5) the Ground Observation Fields, and
6) Repeated Measurement Records

The last three files compose the Ground Observations Table. All Segment Catalog files will be stored on disk and will be readily accessible through user oriented routines. Routines will be designed to perform two separate functions, 1) producing data base status reports for users and 2) providing the data analysis system (e.g. LARSYSP1) routines direct access to the various data components which the processing systems require.

The Segment Index data file is a master index for the Segment Catalog. It is composed of two types of information:

1) information which is unique to each segment (e.g. the segment latitude, the segment longitude, the county in which the segment is located, the state in which the segment is located, etc.), and

2) pointers to the other data files within the Segment Catalog.

The Segment Index data file will include two pointers to other Segment Catalog data files. For example, the first pointer for the Acquisition List data file will point to the first acquisition over the segment of interest in the Acquisition List and the second pointer for the Acquisition List file will point to the last acquisition which has been entered into the data base. The Acquisition List, the Dot Label Table and the Ground Observation Index will each be doubly linked lists. Figure 2 presents an example of how the records in the Segment Index File might appear. If there are no entries in a particular data file for a segment, both pointers to that data file in the Segment Index File will be set to 0. For example, if no satellite data has been collected for a given segment, no entries for that segment will be present in the Acquisition List and the pointers in the Segment Index for the first acquisition and the last acquisition in the Acquisition List will both be set to 0.

Figure 3 presents the candidate set of elements for the Acquisition List File. Of particular interest are the first two elements of each record. The first element, called the previous acquisition element, points backwards through the Acquisition List. This element represents the acquisition list record number which contains information about the acquisition prior to the current acquisition for the segment of interest. When there is no previous acquisition in the data base, this pointer will be set to -N, where N is the pointer to the record in the Segment Index for the segment of interest. The second element in the Acquisition List points to where information about the next chronological acquisition taken is located. If the current Acquisition List record contains information about the most recent acquisition in the data base, then the next acquisition value will be set to -N, where N is again the record in the Segment Index data file which contains information about the segment.

Figures 4 through 7 represent candidate configurations of the Dot Label Table data file and the Ground Observations Table data file of the Segment Catalog. Like the Acquisition List, these data files have as their first two entries, pointers to the previous and the next entries.

SEGMENT CATALOG

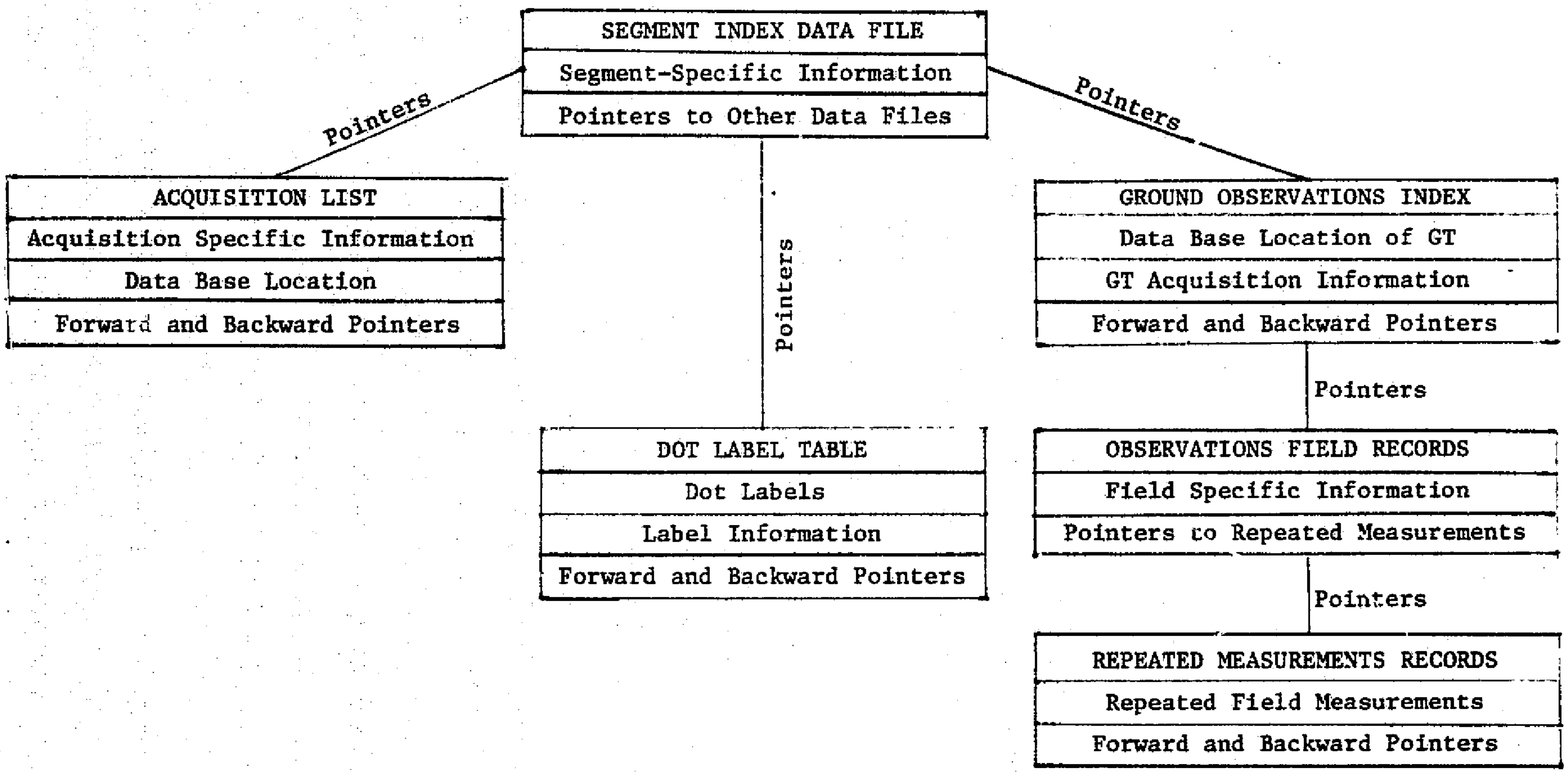

Figure 1

Format of Segment Index Records

Entry		Format	Bytes
Segment Number		I*2	1-2
Segment center latitude (minutes north)		I*2	3-4
Segment longitude (minutes west)		I*2	5-6
Date segment initiated: (YYDDD)		I*4	7-10
Segment Descriptor		8A4	11-42
Acquisition List Pointer:	First Entry	I*2	43-44
	Last Entry	I*2	45-46
Label Index Pointer:	First Entry	I*2	47-48
	Last Entry	I*2	49-50
Ground Observation Index:	First Entry	I*2	51-52
	Last Entry	I*2	53-54
Undefined			55-80

Figure 2

Format of Acquisition List Records

Entry	Bytes Required	Format	Bytes
Previous Acquisition	2	I*2	1-2
Next Acquisition	2	I*2	3-4
Sensor System (MSS1-4, TM, RBV)	8	A8	5-12
Date Data Collected (YYDDD)	4	I*4	13-16
Date Entered in Acq. List (YYDDD)	4	I*4	17-20
Segment Number	4	I*4	21-24
Tape Number	4	I*4	25-28
File	2	I*2	29-30
First Channel	1	L*1	31
Last Channel	1	L*1	32
Lines of Data	2	I*2	33-34
Columns of Data	2	I*2	35-36
Green Number	4		37-40
Haze Number	4		41-44
Sun Elevation (min)	2	I*2	45-46
Sun Azinuth (min)	2	I*2	47-48

Figure 3

Format of Dot Label Table Records

Entry	Format	Bytes
Previous Label Entry	I*2	1-2
Next Label Entry	I*2	3-4
Segment Number		5-6
Analyst Identifier	L*1	7
Number of Categories	L*1	8
Date of Labelling (YYDDD)	I*4	9-12
Acquisitions Used in Labelling		13-44
Date #1 (YYDDD)	I*4	13-16
Date #2 (YYDDD)	I*4	17-20
⋮		
Date #8 (YYDDD)	I*4	41-44
Category Names:		45-140
Crop Annotated as Category 1	A8	45-52
Crop Annotated as Category 2	A8	53-60
Blank fill or Crop Annotated as Category 3	A8	61-68
⋮		
Blank fill or Crop Annotated as Category 12	A8	133-140
Number of Labels (NL)	I*2	141-142
Labels and Annotation:		143-(142+6*NL)
Labelled Line for Dot 1	I*2	143-144
Labelled Column for Dot 1	I*2	145-146
Label Annotation for Dot 1 *	L*1	147
Label for Dot 1 **	L*1	148
Labelled Line for Dot 2	I*2	149-150
Labelled Column for Dot 2	I*2	151-152
Label 2 Annotation *	L*1	153
Dot 2 Label **	L*1	154
⋮		
Labelled Line for Last Dot	I*2	137+6*NL-138+6*NL
Labelled Column for Last Dot	I*2	139+6*NL-140+6*NL
Last Label Annotation *	L*1	141+6*NL
Last Dot Label **	L*1	142+6*NL

Figure 4

* 0 ==>A Field Pixel

1 ==>Dot in DO area

2 ==>Dot in DU area

3 ==>Dot is an edge pixel

4 ==>Dot is a boundary pixel

** 1 $\leq$ N $\leq$ 12 ==> Type one dot corresponding to category name N

129 $\leq$ N $\leq$ 140 ==> Type two dots corresponding to category name N-128

Figure 4 (continued)

Ground Observations Table

Ground Observations Index

Entry	Format	Byte
Previous Ground Truth Entry	I*2	1-2
Next Ground Truth Entry	I*2	3-4
Segment Number	I*2	5-6
Date of initial GT Record (YYDDD)	I*4	7-10
Pointer to Acquisition List for first W to W GT	I*2	11-12
Pointer to Acquisition List for last W to W GT	I*2	13-14
Number of Fields monitored for Agronomic Data	I*2	15-16
Pointer to first Monitored Field	I*2	17-18
Pointer to Last Monitored Field	I*2	19-20

Figure 5

Ground Observations Table cont'd.

Observation Field Records

Entry	Format	Bytes
Previous Field Monitored	I*2	1-2
Next Field Monitored	I*2	3-4
Segment Number	I*2	5-6
Field Number	I*2	7-8
Field Identifier	A8	9-16
Crop	L*1	17
Variety	L*1	18
Date Planted (YDDD)	I*2	19-20
Row Width (meters)	R*4	21-24
Nitrogen Fertilization	I*2	25-26
Pointer to first of Repeated Measures Data	I*4	27-30
Pointer to last of Repeated Measures Data	I*4	31-34
Number of ARCS (NARC)	I*2	35-36
Line Coordinate 1	I*2	37-38
Column Coordinate 1	I*2	39-40
Line Coordinate 2	I*2	41-42
Column Coordinate 2	I*2	43-44
⋮		
Line Coordinate NARC	I*2	33+NARC*4-34+NARC*4
Column Coordinate NARC	I*2	35+NARC*4-36+NARC*4

Figure 6

Ground Observations Table cont'd.

Repeated Measurement Record

Entry	Format	Bytes
Previous Measurement	I*4	1-4
Next Measurement	I*4	5-8
Segment Number	I*2	9-10
Field Number	I*2	11-12
Date Measured (YYDDD)	I*4	13-16
Maturity	L*1	17
% of Ground Cover	L*1	18
% of Green Leaves	L*1	19
Condition	L*1	20

Figure 7