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16. Abstract

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

2.1 Agricultural Scene Understanding
2.2 Processing Technique Development
2.3 Large Area Crop Inventory Design

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2.1 Agricultural Scene Understanding

2.1a LACIE Field Measurements

The LACIE Field Measurements program was initiated in the Fall of 1974 to acquire remote sensing data sets complete with agronomic observations and meteorological data with which to investigate spectral-agronomic-meteorological interactions. The LARS field measurements activities during this quarter have included: project leadership and coordination, data acquisition, data processing and evaluation, data library management, and data analysis.

Project Leadership and Coordination. The implementation plan that describes our activities for the contract extension, June-November, was prepared and submitted to NASA/Johnson Space Center in June. The revised LACIE Field Measurements, 1976-77 project plan was completed and submitted to NASA this quarter.

On July 27-28, Dr. McEwen, Mr. Juday, and Mr. Griffiths met with LARS staff at Purdue to discuss the calibration of the field measurements data and to prepare an outline of a report describing the calibration. The purpose of the document is to describe to users of the data the calibration procedures used and the rationale behind the procedures. The report will also contain the tables used for calibration.

Data Acquisition. Prior to the first North Dakota mission, data were collected in Finney County, Kansas along with the JSC truck system (FSAS) for sensor comparison and correlation of the two systems. Unfortunately, the FSAS data were lost during the recording process, requiring the measurements to be repeated. Although the FSAS could have made the measurements at Garden City, the system was brought to Williston in July. Measurements made at Williston also included data collected by the helicopter (FSS) spectrometer system. The response of each instrument system were measured for six gray panels, including the old and new helicopter calibration panel, and a green panel.

Data were collected at the Williston, North Dakota Agriculture Experiment Station during five two-week missions between May 23 and August 10. Data were collected at the intensive test site, the agriculture experiment station and a modeling field. The missions covered the planting - pre emergence to mature-harvested stages of spring wheat and other small grain development.

Calibration data were collected at the intensive test site over canvas reflectance calibration panels using the Purdue/LARS Exotech 20C field system. These data will be used to calibrate the FSS and the airborne multispectral scanner data. The dates of data collection were: June 19, July 17, and August 4. Also on July 15 gray panel data were collected with the FSAS system at the intensive test site as discussed above.

At the agriculture experiment station, data were collected over 70 spring wheat and other small grain plots using the Exotech 20C field system and an Exotech 100 (Landsat band radiometer) field system. A new experimental design and layout of treatments was used this year which made collection of data more efficient and will improve the statistical soundness of the data (see Figure 2.1a-1). The key aspect is that, for example, if only a portion (16 or 32) plots can be measured in a day, they are a complete statistical unit, i.e. replicated treatments. Six sets of data were collected over the plots: May 31; June 18-19; June 28-July 1, 3,4; July 13-14; July 20,22; and August 5,8. The Exotech 20C field system collected high wavelength resolution data over as many plots as possible once during the day. The Exotech 100 field system collected low wavelength resolution data (four band radiometer) over all 70 plots several times during the day.

The Exotech 100 field system was built during early June. The system was designed to collect lower resolution data over all plots several times during the day to study diurnal reflectance changes. The system consists of a boom and platform mounted on the top of a van, the Exotech 100 instrument, a hard copy data logger, and two operators. One operator, on top of the van, levels the instrument and verifies the target location. The other operator records the data and drives the van. During operation the Exotech 100 radiometer is positioned eleven feet above the ground and ten feet away from the van. The system collected a set of data over all 70 plots in an hour. A set of data were repeated every 90

1977 Williston, North Dakota Agriculture Experiment Station

Remote Sensing Experiments

SPRING WHEAT EXPERIMENT

Plot width 3.5 m; plot length 15.3 m.

Plot No.	Rep	Nitrogen	Variety	Planting Date	1976
35	Winter Wheat				Fallow in 1976
34	Rep 2	N_2	V_1	D_2	Fallow in 1976
33	Rep 2	N_2	V_1	D_1	Fallow in 1976
32	Rep 2	N_1	V_2	D_2	Fallow in 1976
31	Rep 2	N_1	V_2	D_1	Fallow in 1976
30	Rep 2	N_1	V_1	D_1	Fallow in 1976
29	Rep 2	N_1	V_1	D_2	Fallow in 1976
28	Rep 2	N_2	V_2	D_1	Fallow in 1976
27	Rep 2	N_2	V_2	D_2	Fallow in 1976
26	Rep 1	N_2	V_1	D_2	Fallow in 1976
25	Rep 1	N_2	V_2	D_2	Fallow in 1976
24	Rep 1	N_1	V_2	D_1	Fallow in 1976
23	Rep 1	N_1	V_1	D_1	Fallow in 1976
22	Rep 1	N_2	V_1	D_1	Fallow in 1976
21	Rep 1	N_2	V_2	D_1	Fallow in 1976
20	Rep 1	N_1	V_1	D_2	Fallow in 1976
19	Rep 1	N_1	V_2	D_2	Fallow in 1976
	Border				
18	Rep 2	N_1	V_1	D_1	Wheat in 1976
17	Rep 2	N_1	V_2	D_2	Wheat in 1976
16	Rep 2	N_2	V_2	D_1	Wheat in 1976
15	Rep 2	N_2	V_1	D_2	Wheat in 1976
14	Rep 2	N_2	V_1	D_1	Wheat in 1976
13	Rep 2	N_2	V_2	D_2	Wheat in 1976
12	Rep 2	N_1	V_2	D_1	Wheat in 1976
11	Rep 2	N_1	V_1	D_2	Wheat in 1976
10	Rep 1	N_1	V_2	D_2	Wheat in 1976
9	Rep 1	N_1	V_1	D_2	Wheat in 1976
8	Rep 1	N_2	V_2	D_1	Wheat in 1976
7	Rep 1	N_2	V_1	D_1	Wheat in 1976
6	Rep 1	N_1	V_1	D_1	Wheat in 1976
5	Rep 1	N_1	V_2	D_1	Wheat in 1976
4	Rep 1	N_2	V_2	D_2	Wheat in 1976
3	Rep 1	N_2	V_1	D_2	Wheat in 1976
2	Bare Soil				Wheat in 1976
1	Winter Wheat				Wheat in 1976

Nitrogen

N_1 = 0 kg N/ha

N_2 = 44 kg N/ha

Variety

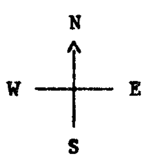
V_1 = Waldron (awnless)

V_2 = Olaf (awned)

Planting Date

D_1 = May 9, 1977

D_2 = May 23, 1977



SMALL GRAINS EXPERIMENT

Plot width 3.5 m; plot length 15.3 m.

Plot No.			
70		Winter Wheat	Fallow in 1976
69	Rep 2	Kando Durum Wheat	Fallow in 1976
68	Rep 2	Olaf Spring Wheat	Fallow in 1976
67	Rep 2	Waldron Spring Wheat	Fallow in 1976
66	Rep 2	Crosby Durum Wheat	Fallow in 1976
65	Rep 2	Beacon Barley	Fallow in 1976
64	Rep 2	Laing Oats	Fallow in 1976
63	Rep 2	Hector Barley	Fallow in 1976
62	Rep 2	Kelsey Oats	Fallow in 1976
61	Rep 1	Laing Oats	Fallow in 1976
60	Rep 1	Olaf Spring Wheat	Fallow in 1976
59	Rep 1	Hector Barley	Fallow in 1976
58	Rep 1	Kelsey Oats	Fallow in 1976
57	Rep 1	Kando Durum Wheat	Fallow in 1976
56	Rep 1	Crosby Durum Wheat	Fallow in 1976
55	Rep 1	Waldron Spring Wheat	Fallow in 1976
54	Rep 1	Beacon Barley	Fallow in 1976
		Border	
53	Rep 2	Crosby Durum Wheat	Wheat in 1976
52	Rep 2	Olaf Spring Wheat	Wheat in 1976
51	Rep 2	Waldron Spring Wheat	Wheat in 1976
50	Rep 2	Laing Oats	Wheat in 1976
49	Rep 2	Kelsey Oats	Wheat in 1976
48	Rep 2	Kando Durum Wheat	Wheat in 1976
47	Rep 2	Beacon Barley	Wheat in 1976
46	Rep 2	Hector Barley	Wheat in 1976
45	Rep 1	Kando Durum Wheat	Wheat in 1976
44	Rep 1	Beacon Barley	Wheat in 1976
43	Rep 1	Kelsey Oats	Wheat in 1976
42	Rep 1	Olaf Spring Wheat	Wheat in 1976
41	Rep 1	Crosby Durum Wheat	Wheat in 1976
40	Rep 1	Hector Barley	Wheat in 1976
39	Rep 1	Waldron Spring Wheat	Wheat in 1976
38	Rep 1	Laing Oats	Wheat in 1976
37		Bare Soil	Wheat in 1976
36		Winter Wheat	Wheat in 1976

Figure 2.1a-1. Spring wheat and small grains experiments at Williston Agriculture Experiment Station.

minutes.

During the July mission data were collected on the interception of solar power by wheat canopies and on the polarization characteristics of wheat in relation to heading.

Detailed agronomic data including leaf area index, fresh biomass, dry weights of leaves, stems, and heads, maturity stage, ground cover, height, soil moisture, and grain yields were obtained for all plots. Supporting meteorological measurements included: cloud cover and type, barometric pressure, total irradiance, wind speed and direction, air temperature and humidity.

At the modeling field, radiometric, photographic, and agronomic data were collected in support of the wheat canopy modeling studies. The modeling data collection activities differed from past years in that a fairly complete set of data were collected over four plots at the agriculture experiment station and only a partial set of data were collected over a large commercial field. Usually modeling data are collected only over a large commercial field, but the commercial fields of spring wheat in the area had been planted two to three weeks earlier than normal and were therefore past the tillering stage before our data collection began.

Following discussions with Mr. Malila of ERIM, it was decided that the first priority was to collect modeling data over four plots at the experiment station in order to obtain data for wheat threshold detection. Modeling data were collected in a commercial field when time and weather allowed.

Dates modeling data were collected are: Four plots - - June 1, 18, 19, 23; July 3, 4, 5, 7, 14, 20, 28; and August 8; Commercial field - - June 19, 22, 23, 25; and July 18.

Data Library. The 1976 Exotech 20C data were distributed to researchers at the Environmental Research Institute of Michigan and Texas A&M University. Also, other data, including photography, flight logs, field maps and calibration reports have been distributed. The Field Measurements Data Library Catalog was updated to reflect the current status of the data. The catalog will be printed at NASA/JSC. Relatively little 1977 data have been received from JSC which may delay processing and distribution of data.

Data Processing. Data processing tasks progressed well under the timetable guidelines that were set up in the first month of the contract. These tasks include: reprogramming the EXOTECH reformatting program, modifying and adding to the EXOSYS data analysis software, finishing the 1976 EXOTECH 20C data processing, rerunning the 1975 EXOTECH 20C data without offset correction, processing FSS data as it becomes available, and digitizing 1977 EXOTECH 20C data. See Table 2.1-1 for the status of LACIE field measurements data processing.

The EXOTECH reformatting program is progressing nicely, although it is a bit behind schedule. The projected completion date for a working program is August 30.

The EXOSYS revisions have to date, even though minor modifications, improved the speed of analysis. Additions to EXOSYS to plot data on the Varian printer/plotter will begin in the next quarter.

The 1976 EXOTECH 20C data have been completed and were sent to researchers at Texas A&M and ERIM. A report was written which summarizes the correction used during processing of the 1976 EXOTECH 20C data to remove the tape recorder wow present in the raw data. Analysis of the data indicates that the correction worked very well. Researchers should not be concerned about any tape recorder wow affects in the processed data. Work has begun on the task of rerunning the 1975 EXOTECH 20C data without offset adjustment.

The Fall 1976 FSS data have been completed with the exception of one date. These data are not ready to send out, however, because the FSAS data collected over the helicopter/FSS calibration panel in October 1976 are needed.

A quarter of the 1977 EXOTECH data have been digitized and are ready for processing upon completion of the reformatting program. The digitizing was halted for a couple weeks because the A/D system was out of commission.

Table 2.1-1. Data Processing/Reformatting Status as of August 10, 1977.

Instrument/Data Type	1974-75 Data	1975-76 Data			1976-77 Data		
	Completed & In Library	Completed & In Library	In Processing	At JSC	Completed & In Library	In Processing	At JSC
Landsat MSS							
Whole Frame CCT (Frames)	20	62	0	N.A.*	12	0	N.A.
Aircraft Scanner (Dates/Runs)	19/149	16/97	0	1	7/35	0	7/
Helicopter Mounted Field Spectrometer (Dates/Runs)							
Field Averages	19/2,343	27/2,193	0	0	0	8/	10/
Individual Scans	19/29,579	27/38,476	0	0	0	8/	10/
Truck Mounted Field Spectrometer (Dates/Runs)							
FSAS	6/65	3/6	0	20/316	0	1/2	10/
Exotech 20C	20/1,129	14/1,356	5/1,361	N.A.	0	17/826	N.A.
Exotech 20D	45/645	-	-	-	-	-	-

* Not Applicable

No 1977 Landsat data have been reformatted so far. The standing order with Goddard was not renewed for the 1977 data until July. We expect Landsat data to begin arriving during the next quarter.

During the next quarter, we are planning to put more effort into using the Graphics Compatibility System (GCS) routines that were obtained in early 1977 to increase the plotting capability in EXOSYS. In addition, some effort will be devoted to the use of the new EXOTECH programs to reformat the 1977 data.

Data Analysis

A. Agriculture Experiment Station Data

Analysis of the truck-mounted spectrometer data from the Garden City, Kansas and Williston, North Dakota Experiments Stations is well underway with data acquired in 1975 and has begun for the 1976 North Dakota data. Recalibration of the 1976 FSAS data from Kansas has delayed any analysis of that data. Analysis of variance and analysis of covariance are being used to investigate treatment differences, evaluate crop separability, and compare discriminability capabilities of the Landsat and proposed thematic mapper bands. Multiple regression, correlation, and plotting techniques are being used to describe the reflectance of the crop canopies.

An investigation to assess the diurnal reflectance changes in spring wheat at the Williston, North Dakota site has been completed. Sixteen plots consisting of two wheat varieties, two planting dates, two nitrogen rates, and two replications were measured at six different times on July 16, 1976. Time from solar noon (a stress effect) and time^2 (a sun effect) were considered as covariates. Data were adjusted for time of day only when statistically necessary for the particular data set and wavelength band. An analysis of variance showed significant (P = .25) interactions of the covariates and some treatment combinations which indicated that separate adjustments, particularly within replications and varieties, should be made. Since data from only one date were suitable for this analysis, caution should be exercised in extending these results to other locations and dates. Nevertheless, the results of this initial analysis clearly indicate that the time interval required to measure all plots of an experiment is an important source of variation and should be minimized. More extensive information will be available after the 1977 field measurements data are processed and analyzed. Sufficient information on covariance which would allow reasonable adjustments for time of day effects is not available for most of the 1975 and 1976 data. Analyses of variance on these data sets may be performed if one recognizes that the effects of time are confounded with the effects due to treatments and carefully interprets the results.

Significant differences appear to exist among crops and treatments on several dates but the discriminability of wheat and other small grains has proved to be limited due to the small data sets available for testing the algorithms.

The ability to accurately assess a crop's physiological condition and to predict crop yields by remote sensing techniques will depend on how well variation in key agronomic factors can be explained by the crop's reflectance. More than 80% of the variation in leaf area index (leaf area per unit ground area) is accounted for by reflectance in the chlorophyll absorption region (0.63 - 0.69 μm) and by reflectance in a near infrared region (0.76 - 0.90 μm). Estimates of leaf area index, plant height, percent ground cover, and growth stage generally can be improved by using a subset of the narrower bands of the proposed thematic mapper rather than the bands of Landsat. Reflectance of wheat throughout its growing season typically is curvilinear in nature with the minima (or maxima depending on wavelength region) occurring just prior to grain ripening when the wheat has maximum leaf area and greatest plant height. Correlations between many agronomic variables and reflectance can be enhanced by using data collected prior to grain ripening. Investigations are continuing to detect the initiation of grain ripening and crop senescence. Further analyses of the discriminability of the various small grains are also proceeding.

B. Intensive Test Site Data

The effects of spectral reflectance and maturity stage on the separability of wheat and other cover types using multitemporal data is being investigated. Specifically, detection of changes over time in reflectance of wheat as well as other cover types (e.g., pasture and fallow) is being studied to determine at what maturity stages successful identification and classification of wheat can be accomplished.

Subsequent analyses will be aimed at examination of the relationship of agronomic factors and spectral reflectance and recognition of wheat. Of particular interest would be such crop characteristics as leaf area index (LAI), plant height and biomass as well as such soil and management variables as amount of irrigation and fertilization.

Single scan Field Spectrometer System (FSS) data were available for 1975 and 1976 for the North Dakota and Kansas test sites and for South Dakota test site for 1976. Data analysis procedures were developed using the 1975 North Dakota data. Some drawbacks found while verifying the available data from this particular set included insufficient data for analysis of small grains other than wheat and poor data quality due to cloud cover on several missions. At each maturity stage two passes were available for most fields so that within field variability could be assessed.

Spectral separability for the 1975 North Dakota data was investigated using analysis of variance (ANOVA) and discriminant analysis techniques.

1. Separability of cover types using ANOVA

An ANOVA was performed on spectral reflectance for each Landsat and proposed thematic mapper bands for each of nine maturity stages. Cover type produced a significant effect overall for nearly all times and bands. This result indicated that the cover types of spring wheat, pasture, and fallow could be easily identified at particular growing stages.

Subsequent multicomparison analyses were carried out to determine which cover type was easily identified at particular maturity stages and wavelengths. Newman-Keuls range tests showed that during the early stages pasture differed significantly from wheat and fallow. The latter two tended to resemble bare soil and were not easily identifiable. During certain growing stages fallow was more easily identifiable but this was not a consistent trend. On only one date during the middle of the growing season were all three cover types distinguishable across all bands using this procedures.

2. Separability by maturity stage using discriminant analysis

Individual scans were categorized using percent reflectance as the dependent measure and category size proportional to established class sizes. The percentage of wheat scans correctly classified generally increased with maturity stage for both Landsat and thematic mapper bands and was optimal before harvest. On the average 90% of the wheat scans were correctly classified on each date.

Similar analyses will be carried out on the remaining intensive test sites with particular attention being given to the effect of maturity stage on reflectance. Specifically, the interaction of cover type over time will be examined for changes in reflectance between growing stages and separability of cover types across time periods. By using multitemporal data in one analysis for each band both the effect of maturity stage and separability of cover types and their interaction can be examined.

In addition, agronomic factors will be introduced into both prediction and inferential analyses. The separability of cover types on the basis of agronomic data and prediction of spectral reflectance will be studied to achieve a model for temporal-spectral characteristics of crops.

The use of basis functions as a means to reduce the dimensionality of the spectral reflectance data is also being examined and some preliminary results obtained.

Plans for Next Quarter. Primary activities during next quarter will be data processing and data analysis. Field data acquired in North Dakota will be prepared for processing. The data calibration report will be written. A presentation will be prepared and made to NASA Headquarters on results obtained and planned analyses of LACIE Field Measurements data. A catalog of spectra illustrating various crop and soil conditions will also be prepared.

2.1b Interpretation of Thermal Band Data

The radiance temperature of a wheat canopy measured from a remote overhead position is an integration of the soil temperature and the various temperatures within the wheat canopy. The goal of the thermal modeling task is to gain an understanding of the relationship between the temperatures within the canopy and the geometry of the canopy. To achieve this goal, the following working objectives were set:

1. To correlate canopy parameters including: radiance temperature measured from an overhead position, vertical temperature profile, soil temperature, and canopy geometric characterization.
2. To determine the quality of the laser technique in providing geometric characterization of the canopy.
3. To determine wind velocity effects on canopy temperatures.
4. To observe diurnal thermal phenomena.
5. To compare radiance temperature profiles with air temperature profiles.

Field Data Collection. Spectral-thermal measurements were made on June 28 and July 1 on different types of wheat canopies at the Larry O'Brian farm, adjacent to the University of North Dakota Agriculture Research Station at Williston, North Dakota. The wheat had the following agronomic description: hard red winter wheat, fully headed, approximately 80 cm in height, row spacing of 17-18 cm.

Figure 1 illustrates the procedure for the data acquisition and the location of the thermal scanner, thermistors, and blackbodies. The procedures used were improved versions of those used during missions of the previous two summers.

The Dynarad thermal scanner was used to determine the vertical temperature profile. The wheat canopy, planted in north-south rows, was observed from the east and west directions. The west canopy was shielded from the wind by a 2.4 meter high polyvinyl barrier to provide a virtually motionless canopy. The east canopy was not shielded from the wind and provided a canopy under prevailing conditions. The purpose of the two types of canopies (with and without wind velocity) was to determine the effect of wind velocity in a wheat canopy and to provide a motionless canopy for determining geometric characterization using the laser technique.

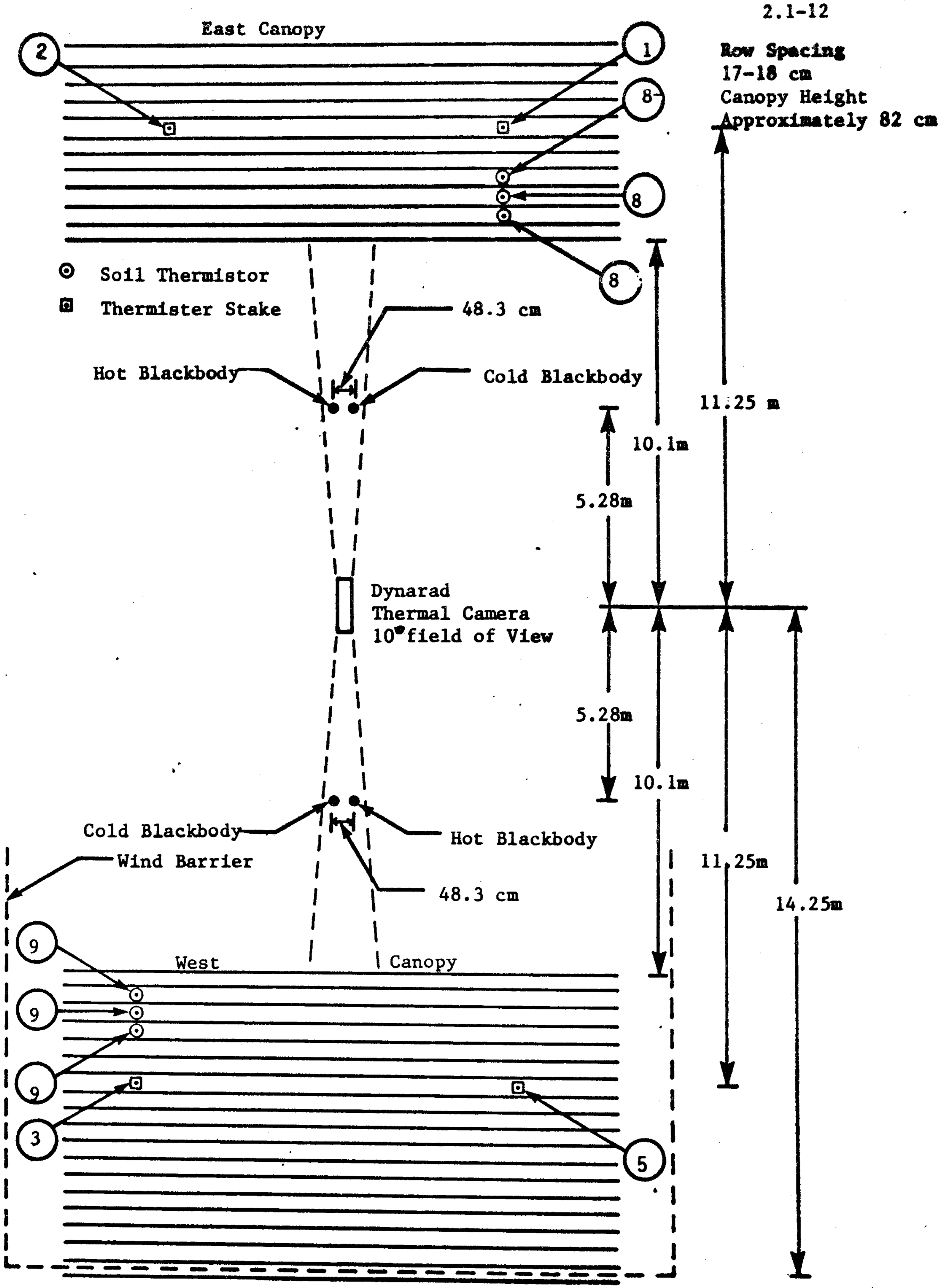


Figure 1: Equipment setup for thermal measurements taken on Larry O'Brian Farm adjacent to University of North Dakota Agriculture Research Farm in Williston, North Dakota.

The Barnes Precision Radiation Thermometer, Model PRT-5 was used to measure the radiance temperature from an overhead position at a zenith angle of 0°. The PRT-5 was mounted on a support which could be rotated 2.75 meters above the soil. An average overhead radiance temperature was obtained by taking measurements at six positions across the front of the canopy. At each position the PRT-5 was rotated at 30° increments in a semicircle; a total of 72 measurements were recorced for each set of measurements. This procedure provided an average of the soil and canopy temperatures.

The laser technique provided the necessary data to determine the geometric characterization of the wheat canopy. This technique consisted of pointing a laser at the canopy at a zenith angle of 0° and measuring the height of the intersection between the canopy (awn, head, leaf, or stem) and the laser beam. From this information it is then possible to determine the fraction that each horizontal layer contributes to the radiance leaving the canopy in the normal direction.

Thermistors were used to measure the soil temperature and the air temperature profile within the wheat canopy. See Figure 1 for thermistor probe placement.

A total of 24 sets of thermal data were collected: eight on 28 June and 16 on 1 July, 1977. Half of the data sets were collected on the east canopy and half on the west (motionless) canopy. The data sets were collected in pairs; east/west data sets were acquired within 10-15 minutes of each other. In addition to the thermal data, five sets of laser data were taken for a total of approximately 2,000 points.

Data Analysis. The geometric characterization of the wheat canopy is determined by the following method. The canopy is divided into 10 horizontal layers; one soil surface at 9-10cm layers. The fraction that each layer contributes to the total normal view is calculated by dividing the number of hits in each layer by the total number of hits in all of the layers. A hit is the intersection between the canopy and the laser beam.

$$X_i = \frac{H_i}{H}$$

where, X_i = fraction layer i contributes to total view, H_i = number of hits in layer i, and H = total number of hits in all layers. Figure 2 shows some typical results of the determination of vertical biomass distribution.

The proposed method for correlating the temperature profile and the overhead radiance temperature is:

1. To determine geometric characterization of the wheat canopy, using the laser technique.

2. To divide the canopy into 10 horizontal layers (same as laser technique) and determine the average temperature of each layer from the temperature profiles and soil thermistor probes.

3. To sum the product of the average temperature of each layer and the fraction that the layer contributes to the total scene. This temperature will be compared with the overhead radiance temperature measured with the PRT-5 observations.

$$T = \sum_{L=1}^{10} X_i T_i$$

where, X_i = fraction layer i contributes to total view, T_i = average temperature of layer i, and T = predicted overhead radiance temperature.

All of the data observations have been reduced except for the vertical temperature profiles. The present digitization method of the thermal scans has some deficiencies, therefore, radiance temperature profiles have not been obtained for most of the data sets. At the present time, a labor intensive method is being used to obtain temperature profiles for a few of the more interesting data sets. A new system, which provides direct digitization, should be available in two-three weeks and will significantly aid the analysis.

Next Quarter Activities. The work next quarter will include:

1. The completion of all data reduction and obtaining radiance temperature profiles for all data sets.

2. The correlation of the canopy parameters: radiance temperature measured from an overhead position, vertical temperature profile, soil temperature, and canopy geometry.

3. Preparation of final report describing procedures, data, and results.

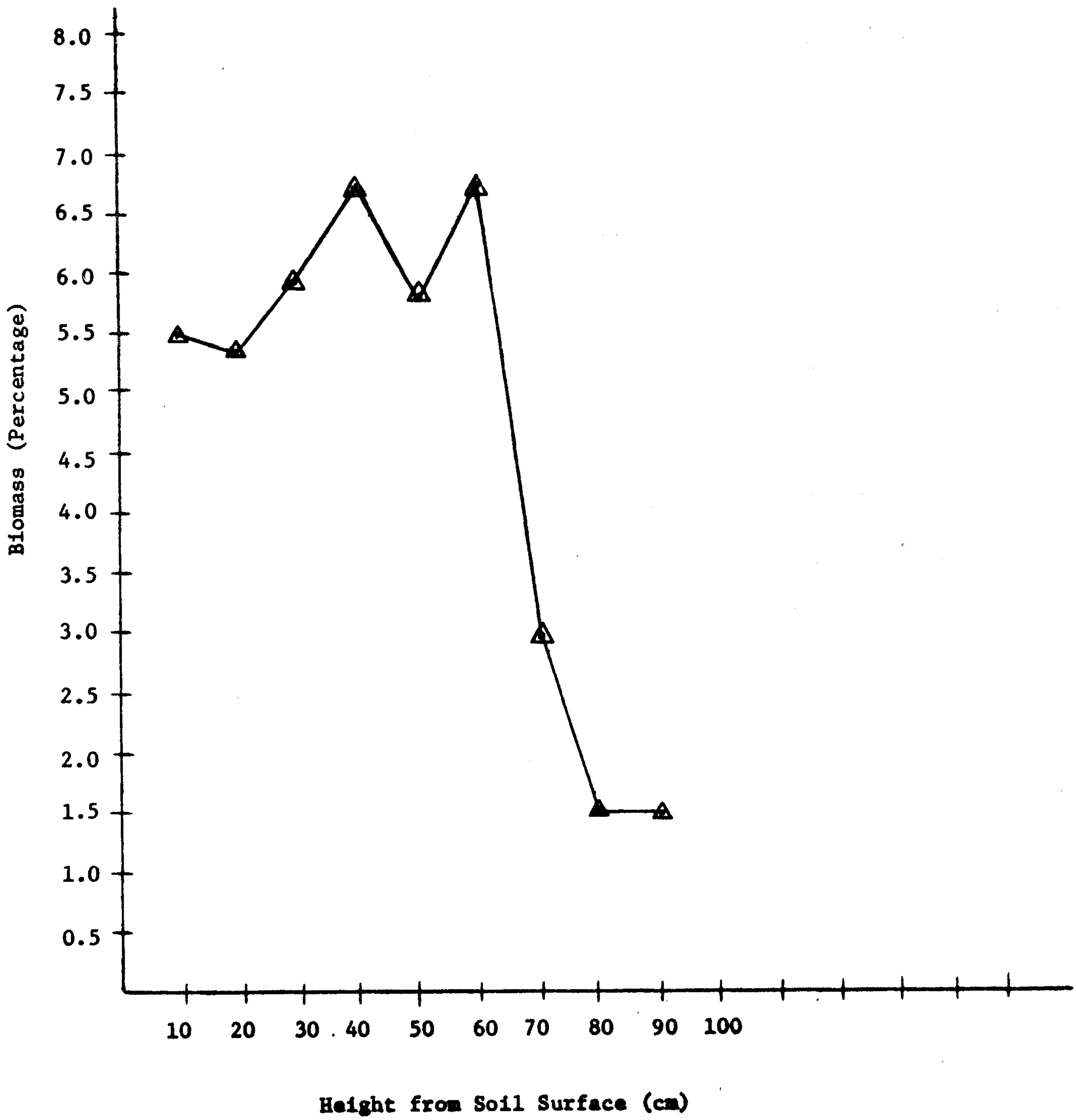


Figure 2: Biomass Vertical Distribution as Viewed from Normal Overhead Position (Laser Technique, 1 July 1977, 1650-1740 GMT) Soil Surface 38.2% of Normal View

2.1c Forestry Applications Project

Task I: Area Estimation

Data Compliation. This activity involves collecting statistical information to test the hypothesis that Landsat classification estimates of forest acreage are equal to Forestry Survey estimates of acreage.

To test the hypothesis, Level I classification results are being compared to Forest Survey Statistics for 156 counties in five states. The test data are from the following areas:

Forest Region	State	No. of Counties
North Central	Michigan	83
	Minnesota	4
	Missouri	17
	Wisconsin	31
North East	New York	21

Data will be compared on a county by county basis, as well as for counties within forest survey units. An analysis of variance test will be run to determine if analyst, training county, and gross forest coverage have any effect on the result. Landsat classification results for percent forest within counties are being complied from previous LARS projects. Forest Survey data is from published timber resource survey reports for the respective states.

Results from the statistical evaluation of this study are critical to the development of inventory procedures which will be recommended at the completion of this task.

Use of Permanent Plot Data. Forestry Survey permanent plot data has been acquired for a 140,000 acre test site in Southern Indiana. This data consists of one acre ground plots whose location is identified on 1:15840 aerial photos and 10-point plot cluster survey sheets.

Our initial impression is that the data in the format we have available is of little use in classifying a Landsat scene. The mass of field data is such that the analyst is hard pressed to correlate it with spectral data. Furthermore, an absolutely positive location of the one pixel that a ground plot represents is impossible in the Landsat scene.

However, we are aware that Forest Survey is modifying their point classification procedure from the aerial photos. This modification involves classifying the homogenous area around the ground point in addition to the point. Such a change would make identification of the point easier in the data because the area involved would be much larger thereby improving our chances in using this information in the classification. Unfortunately, we have none of the data from this new procedure available to test our assumptions.

Task II: Training Statistics Development

Task II involves defining and documenting an efficient and cost effective method for developing an optimal set of training statistics for forest cover mapping. All analysis on this task has been completed and the draft of the final report has been completed. However, due to the length of the report and the work schedules of some of the reviewers, the final review and modification have not been completed. It is anticipated that the review and modifications will be completed by Sept. 9, and that the final report (in the form of a LARS Information Note) will be published by Sept. 30th. After reviewing the results of this study, it is even more apparent that this work is particularly significant because of its thrust in defining an efficient method to develop training statistics, and because of the comparisons between the various approaches for developing training statistics.

Task III: Comparison of Classification Techniques

This task involves a comparison of different classification techniques in terms of cost, performance, and characteristics of the output products. Because some time was freed up due to the delays in Task II, work on Task III was begun ahead of schedule and is well underway. Two test site areas have been selected because of the detailed amount of reference data and the large amount of test sample data that already exists on these areas, which include the Platoro Test Site and the Southern San Juan Mountain Planning Unit area in southwestern Colorado. The Platoro Test Site is approximately 15,220 hectares (1 USGS 7½ min. quadrangle), whereas the Southern San Juan Mountain Planning Unit includes all or portions of 31 USGS 7 ½ minute quadrangles. Classifications have already been run on both test sites using the maximum liklihood per point classifier. In addition, the minimum distance per point classifier has been run on the Platoro Test Site Data. There is some question about the best procedure to follow for comparing the levels classifier results with the other classification algorithms because a different training procedure will be required for the levels classifier. The output products for the Southern San Juan Mountain Planning Unit will be restricted to tabular results for the most part, whereas the complete series of line printer outputs, color display outputs and Calcomp Plotter outputs will be developed for the Platoro quadrangle results.

Task IV: Forestry Research Program Definition

This task involves the definition of the objectives and scope of the forestry research thrust to be pursued by LARS within the FAP five year program. A meeting was held at NASA/JSC on June 28 between Dr. Phillip Weber (U.S. Forest Service), Mr. Rigdon Jooston (NASA), and Dr. Roger Hoffer (LARS/Purdue), to discuss the forestry research thrust to be pursued by LARS in the future. After some interesting technical discussions, Dr. Weber pointed out that there have been severe funding cuts in the Forestry Applications Program, and that because of this, there are no plans to involve LARS in future FAP research activities, at least for the upcoming fiscal year. Thus, it became clear that there is no need or potential for developing a proposal for FY 78 for submission with the major LARS SR&T proposal. In view of the apparent lack of interest by NASA/JSC in continuing a Forestry Applications research project as part of the LARS SR&T program, Task IV is considered to be finished with the submission of this quarterly report.

2.1d Soil Classification and Survey

Spectral Relationships - Outdoor Exotech Experiment. The Exotech Model 20-C spectroradiometer was used to measure the spectral reflectance from surface soils at the Purdue University Agronomy Farm during the week of May 11-12, 1977. An experiment was designed and laid out to measure the effects of organic surface residue (corn stover) and soil moisture content on the reflectance of two soils differing greatly in surface soil color, organic matter content, and natural drainage.

Surface soil samples of the upper one centimeter of soil collected at the time of the Exotech readings were analyzed for moisture content, organic matter content, and other physical/chemical properties. Table 2.1d-A lists the results for the averaged values from the twelve plots for each soil. Moisture levels were approximately equal for both soils in the wet and dry treatment combinations. Mechanical analysis for soil texture has not been performed yet due to a backlog at the Purdue Soil Characterization Laboratory.

Spectral data taken on May 12 appears to be of excellent quality; however, problems with the analog to digital tape conversion have prevented even a preliminary analysis of the reflectance data in this quarter. Emphasis will be placed on the early resolution of this problem in order to be able to extract the reflectance data using EXOSYS.

Table 2.1d-A. Summary results of surface soil analyses, averaged from twelve plots for each soil.

	Chalmers silty clay loam	Fincastle silt loam
Organic Matter Content	4.74%	1.39%
Moisture Content		
Dry treatment	3.05%	3.64%
Moist Treatment	24.57%	24.40%
Cation Exchange Capacity (CEC)	38.1 meg/100 g	14.6 meg/100 g
Base Saturation	68.7%	58.4%

Analysis of Landsat Data. Landsat multispectral scanner data for three dates (9 June 1973, 6 April 1975, 29 June 1976) are being used to delineate meaningful soil boundaries in Tippecanoe County, Indiana. Temporal overlay was achieved for the three dates with subsequent registration of the digital data to 1:24,000 scale USGS quadrangle map sheets. This permits the creation of computer-implemented spectral maps at a scale of 1:24,000. Preliminary results indicate that an excellent data set is available from this overlaid data.

A non-supervised approach was used to request 29 spectrally separable cluster classes from the entire county in intervals of every five lines and five columns. The 20 June 1976 data was used for this purpose because of the distinct definition of soil and green vegetation classes. The resulting 29 spectral classes are being analyzed along with ground information and photographic data for their positive identification. Magnitude and ratio information for these 29 classes from the three dates are also being used to explain their probable cover type class.

Results suggest that all three dates can be used to delineate soil boundaries, but that superior results in separation of soils were obtained with spectral data for 6 April 1975 and 9 June 1973. Spectral separations were obtained with 20 June 1976, but rather dense green vegetation in many fields made some soil delineations more difficult. Climatological data proved useful in the interpretation of differences in spectral reflectance from the same test areas on different dates. More than two centimeters of rainfall were recorded several hours prior to the Landsat pass on 6 April 1975. Dry weather conditions and unusually high temperatures prevailed for several days prior to the 9 June 1973 pass. Rainfall was recorded on each of the three days preceding the 20 June 1976 pass.

2.2 Processing Techniques Development

Task 2.2, Processing Techniques Development, contains two subtasks: 2.2a. Technology Evaluation and Development and 2.2b. Scanner System Parameter Selection.

2.2a Technology Evaluation and Development

This subtask consists of two parts: 2.2a1, Technology Development, which is concerned with the development of effective procedures for training the classifier and for accurately and reliably labeling pixels, objects, clusters, or fields; and 2.2a2, Technology Interchange System Development, which concerns continuing and upgrading the support of the remote terminal at JSC and increasing technique interchange between NASA/JSC and Purdue/LARS.

2.2a1 Technology Development

Introduction. The specific near term goal of this research is to develop effective procedures making it possible, for a given geographic region and remote sensing data analysis objective, to specify the optimal allocation and selection of training areas; and to accurately and reliably label pixels, objects, or clusters so as to derive statistics for classifying the region to satisfy the requirements of the given analysis objective. Under the current contract extension, the objectives are:

1. To acquire information about recent developments in the LACIE procedures and assess their implications relative to the general problem.
2. To formulate in detail (taking account of the LACIE developments) constructive alternative approaches to the long term problem.
3. To determine the technical and resource requirements needed to evaluate the alternative approaches; and to set priorities for their evaluation.
4. To complete the ECHO classifier work begun in FY77 so that it will be available at JSC and for the purposes of this task.

Major Activities. The contract monitor had indicated a strong interest in negotiating the details of this subtask. At the end of

June 1977, discussions were held with JSC personnel (Heydorn, Trichel) focusing on a straw-man implementation plan for the subtask as formulated by LARS. The outcome of these discussions was that:

1. It was concluded that the technological needs for research and development as seen by the representatives of the contract monitor and LARS personnel were not incompatible but that additional effort would be required to develop an appropriate implementation plan for the subtask. The end of the first three months of the contract extension period was set as a goal for completing related negotiations.
2. It was agreed to pursue the ECHO test and documentation effort to completion, estimated to require approximately three months (a detailed estimate of the resources required had been submitted by LARS).

A revised implementation plan was completed by LARS on August 2, 1977, and transmitted to NASA/JSC on August 3, 1977. We anticipate that further discussion of this work will commence well before the end of August. Resources which have been heavily concentrated on completing the ECHO test and documentation will soon be available for focusing on the training area selection/pixel labeling aspects of this task.

Progress in the ECHO completion task included completion of the programming for the nonsupervised ECHO processor, generation of program documentation and an ECHO User's Guide, statistical analysis of the experimental results for the nonsupervised processor, and drafting of the final report for the ECHO project.

Clean-up and debugging of the nonsupervised ECHO software were completed during the first week of July, one week later than had been projected. This slip in the schedule delayed by a week the completion of the program abstracts and ECHO User's Guide. Also, an error discovered in the field extraction programming made it necessary to regenerate the intermediate results ("object maps") produced during May and June 1977.

The ECHO User's Guide will be printed near the end of August and will be delivered to NASA/JSC under separate cover. The contents of the User's Guide are as follows:

I. Synopsis of the ECHO Approach to Classification

II. Supervised ECHO

   A. Input and Output

   B. Extraction and Classification Algorithm

   C. Usage Considerations

III. Nonsupervised ECHO

   A. Input and Output

   B. Extraction and Classification Algorithm

   C. Usage Considerations

Completion of the Usage Considerations section of the nonsupervised ECHO description depends on the completion of the statistical analysis of the test results, which depended in turn on completion of the programming for the nonsupervised processor. Unfortunately, both of the latter tasks have required more time than expected.

Due to the time required to regenerate all previously produced intermediate results (after the programming error was discovered), not all of the data sets listed in the ECHO experimental plan have been classified. Six simulated Thematic Mapper data sets (2 sites, 3 resolutions), nine Landsat and one aircraft data sets have been processed using a range of parameter settings. Although the statistical analysis of these results is not complete at this writing, we expect to have concluded this work by the end of August.

The final report for the ECHO project will include the statistical analysis results for both the supervised ECHO and nonsupervised ECHO tests. Also included will be an evaluation of the object maps produced by the nonsupervised field extraction algorithm and a comparison of the results obtained using the nonsupervised and supervised ECHO algorithms. The complete FORTRAN program listings and abstracts will appear as an appendix to the ECHO final report. The results of the parameter selection studies will be incorporated in the Usage Considerations sections of the ECHO User's Guide.

<u>Status and Recommendations</u>. During the quarter, attention has

focused on reformulation of the task implementation plan and completion of the ECHO project begun during the previous contract year. Pursuit of research related to classifier training and pixel labeling awaits agreement on the implementation plan and conclusion of the ECHO effort.

The ECHO project will in all likelihood have been completed by the end of the quarter. It has been demonstrated that the supervised ECHO algorithms provide a statistically significant improvement in accuracy over the conventional pointwise classifier. The nonsupervised algorithm shows promise of improved classification accuracy. The nonsupervised field extraction phase is useful as a spectral/spatial clustering algorithm.

All of the ECHO processors are available to NASA (including, of course, JSC) via the LARS remote terminal. Relative to ECHO, it is recommended that:

1. Upon delivery to JSC of the ECHO User's Guide, JSC personnel should be encouraged (or better, assigned) to use the ECHO algorithms via the remote terminal. Only through this type of experience will NASA personnel develop experience and confidence in using this approach to classification and sufficient insight to appreciate the potential impact of this approach in the context of large area surveys.
2. In order to further evaluate the utility of the nonsupervised field extraction algorithm as a method for spectral/spatial clustering, tests should be initiated involving it and ERIM's "Glob and Blob" algorithm. These tests could be carried out either by LARS or by personnel at JSC via the LARS terminal.
3. The general utility of the ECHO processors in training procedures and classification analysis should be pursued. For example, the singular cell map produced by the supervised ECHO processor provides an indicator of the adequacy of training statistics for a given area; groups of contiguous singular cells where fields or other objects are

known to exist indicates the omission of one or more spectral classes from the statistics. We propose to include investigations of this nature in the training area selection/pixel labeling subtask. Also needed are training procedures geared specifically for training sample classifiers. Although these have been evolving gradually, present methods are still most appropriate for training pointwise classifiers.

2.2a2 Technology Interchange System Development

Work Accomplished. During this past quarter an implementation plan has been written and approved for this subtask, software conversion support has been provided to JSC, the ECHO case study has been completed, progress has been made on the technique interchange plan, LARS has provided support of the 2780 to JSC, and this document will complete the task entitled "Quarterly Report".

A draft narrative of the technique interchange plan exists. It includes the series of figures and narrative explaining the concept. In support of this plan, a Data-100 "Hands-On" instructional package is in the draft stage. Also a short course describing how to use the extended user facilities on the LARS system is being outlined.

Support of the JSC 2780 terminal continues. The rate of use of this terminal has been greater than planned. $10,000.00 were spent for services during June and July out of $24,000.00 available for June through November.

Problems Encountered. Purdue has not been informed of the Data-100 installation decision expected August 1. Our understanding is that an affirmative decision is in process. This has affected our tape copy software plan. This plan will be delayed until further instructions are received from JSC.

The increased usage of the remote terminal could be a problem if action is not taken to support services greater than those budgeted. It is assumed that a separate activity providing for an implementation of JSC software on the LARS computer will solve this problem.

Plans for the Next Reporting Period. During the next reporting period the technique interchange plan and a final report is expected to be delivered. Purdue stands ready to provide additional software conversion support and/or to support the installation of a Data-100 as described in the detailed implementation schedule.

2.2b Scanner System Parameter Selection

The scanner parameter study pursued two problem areas during the quarter; 1.) Identification of the classification error prediction algorithm, 2.) Spectral sampling function modeling. Several comparison tests were run on the classification error predictor to provide further evidence on its performance. Work continued on the Karhumen-Loeve and information theory approaches to design of optimum spectral sampling functions. This work is described in the following sections.

Task 2 Test and Evaluate Classification Error Prediction Algorithm. In the previous reports, the error estimating algorithm was applied to the high resolution data, specifically those used in thematic mapper simulation study. Appropriate comparisons were reported with favorable results. In this quarter, to obtain a more complete and convincing evaluation of the error estimating algorithm, multispectral Landsat data was classified and the resulting classification accuracy was compared with the output of the error predictor. A further test was conducted on the following basis: Normality of the statistics of the multispectral data is a generally accepted feature. Whenever a new method is developed, however, the performance of it cannot be evaluated satisfactorily because any deviations from the desired results can be attributed to the nonnormality of the particular data set. It would be significant if this element of uncertainty could be eliminated from the analysis, then any inadequacies can be traced back to the algorithm or the data.

This goal is achieved by generating synthetic normal data which has the same statistics as the multispectral data but is statistically Gaussian. This simulated data is again classified by LARS point classifier and its classification accuracy compared with the error predictor algorithm output.

Results. Three test areas were selected; 1. Ogle County, Illinois, 2. Graham County, Kansas, and 3. Grant County, Kansas.

Ogle County, Illinois region. This data has a LARS runtable entry of 72032806. There are 3 training classes and classification is performed using four spectral bands, i.e. channels 1 thru 4. Table 2.2b1 shows the classification accuracies obtained using both the LARS point classifier and space partitioning error estimates.

Table 2.2b1 Classification Performance Comparison for Ogle County, Illinois data, August 9, 1972.

Class	No. Points	Pt. Clsf.	Sp. Part.
Corn	411	87.3	91.7
Soybean	224	90.6	91.3
Other	217	94.0	90.6
Overall	852	90.7	91.2

Graham County, Kansas. This area has a runtable entry of 74028500. There are 4 training classes and 229 training fields. Channels 9 thru 12 were used, i.e. third time of multitemporal data set. Results are tabulated in Table 2.2b2.

Table 2.2b2 Classification Comparison for Graham County, Kansas data, May 26, 1974.

Class	No. Points	Pt. Clsf.	Sp. Part.
Baresoil	443	65.9	78.3
Corn	99	89.9	91.0
Pasture	1376	98.4	95.1
Wheat	459	94.8	93.9
Overall	2377	87.2	89.6

Grant County, Kansas. This area has a runtable entry of 74027600. There are 5 training classes and 388 training fields. Channels 5 thru 8 are used in the classification study, i.e. second time of a multitemporal data set. Results are tabulated in Table 2.2b3.

Table 2.2b3 Classification Comparison for Grant County, Kansas data, May 9, 1974.

Class	No. Points	Pt. Clsf.	Sp. Part.
AG 1	793	52.3	59.3
AG 2	446	75.8	73.3
AG 3	134	90.3	88.8
Nonfarm	762	94.9	90.5
Wheat	930	82.7	79.7
Overall	3065	79.2	78.3

Simulation of Graham County Statistics. As explained in the above, the aim here is to generate data with normal statistics. The algorithm that accomplishes this task uses the statistics of an already classified area and generates random numbers having the appropriate class statistics. In the final output, there will be a one to one correspondence between the field coordinates in the simulated data and original data. Results are shown in Table 2.2b4.

Table 2.2b4 Comparison of Classification Performance Using Simulated Data.

CLASSES	Pt. Clsf.	Sp. Part.
CLASS 1	50.1	69.0
CLASS 2	86.9	86.0
CLASS 3	92.9	90.6
CLASS 4	89.1	84.9
OVERALL	79.7	82.6

Comments on the Results. Throughout the three test cases reported above, a generally good agreement exists between the classification accuracies obtained using LARS point classifier and the space quantization method. The difference between the two overall correct classification rates range from 2.4% for the Graham County, Kansas, down to 0.5% for the Ogle County, Illinois region. The difference is greater for the individual class conditional probability of correct classification.

One remark is in order regarding the classification of the simulated data. Although the random numbers generated do have statistics very close to the actual data statistic, a subset of those random numbers is used to generate simulated data. To classify this simulated data, statistics need to be recomputed and will not be necessarily the same as the original data, therefore, resulting in different classification accuracies.

Conclusion. It was intended through these test runs to further validate the space partitioning method for obtaining correct classification accuracies. Regions were selected to provide error rates of different magnitudes. In the previous reports, correct classification accuracies were in the high 90% range and comparable results were obtained for both methods. The regions analyzed in this report, exhibit classification accuracies in the high 70, 80 and low 90% range. In all of the test runs, overall classification accuracies obtained through the space partitioning method compared to the LARS point classifier was well within the analyst's tolerance, therefore, making this method a viable alternative to the present classification scheme and a necessary tool in theoretical analysis of a multispectral scanner system.

Task 4 K-L and I-T Scanner Model Development. K-L Approach: The objective of this task is to develop an analytical procedure, applicable to any well defined remote sensing problem which will establish a theoretically optimal classifier against which the performance of candidate practical systems can be compared. The data that will be used in this procedure consists of sampled waveforms from the ensemble of random functions of wavelength which may be present at the input to a multispectral scanner. Some of the problems encountered in developing this procedure are the evaluation of the information content of the waveforms with regard to discrimination between spectral classes, determination of the intrinsic dimensionality of the ensemble, estimation of the parameters of the density functions, and estimation of the probability of correct classification.

To date, data sets, which will be used to develop and test the procedure, have been assembled using artifically generated data, aircraft scanner data, and field spectrometer measurements. A method of reducing the dimensionality of the data set using the Karhunen-Loeve expansion with the covariance matrix of the mixture density as the kernel in the integral equation has been implemented; however, it has not been thoroughly tested. As a step toward estimating the probability of correct classification distance measures such as the Bhattacharyya distance have been investigated. In particular, a method of using a whitening transformation has been shown to make computation of this distance quite simple.

Present work is being directed toward the study of the mapping from the continuous waveforms in the ensemble to the finite dimensional vectors which are used to represent the waveforms. In conventional scanners the elements of these vectors correspond to the spectral bands. The question that arises is, 'Does the vector representation contain all of the information that is necessary to classify the objects in the scene?' One approach, which is being used, is to generate random waveforms using the computer and sample them using different waveband sets. Estimates of the classification performance can then be made using the generated waveforms.

In the next quarter, it is planned to implement a classification performance estimation technique using simulation methods to test performance for different waveband sets. Also, work will continue on the dimensionality problem with testing of the K-L expansion method as well as the investigation of some different approaches. The goal for the next quarter is to be able to estimate the performance for a given data set and be able to say something about the intrinsic dimensionality of the data set.

Information Theory Approach. The analytical technique employed here to study the parameters of multispectral scanners is to model the spectral response as a portion of a realization of a stochastic process in wavelength. The particular approaches to various aspects of the problem have been outlined in previous quarterly reports.

First consider the problem of fitting adequate models to the spectral response data. To facilitate the study, the spectral response data was arbitrarily divided into ten spectral bands. The spectral bands were initially defined so that all bands were of equal spectral bandwidth. The ten initial spectral bands are:

Band 1	.4528 - .5380 μm
Band 2	.5380 - .6239 μm
Band 3	.6239 - .7097 μm
Band 4	.7097 - .8517 μm
Band 5	.8517 - .9910 μm
Band 6	.9910 - 1.130 μm
Band 7	1.130 - 1.270 μm
Band 8	1.270 - 1.344 & 1.446 - 1.643 μm
Band 9	1.643 - 1.821 & 1.957 - 2.083 μm
Band 10	2.083 - 2.384 μm

The gaps in bands 8 and 9 are due to water absorbtion bands in the measurement spectrum. It was thought that these gaps would result in models that were inaccurate and inadequate for representing the spectral process. Hence bands 7 through 10 were consolidated and redefined as follows:

Band 7A	1.130 - 1.344 μm

Band 8A 1.446 - 1.821 μm

Band 9A 1.959 - 2.386 μm

For each band, three different types of models of several different orders were hypothesized. The first model type is the autoregressive model of order n defined by:

$$y(k) = a_1 y(k-1) + a_2 y(k-2) + \ldots + a_n y(k-n) + w(k) \qquad (1)$$

where: k is a discrete wavelength

a_j, j = 1, ..., n are coefficients to be identified.

w(k) are independent, identically distributed samples of a Guassian random process.

The second type of model is the autoregressive plus constant model of order n defined by:

$$y(k) = c + a_1 y(k-1) + \ldots + a_n y(k-n) + w(k) \qquad (2)$$

where: c is a constant to be identified.

Other parameters are the same as in the first model type.

The third model type is the integrated autoregressive model of order n. This model may be written as:

$$\nabla y(k) = a_1 \nabla y(k-1) + \ldots + a_n \nabla y(k-n) + w(k) \qquad (3)$$

where: $\nabla y(k) = y(k) - y(k-1)$.

Other parameters are as previously defined. An excellent discussion of these models is given by Kashyap and Rao [1].

The identification procedure for these models consists of estimating the coefficients a_j, j = 1, . . . , n such that the model gives the best fit to the actual measurement data according to some optimization criterion. In this particular study, maximum likelihood identification techniques are used. Reference [1] gives details.

Each of the three types of models were identified for orders n = 1, . . . , 10 for each of the defined spectral bands. Thus more than 330 models were identified. Of these models, one was selected to represent each band. Selection of a model for a particular band was based on a criterion that included goodness of fit and reflected the principle of parsimony. Simply stated, the principle of parsimony means that one should use the smallest possible number of parameters to adequately represent the spectral process. The idea of parsimony is amplified in references [1] and [2]. Each selected model was then subjected to various validation tests that tested assumptions about the model and the similarity of statistical characteristics of the actual measurement data and simulated data generated from the model. These tests are discussed by Kashyap and Rao [1]. Only after successfully completing these validation tests was a model accepted as representative of the spectral response process of a particular spectral band.

Based on the above ideas, the following models were identified as representing the spectral response process of the respective spectral bands:

Band 1	AR(6)
Band 2	AR(2)
Band 3	IAR(10)
Band 4	AR(1) + C
Band 5	AR(1)
Band 6	AR(2) + C
Band 7A	IAR(9)
Band 8A	IAR(9)
Band 9A	IAR(6)

where:

AR(n) = autoregressive model of order n

AR(n) + C = autoregressive + constant model of order n

IAR(n) = integrated autoregressive model of order n.

As mentioned in previous quarterly reports, one reason for formulating these models was to study the informational characteristics of the spectral bands. These models are amenable to Kalman filtering techniques for calculating mutual information in a received spectral response z(k) about a spectral response y(k). The equation relating z(k) and y(k) is:

$$z(k) = y(k) + v(k) \tag{4}$$

where: v(k) is Gaussian observation noise and $k \in [\lambda_1, \lambda_2]$ is the spectral band of interest. An exposition on the relationship of Kalman filtering and mutual information is given by Tomita, Omatu, and Soeda [3].

The general Kalman filter expressions were implemented for this informational study. From this filter formulation, mutual information for each of the different spectral bands was computed. For computational purposes it was assumed that the variance of v(k) and w(k) were identical. Although different variances produce different amounts of mutual information, the change is not severe. However, the fact that there is a change is an advantage of this method of computation since the effects of different amounts of noise can readily be studied. Some (very) preliminary results for the computation of mutual information are given below.

Band	Mutual Information
1	30.6 bits
2	33.1 bits
3	36.8 bits
4	36.3 bits
5	35.5 bits
6	33.5 bits
7A	49.7 bits
8A	46.0 bits
9A	51.9 bits

It should be noted that bands 7A, 8A, and 9A are wider than the other spectral bands. Hence it is reasonable that there would be more mutual information in the received process about the spectral process in these bands than the other bands. The effects of different types of noise in different bands has not been considered yet.

Further Investigation. These information theoretic ideas will be pursued further in the next quarter. It is noted that mutual information seems to be related to model type. This aspect remains to be pursued. Eventually these studies should lead to a better understanding of the parameters of multispectral scanners. Relation of the information content to classification problems remains to be pursued in depth.

References

[1] R.L. Kashyap and A.R. Rao, Dynamic Stochastic Models from Empirical Data, Academic Press, 1976.

[2] G.E.P. Box and G.M. Jenkins, Time Series Analysis, Holden-Day, 1970.

[3] Y. Tomita, S. Omatu, and T. Soeda, "On Application of the Information Theory to Filtering Problems", Information Sciences, 11, p. 13-27, 1976.

2.3 Large Area Agricultural Inventory Design

The objectives of this project are to develop a conceptual framework, to identify the users and to define the desired information output of a global information system designed to improve the management, production and distribution of food and fiber. To undertake this objective a broad involvement of specialists representing many different disciplines in the agricultural sciences was sought from the Agricultural Experiment Station at Purdue University.

Organization. Four faculty members of the Purdue School of Agriculture were selected to provide the major expertise in this study. It is their primary responsibility to give continuity and direction to the project. They are working together closely as an interdisciplinary team to accomplish the objectives and to review, coordinate, and integrate contributions to the study by other participants. This group, known as the Implementation Committee, consists of: M. F. Baumgardner, Agronomist, Project Manager; M. E. Bauer, Agronomist and Specialist in Crop Inventory; M. A. Martin, Agricultural Economist and Specialist in Food and Agricultural Policy; and R. M. Peart, Agricultural Engineer and Specialist in Energy Systems.

Approximately 20 other Purdue faculty members with interest in the study and significant expertise in areas related to global food and fiber have been identified to serve on an Advisory Committee. They are asked at appropriate times to contribute individually or as a group to provide ideas and written subject matter and to critique materials prepared by the Implementation Committee.

Appropriate representatives of agricultural industry, international development organizations, the agricultural producer community, and the broad scientific community will be invited to participate in the conceptualization process, the description of decision-making in agricultural production, the identification of information needs, and the description of potential users of a global information system for agriculture.

Specific consultants outside the current Purdue University faculty, because of their unique qualifications, are asked to contribute to this study when their expertise seems appropriate. Consultants with expertise in agricultural policy, administration of agricultural development programs, and rangeland ecology have been identified and invited to participate in this study.

Consideration is being given to three different time frames in the design of a global information system. These periods include:

1. Five year plan (1978-1983)
2. September - November 1977
3. December 1977 - November 1978 (FY78)

It is necessary to look at the long range goals and implications in order to provide the basis and guidelines for short range objectives and research. Therefore, broad attention is being given to the desired milestones or achievements to be attained by 1983. Although there are many unknowns in looking that far into the future of a rapidly developing information technology, desired goals to be met by 1983 can provide some rather important guidelines for planning for immediate research and development activity.

The present contract under which this activity is being done will terminate on 30 November 1977. Therefore, the greatest amount of attention is being given to an important component of a global information system, a component which has been narrowed sufficiently so that a significant contribution can be made in the immediate future. It has been decided that major attention will be given to the design of an information system for corn with emphasis on the kinds of decisions which are made by those information users involved in the production of corn. This includes the farmer producer, agricultural industry, agricultural development agencies, international development and funding agencies, government agencies and others. An important concern is that information in the corn production equation not be limited to physical parameters. Although the meaning of the relationships between physical, biological, social, political, economic, and cultural parameters are not well understood, it is important that those participating in this study be aware that such relationships do occur and are important.

As the study team has delved more deeply into the problems of describing important decisions which are made in corn production, it has become apparent that this is no easy and simple task. The team of interdisciplinary specialists is continuing in its study of defining the important decisions, identifying the important decision makers in corn production, describing how decisions are made and the kinds of information that are used in the making of decisions.

Calendar of specific activities.

Date	Activity
20 August to 15 September 1977	Preparation of study papers on: a) Global information system for corn production b) Five year plan for research and development of a global information system for food and fiber.
22-23 September 1977	"Think tank" session to review and critique study documents on global information system for corn production and five year plan for research and development of a global information system.
25 September to 20 October 1977	Preparation of background document on global information system for corn production.
2-3 November 1977	Workshop involving representatives from agricultural industry, agricultural producers, international development agencies, government agencies, and Purdue University. To be considered and critiqued: Background paper on global information system for corn production and a preliminary five-year plan for a program for research and development on a global information system for food and fiber.
5-30 November 1977	Preparation and submission of report on global information system for corn production.

Conclusion. Although funding at the level proposed in the Implementation Plan for Task 2.3 has been significantly less than that requested, support has been sufficient to make a significant start in this study. The direction seems to be quite clear now, and a plan of action has been developed commensurate with the long range objectives to design a global information system and to describe the information requirements of such a system.

The budget for this task was funded for the months of June and July only. It has been possible to stretch out these funds to some extent, however they will be all expended by mid September and further work will not be possible without additional funding.

Technical Reports Issued
During June-August 1977
Funded by Contract NAS 9-14970
and Its Predecessor's

022575 ERTS Multispectral Image Transformations for Geological Lineament Enhancement by P. E. Anuta and B. Mobasseri.

The enhancement and detection of linear features in LANDSAT imagery is of interest in geological mapping. This report describes tests of gradient and laplacian transforms for lineament enhancement. A test site in central Nevada is evaluated using continuous and thresholded gradient and laplacian enhancement.

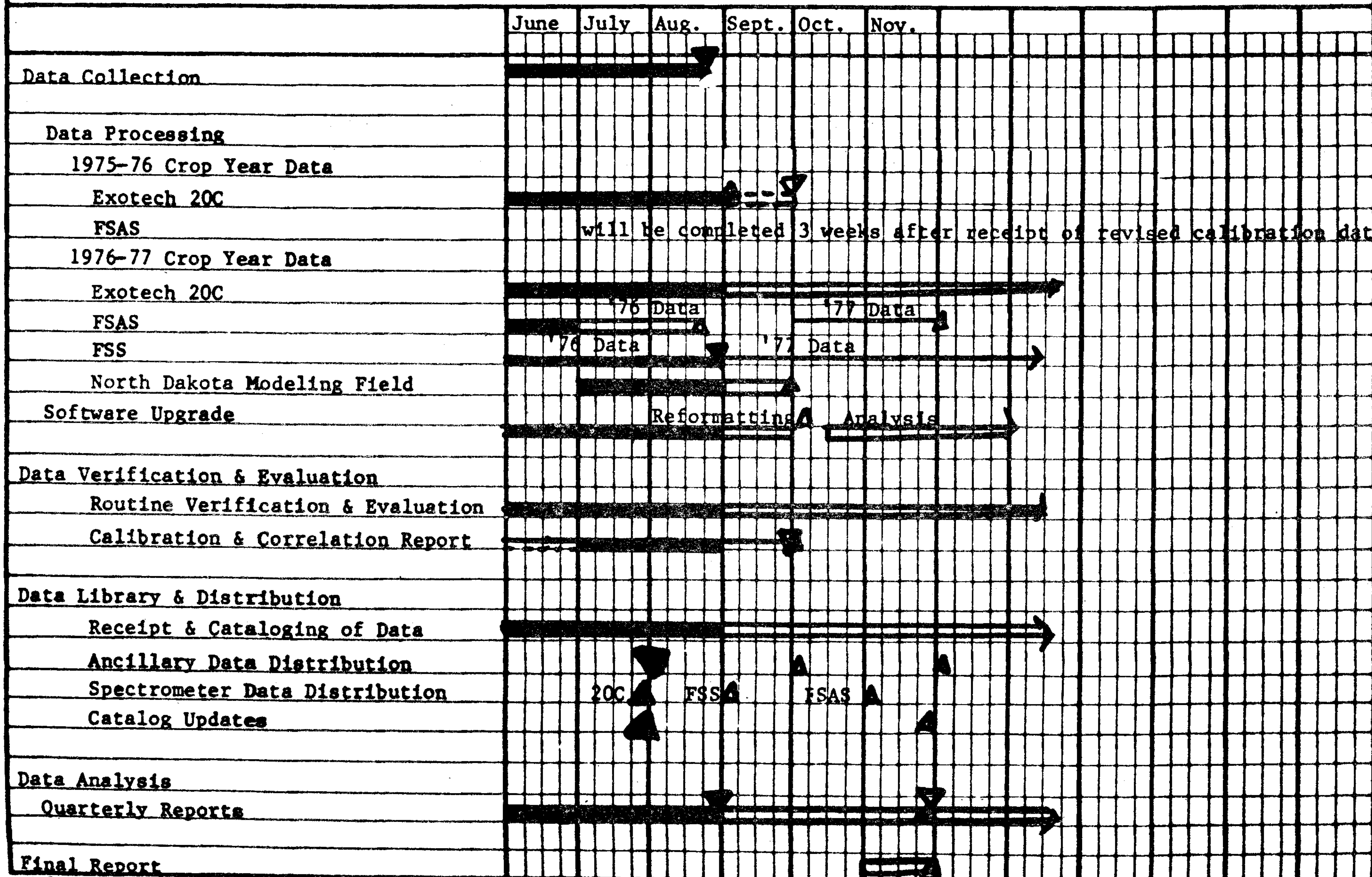
062277 Evaluation of Change Detection Techniques for Monitoring Coastal Zone Environments by R. A. Weismiller, S. J. Kristof, D. K. Scholz, P. E. Anuta, and S. M. Momin.

Development of satisfactory techniques for detecting change in coastal zone environments is required before operational monitoring procedures can be established. In an effort to meet this need a study was directed toward developing and evaluating different types of change detection techniques, based upon computer-aided analysis of LANDSAT multispectral scanner (MSS) data, to monitor these environments.

072277 The Decision Tree Classifier: Design and Potential by P. H. Swain and H. Hauska.

This paper presents the basic concepts of a multistage classification strategy called the decision tree classifier. Two methods for designing decision trees are discussed and experimental results are reported. The relative advantages and disadvantages of each design method are considered. A spectrum of typical applications in remote sensing is noted.

2.1-A LACIE Field Measurements Implementation Schedule



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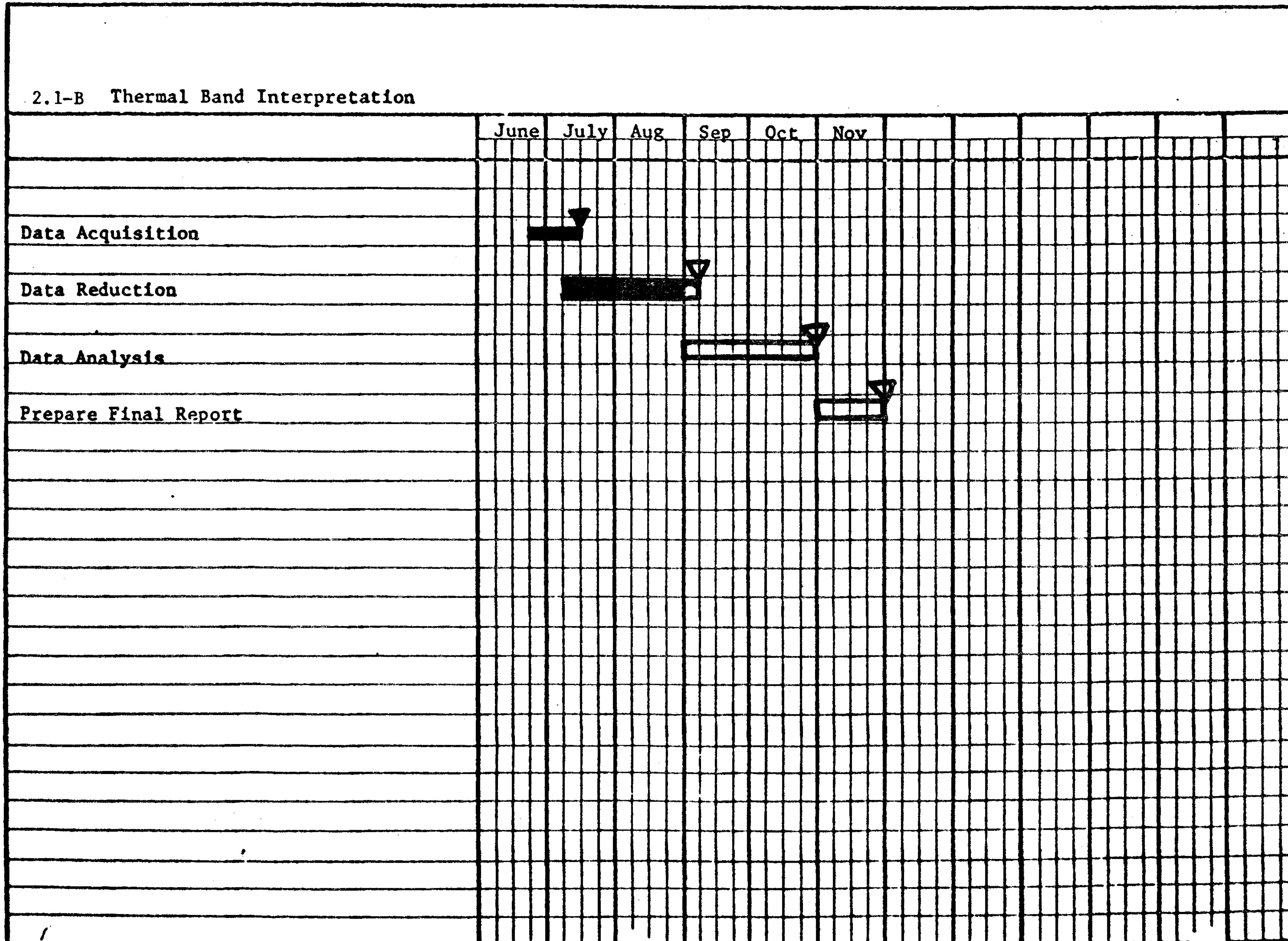
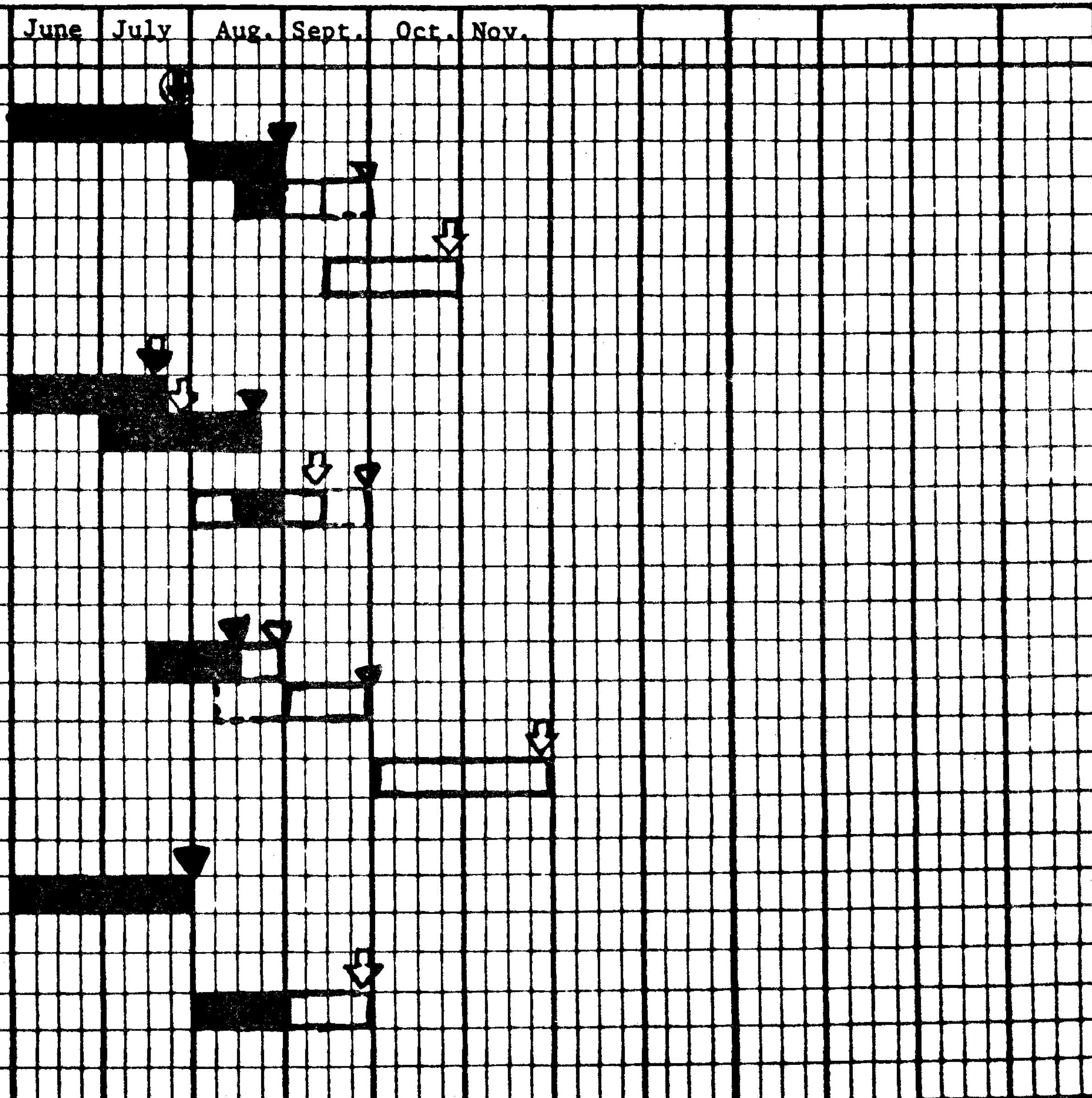

2.1-B Thermal Band Interpretation
June
July
Aug
Sep
Oct
Nov
Data Acquisition
Data Reduction
Data Analysis
Prepare Final Report

2.1-C Forestry Applications Project Implementation Schedule



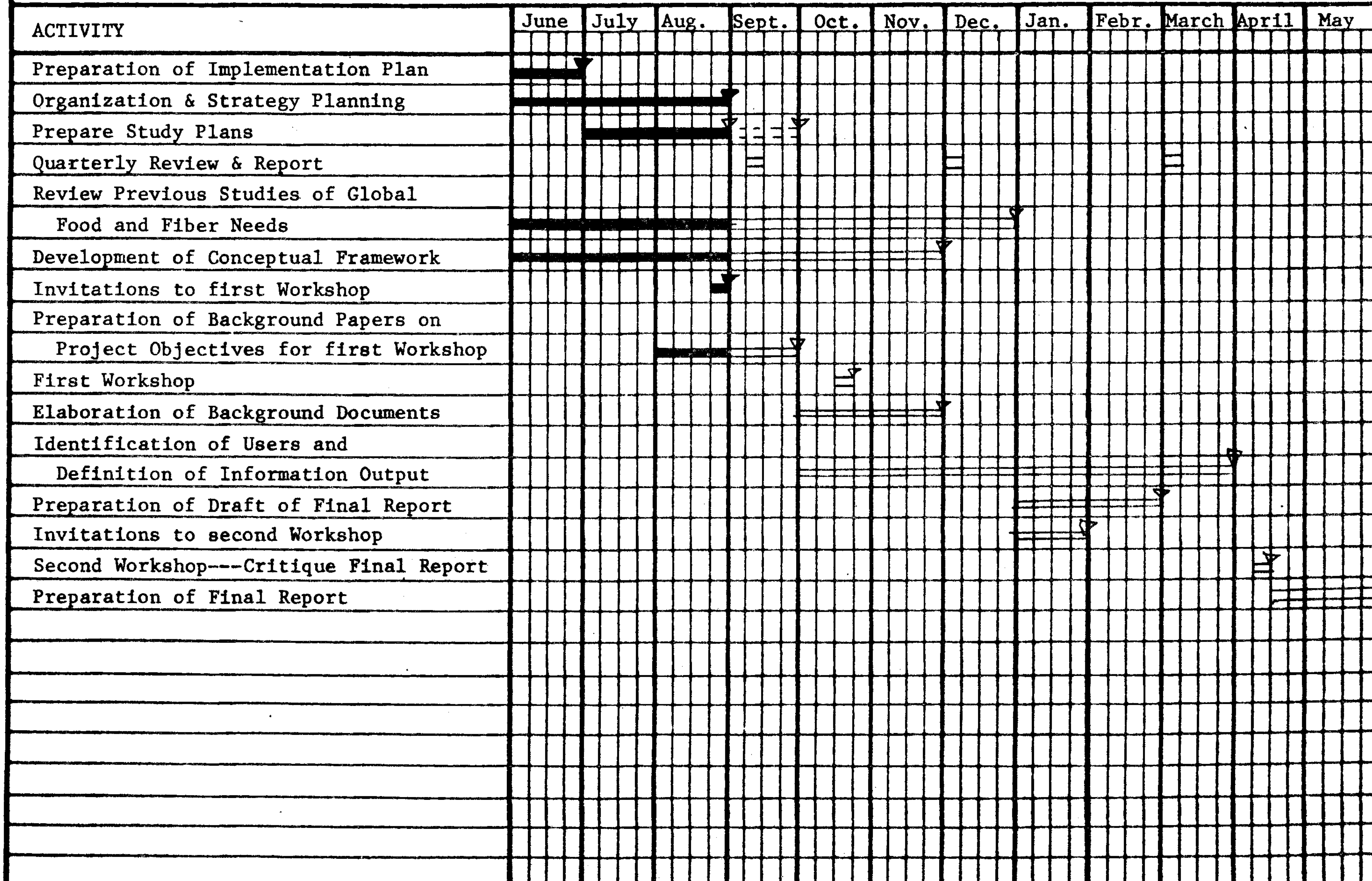
Task 1
- **Finish Data Collection**
- **Data Compilation**
- **Data Analysis**
- **Comparison of Results and Preparation of Final Report**

Task 2
- **Finish Draft Report**
- **Review and Modify Draft**
- **Prepare and Publish Final Report as a LARS Information Note**

Task 3
- **Definition of Data Set and Classification Techniques to be Used**
- **Classify Data and Compare Results**
- **Evaluation of Results and Preparation of Final Report**

Task 4
- **Discussions with FAP Personnel**
- **Definition of LARS Research Program for Forestry Applications, and Submission of Proposal for FY78**

2.3 Large Area Agriculture Inventory Design Implementation Schedule

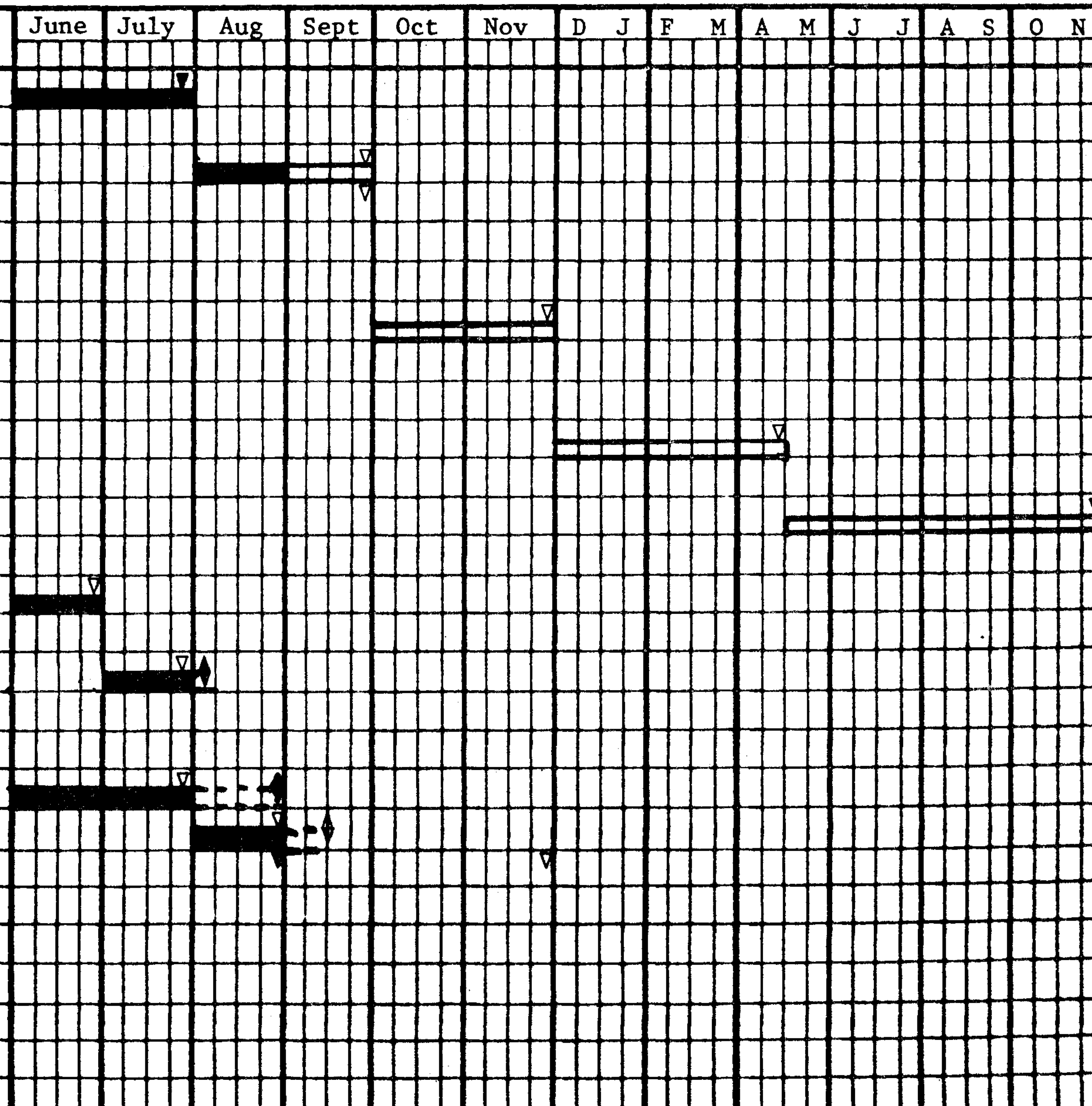


Task 2.2al. Technology Development Implementation Schedule.

Implementation Plan

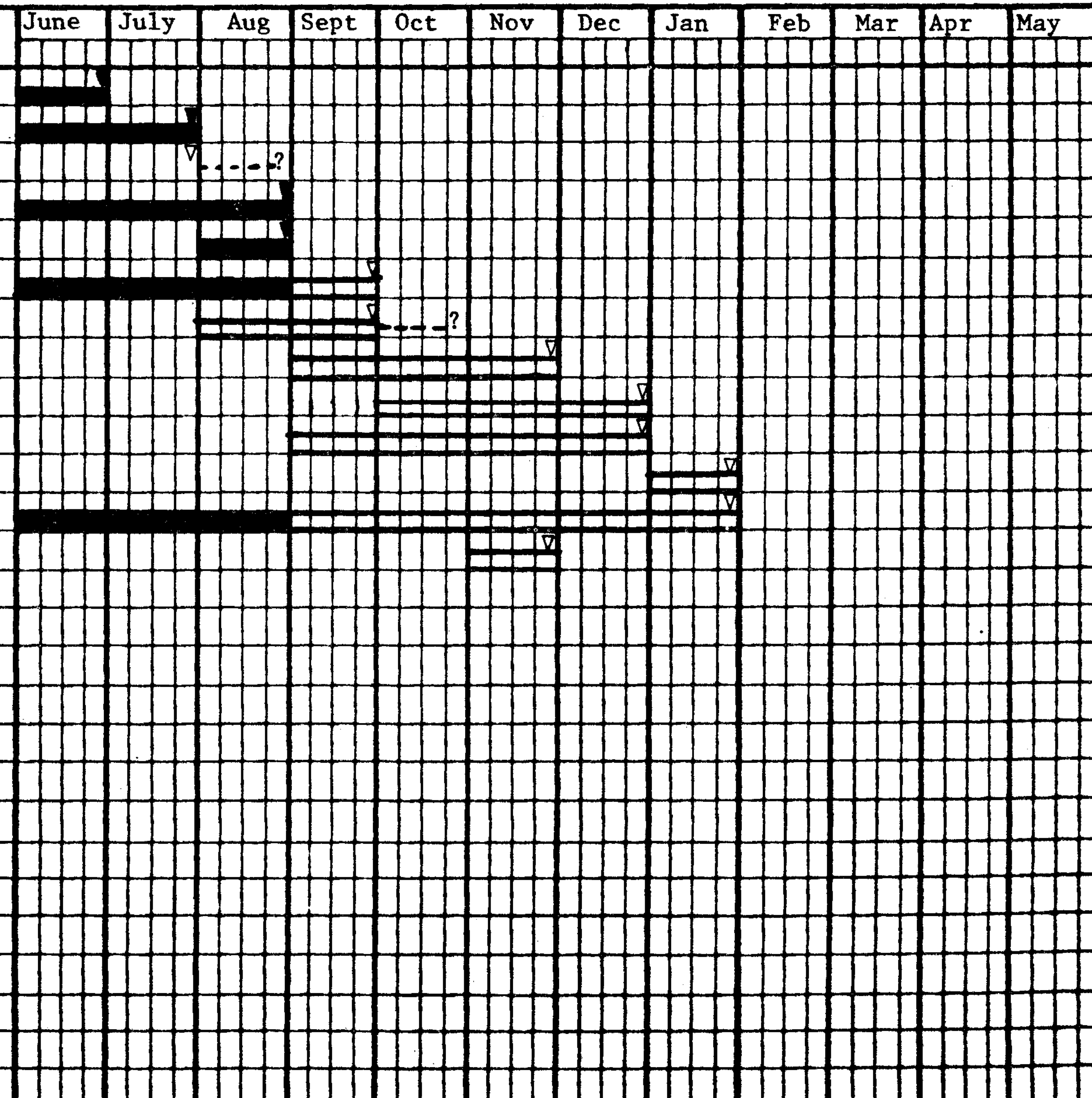
1. Familiarize LARS personnel with P1 and list method
2. Formulate alternative approaches
3. Formalize and report candidate approaches and resource requirements for evaluation studies
4. Evaluate candidate approaches from 3 and specify two or more "best" approaches
5. Evaluate and compare effectiveness of selected procedures
6. Complete nonsupervised ECHO programming.
7. Complete program documentation and User's Guide
8. Statistical analysis of nonsupervised results and comparison with supervised ECHO and perpoint
9. ECHO Final Report

Reporting



Task 2.2a2. Technology Interchange System Development Implementation Schedule

1. Write Implementation Plan
2. Software Conversion Support
3. Data-100 Installation Decision
4. ECHO Case Study
5. Quarterly Report
6. Technique Interchange Plan
7. Tape Copy Software Plan
8. Hardware Installation
9. Tape Copy Software Implementation
10. Data-100 Training
11. Data-100 Installation Evaluation
12. 2780 Support
13. Final Report



Task 2.2b. Scanner System Parameter Selection Implementation Schedule

1. Implementation Plan
2. Test and Evaluate Classification Error Prediction Algorithm
3. Develop and Test Spatial Model for Scanner System
4. Complete Software System to Represent and Evaluate Scanner Parameter Sets Using K-L and IT Representations
5. Develop and Evaluate Sensor Noise Parameter Model
6. Integrate and Test Scanner System Parameter Modeling System
7. Reporting