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FIELD MEASUREMENTS PROJECT

STATUS REPORT

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PREPARED BY

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I. INTRODUCTION

This report presents a summary of the operation and current status of the field measurements project during 1974-75. An overview of the objectives, test sites, sensors utilized, ag/met data collected, data processing, and data library are presented first. Then summaries of the data acquisition missions, status of data processing, data quality evaluation, data library, and data distribution are presented in Sections III to VII. Finally, more detailed discussions of data processing and data quality are discussed in Appendices A and B. Data received at LARS and currently in the data library is summarized in Appendix C. Examples of several of the less familar data products available for the truck-mounted and helicopter-borne spectrometers are presented in Appendix D. With the exception of the appendices the report is presented in the form of charts and figures which can be easily and quickly read.

II. PROJECT OVERVIEW

OVERALL OBJECTIVES

1. OBTAIN MULTITEMPORAL SET OF SPECTRAL MEASUREMENTS AND SUPPORTING AGRONOMIC AND METEOROLOGICAL DATA TO SERVE AS DATA BASE FOR RESEARCH IN DEFINING FUTURE REMOTE SENSING SYSTEMS.

2. PROVIDE DATA TO VARIOUS ON-GOING CROP INVENTORY RESEARCH AND DEVELOPMENT PROGRAMS.

SPECIFIC OBJECTIVES OF SR&T PROGRAMS SUPPORTED BY FIELD MEASUREMENTS

DETERMINE:

1. SPECTRAL SEPARABILITY OF WHEAT AND OTHER CROPS AS A FUNCTION OF CROP GROWTH STAGE. (ERIM)

2. EFFECT OF CROP, SOIL, AND MANAGEMENT VARIABLES ON SPECTRAL REFLECTANCE. (PURDUE)

3. DISCRIMINABILITY OF HARVESTED AND UNHARVESTED WHEAT. (TEXAS A&M)

4. RELATION OF GRAIN YIELD AND SPECTRAL RESPONSE. (TEXAS A&M)

5. CORRELATION OF LANDSAT, AIRCRAFT, AND GROUND ACQUIRED SPECTRAL MEASUREMENTS. (TEXAS A&M)

6. CHARACTERISTICS AND VALUE OF THERMAL MEASUREMENTS. (PURDUE)

7. EFFECT OF SUN ANGLE AND VIEW ANGLES OF SPECTRAL RESPONSE. (COLORADO)

8. PREDICTION OF PERFORMANCE OF FUTURE SCANNERS. (PURDUE)

EXPERIMENTAL APPROACH

COLLECT DATA OVER:

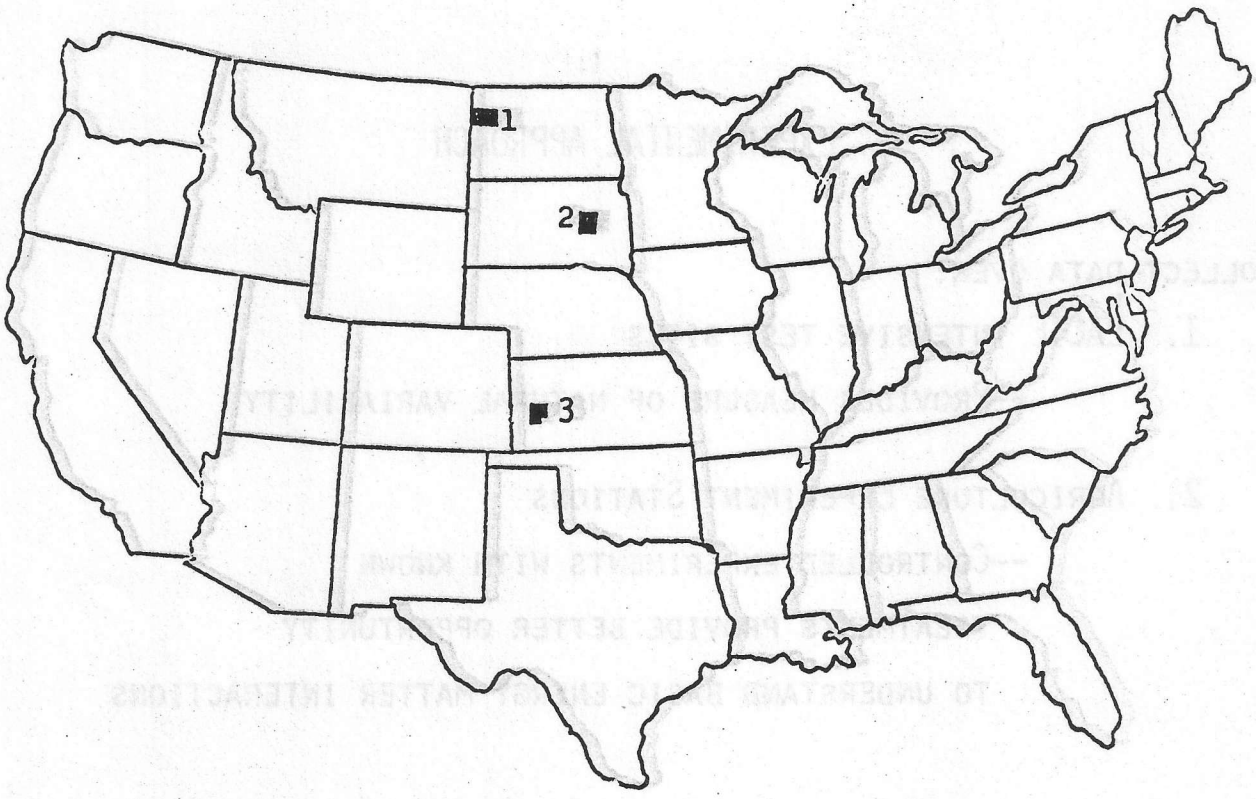
1. LACIE INTENSIVE TEST SITES

   --PROVIDES MEASURE OF NATURAL VARIABILITY

2. AGRICULTURE EXPERIMENT STATIONS

   --CONTROLLED EXPERIMENTS WITH KNOWN TREATMENTS PROVIDE BETTER OPPORTUNITY TO UNDERSTAND BASIC ENERGY-MATTER INTERACTIONS

TEST SITES



1. WILLIAMS CO., N. DAKOTA
2. HAND CO., S. DAKOTA
3. FINNEY CO., KANSAS

REMOTE SENSOR SYSTEMS

INTENSIVE TEST SITE FLIGHTLINES

- HELICOPTER: S-191 AND PHOTOGRAPHY
- C-130: 24-CHANNEL MSS AND PHOTOGRAPHY
- LANDSAT: MSS

AG EXPERIMENT STATIONS

- FIELD SPECTRORADIOMETERS/INTERFEROMETER
- PRT-5
- OTHER SPECIALIZED INSTRUMENTATION (THERMISTORS, ETC.)

AGRONOMIC OBSERVATIONS AND MEASUREMENTS

Intensive Test Sites

- Crop Species
- Cultural Practices: Fertilization, Planting Date, etc.
- Crop Maturity
- Plant Height
- Ground Cover
- Stresses: Disease, Insects, Moisture Deficits
- Field Operations: Cultivation, Harvesting
- Vertical Photographs
- Grain Yield

Experiment Stations

- Above plus,
- Leaf Area Index
- Dry Weight: Leaves, Stems, Heads
- Soil Moisture

ATMOSPHERIC AND METEOROLOGICAL MEASUREMENTS

% Cloud Cover and Type
Temperature
Relative Humidity
Wind Speed and Direction
Barometric Pressure
Sky Brightness
Total Irradiance
Optical Depth

DATA PROCESSING, LIBRARY, AND DISTRIBUTION TASKS

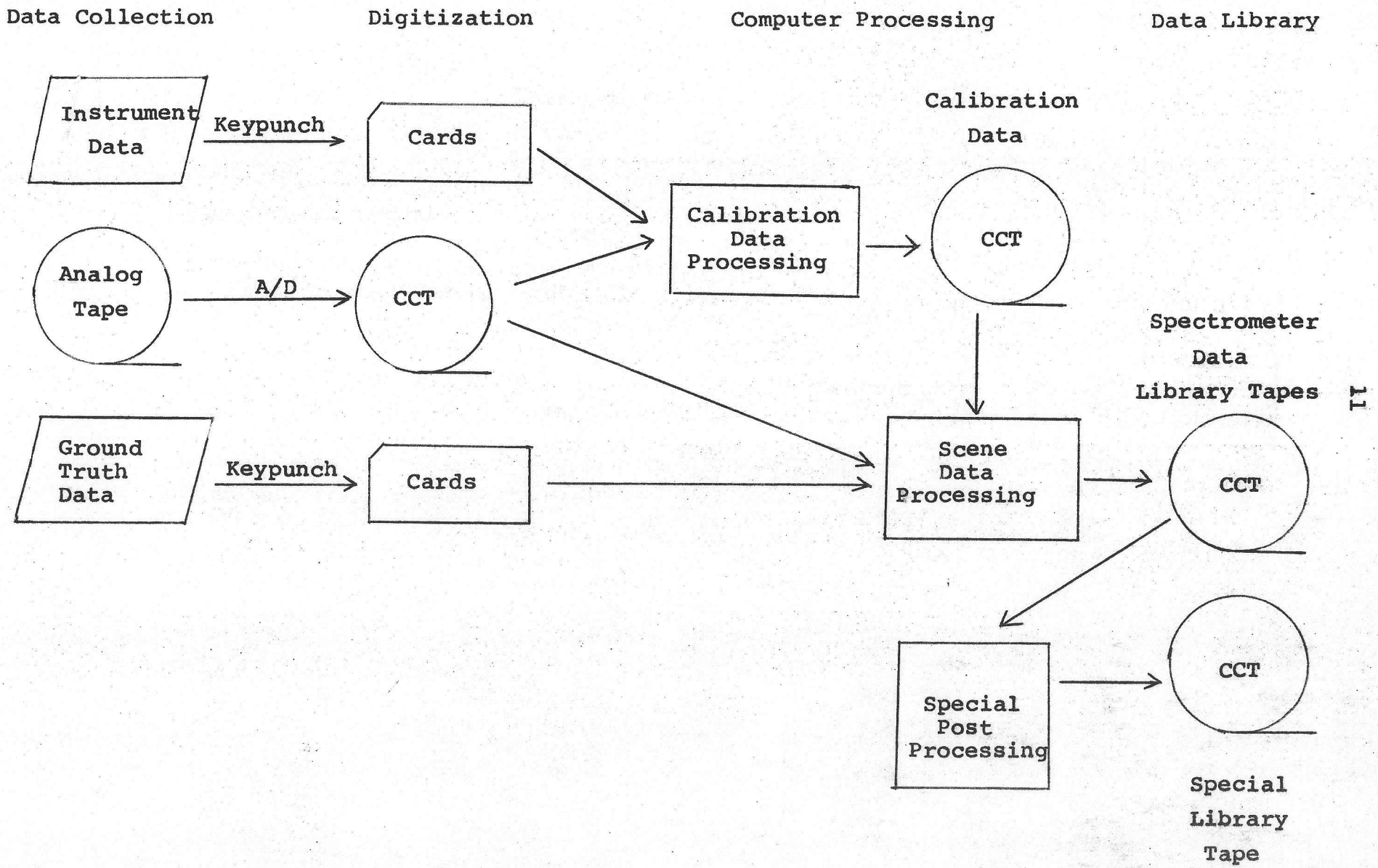
1. PROCESS DATA FROM THE VARIOUS SENSORS AND SOURCES TO PRODUCE ANNOTATED, CALIBRATED DATA SETS WITH COMMON UNITS AND FORMATS.

2. ESTABLISH AND MAINTAIN DATA LIBRARY SYSTEM.

3. DISTRIBUTE DATA TO RESEARCHERS.

THESE FUNCTIONS ARE PRIMARILY PERFORMED BY LARS/PURDUE.

GENERALIZED DATA HANDLING DESCRIPTION



III. SUMMARY OF DATA ACQUISITION MISSIONS

SUMMARY OF DATA ACQUISITION, 1974-1975

FINNEY CO., KANSAS

MISSION	WHEAT GROWTH STAGE	SENSOR TYPE			
		LANDSAT	A/C MSS	S-191	TRUCK
OCT. 17-20	SEEDLING	X			X
NOV. 4-7	TILLERING	X		X	X
MAR. 19-22	TILLERING	X		X	X
APRIL 6-9	JOINTING		X	X	X
APRIL 24-27	JOINTING				X
MAY 13-16	BOOT		X	X	X
MAY 21-24	HEADING		X	X	X
MAY 30-JUNE 2	MILK	X	X	X	X
JUNE 8-11	DOUGH	X	X	X	X
JUNE 17-20	RIPENING	X	X	X	X
JUNE 4-6	MATURE	X	X	X	X
JULY 5-8	POST HARVEST	X	X	X	X
SEPT. 14-17	PRE-EMERGENCE	X	X	X	
OCT. 2-5	SEEDLING			X	X
OCT. 20-23	SEEDLING	X		X	X
NOV. 11-12	TILLERING		X	X	

SUMMARY OF DATA ACQUISITION, 1974-1975

WILLIAMS CO., NORTH DAKOTA

MISSION	WHEAT GROWTH STAGE	SENSOR TYPE			
		LANDSAT	A/C MSS	S-191	TRUCK
MAY 25-28	EMERGENCE	X	X		X
JUNE 3-7	SEEDLING		X	X	X
JUNE 12-15	SEEDLING	X	X		
JUNE 21-24	TILLERING	X	X	X	X
JUNE 30-JULY 3	JOINTING		X		X
JULY 9-12	BOOT	X	X	X	X
JULY 18-21	HEADING		X	X	X
JULY 27-30	HEADED	X		X	X
AUG. 5-8	MILK-DOUGH		X	X	X
AUG. 14-17	RIPENING	X	X	X	X
AUG. 23-26	MATURE		X	X	X
SEPT. 1-4	POST HARVEST		X	X	X

SUMMARY OF DATA ACQUISITION, 1975

HAND CO., SOUTH DAKOTA

MISSION	WHEAT GROWTH STAGE	SENSOR TYPE	
		A/C MSS	S-191
OCT. 15-16	EMERGENCE		X
OCT. 29-30	SEEDLING		X
NOV. 5	TILLERING	X	X

LANDSAT DATA IS ALSO ACQUIRED, BUT NOT COINCIDENT WITH MISSIONS.

IV. SUMMARY OF DATA PROCESSING AND REFORMATTING STATUS

LANDSAT MSS DATA

20 DATA COLLECTION MISSIONS

10 MISSIONS B & W AND COLOR IMAGERY RECEIVED AT LARS

2 MISSIONS CCT'S RECEIVED AT LARS

MSDS/24 CHANNEL MSS DATA

23 DATA COLLECTION MISSIONS

5 MISSIONS RECEIVED AT LARS

5 MISSIONS REFORMATTED AND IN LIBRARY

FSS/HELICOPTER S-191 DATA

20 DATA COLLECTION MISSIONS

8 MISSIONS IN PROCESSING AT JSC

12 MISSIONS RECEIVED AT LARS*

2 MISSIONS REFORMATTED, IN LIBRARY AND DISTRIBUTED

2 MISSIONS IN REFORMATTING PROCESS

*9 TO BE REPROCESSED AT JSC TO CORRECT THERMAL DATA

20C SPECTRORADIOMETER DATA

9 DATA COLLECTION MISSIONS

5 MISSIONS PROCESSED, REFORMATTED, AND IN LIBRARY

4 MISSIONS IN REFORMATTING PROCESS

2 MISSIONS DISTRIBUTED

SUMMARY OF DATA PROCESSING AND REFORMATTING STATUS, CONT.

20D SPECTRORADIOMETER DATA

15 DATA COLLECTION MISSIONS

2 MISSIONS RECEIVED AT LARS

13 MISSIONS IN PROCESS AT ERL

FSAS INTERFEROMETER DATA

3 DATA COLLECTION MISSIONS (FALL 1974)

3 MISSIONS RECEIVED AT LARS

V. SUMMARY OF DATA QUALITY EVALUATIONS

A. LANDSAT MSS

GREATEST LIMITATION IS MISSING DATA DUE TO CLOUD COVER.

B. MSDS/24-CHANNEL SCANNER DATA

BANDING, BIT ERRORS, SATURATION, AND INOPERATIVE BANDS HAVE REDUCED THE DATA QUALITY; BUT PRELIMINARY ANALYSES INDICATE THAT THE DATA IS USEFUL FOR CLASSIFICATIONS.

C. FSS/S-191 HELICOPTER DATA

PRELIMINARY ANALYSES INDICATE GOOD DATA WAS ACQUIRED. HOWEVER, ADDITIONAL INSTRUMENT TESTS ARE NEEDED TO INSURE THAT THE FOV IS FILLED DURING CALIBRATION SCANS. THERMAL DATA QUALITY PROBLEM DUE TO FAULTY DICHROIC HAS BEEN LARGELY CORRECTED WITH DATA PROCESSING.

D. LARS FIELD SPECTRORADIOMETER DATA

REPEATABLE DATA WITH HIGH ACCURACY WAS ACQUIRED.

E. ERL FIELD SPECTRORADIOMETER DATA

PROBLEMS WITH MISALIGNED OPTICS CAUSED LOSS OF SOME DATA AND GREATER UNCERTAINITY IN ACCURACY OF DATA; BUT THE PROBLEM HAS LARGELY BEEN CORRECTED BY DATA PROCESSING AT ERL.

Data Types Available

Intensive Test Sites

LANDSAT MSS Data

Digital data, CCT's in LARSYS format

3-band color and single-band B & W imagery

Aircraft Data

24-Channel MSS data in LARSYS format

9-inch color and color infrared photography

Helicopter Data

Continuous wavelength spectrometer data

from 0.4-1.4μm at .02 intervals

" 1.4-2.4 " .05 "

" 2.7-14.0 " .10 "

70-mm color photography

Ground Truth and Ancillary Data

Crop inventory

Periodic observations for each mission

Grain yield, for selected fields

weather data for entire season, including precip. at site

Meteorological measurements made during mission

Photo, plus field boundary overlay

Soil maps

DATA TYPES AVAILABLE, CONT.

AGRICULTURE EXPERIMENT STATIONS

FIELD SPECTRORADIOMETER DATA

SAME WAVELENGTHS AND INTERVALS AS HELICOPTER DATA

GROUND TRUTH AND ANCILLARY DATA

VERTICAL AND GROUND LEVEL PHOTOGRAPHY

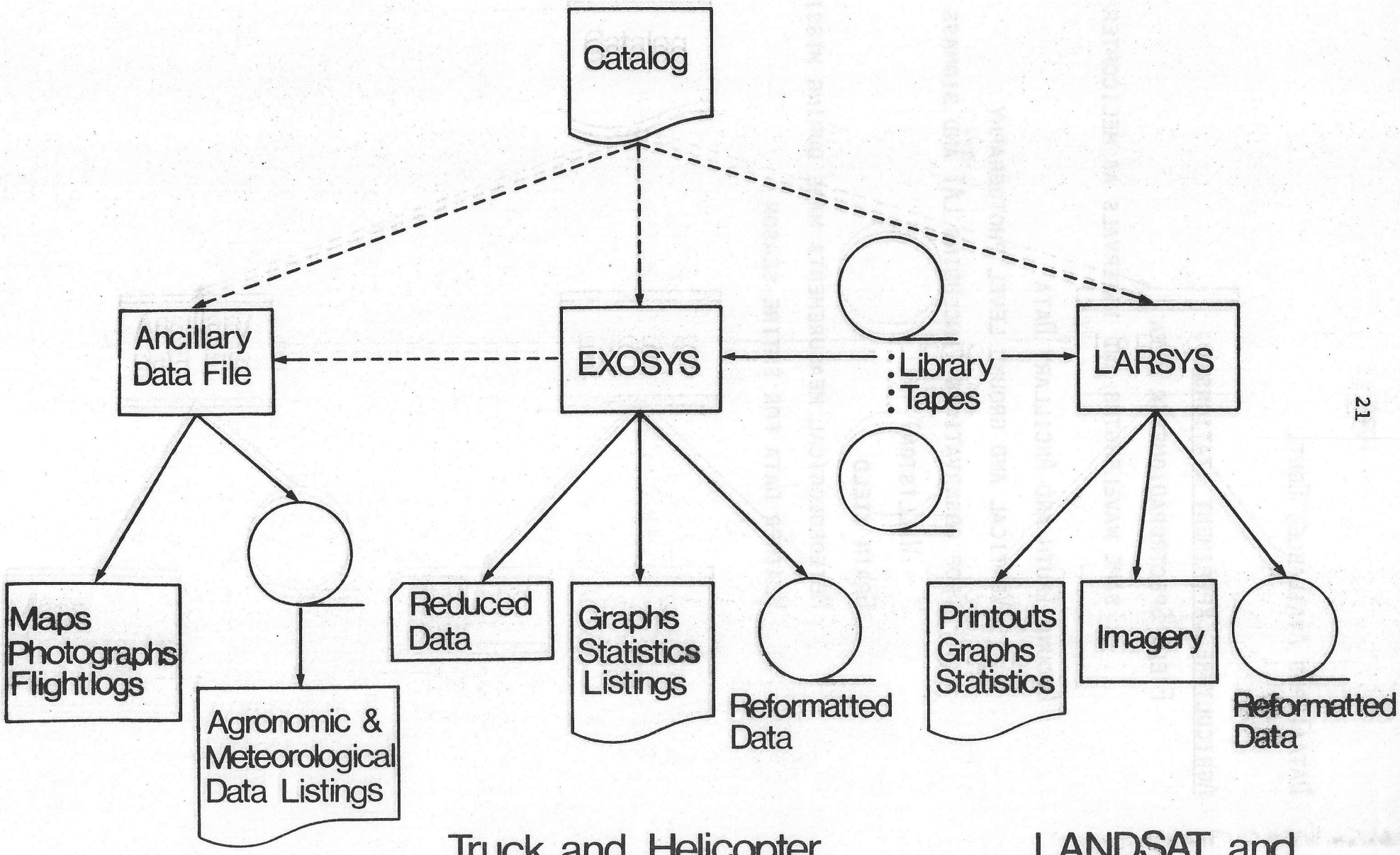
CROP OBSERVATIONS (INCLUDING LAI AND BIOMASS AT WILLISTON)

GRAIN YIELD

METEOROLOGICAL MEASUREMENTS MADE DURING MISSION

WEATHER DATA FOR ENTIRE SEASON

FIELD MEASUREMENTS DATA LIBRARY



VII. DATA DISTRIBUTION

1. SELECTED BANDS OF 24-CHANNEL MSS DATA FOR FOUR MISSIONS PLUS COLOR INFRARED PHOTOGRAPHY AND GROUND TRUTH DATA HAVE BEEN SENT TO ERL, GISS, GSFC, AND LARS FOR THE THEMATIC MAPPER SIMULATION EXPERIMENTS.

2. S-191 DATA FOR EIGHT MISSIONS HAVE BEEN SENT TO TEXAS A&M AND FOR TWO MISSIONS TO ERIM.

3. EXOTECH 20C (LARS) DATA FOR FOUR MISSIONS HAVE BEEN SENT TO TEXAS A&M AND ERIM.

4. USDA INVENTORY AND PERIODIC OBSERVATION DATA (26 DATES) HAVE BEEN SENT TO TEXAS A&M AND ERIM.

VIII. CONCLUSIONS AND RECOMMENDATIONS

Although certain deficiencies and limitations exist in the data it is believed that the project is supplying and will continue to provide data sets which are useful for a wide range of research tasks. Attempts are being made to eliminate as many of these problems as possible during year two. For example, increased effort will be devoted to data quality evaluation and verification by both JSC and LARS. And, additional ground observation data including more yield and soil moisture determinations will be made.

Valuable experience was gained during the first year of the project in coordinating the various elements of the project from acquisition through processing and distribution of the data. This experience will be beneficial to future years efforts. Procedures and systems developed and tested during the first year can be expected to result in smoother operation of the project, in improved data quality, and faster turn-around of data.

Specific recommendations include:

- -Refurbishment and continued use of the MSDS.
- -Implementation of data quality control procedures by JSC for MSDS, FSS, and FSAS data.
- -Decreased turn-around time for data delivery.
- -Additional effort and resources devoted to characterization of crop and soil conditions for both intensive test site fields and experiment station plots.
- -Development of plans for continuation of this type effort over new crops and locations, e.g. corn and soybeans in the Corn Belt.

APPENDIX A: DATA PROCESSING DESCRIPTION

A. MSDS 24-Channel Scanner Data

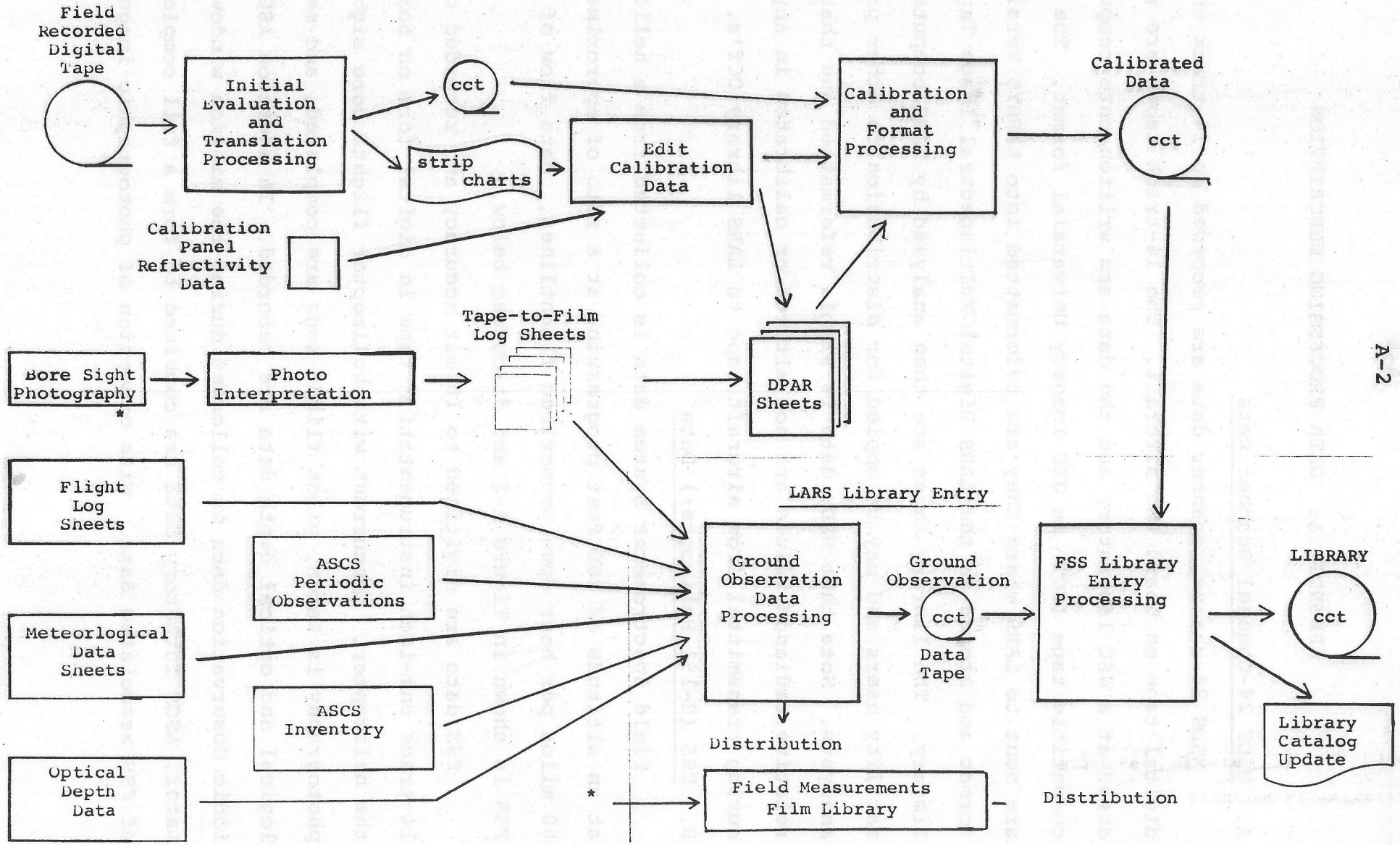
MSDS 24-channel scanner data are recorded on 14-track one-inch digital tape on board the aircraft. The 14-track tapes are reproduced at a JSC laboratory and the data are written onto computer compatible tape (CCT) in JSC Imagery Universial format. The CCT's are sent to LARS where they are reformatted into LARSYS Version 3 format and stored in the LARS Digital Multispectral Image Tape Library. The library tapes are then analyzed by LARS computer facility users and may be copied for distribution to other project analysts. Note that MSDS data is simple reformatted and that scene relative radiance values are not altered or calibrated in any way during transmittal from aircraft tape to LARS library CCT's.

B. FSS (S-191 Helicopter) Data

Field Spectrometer System data is collected from a helicopter at an altitude of 200 feet progressing at a rate of approximately 60 miles per hour down prescribed flightlines. Data flow of the FSS is shown in Figure A-1 and discussed below.

FSS data are digitized to 10 bit accuracy and recorded on 14-track one-inch instrumentation tape in digital form on board the helicopter. Concurrent with helicopter flights bore sight photography is taken, pilot flight logs are completed, and meteorological and optical depth data are recorded. In addition ASCS Periodic Observation data is collected during the mission window. Later, ASCS Inventory data are combined to form a full complement of FSS associated data. With exception of photographic images and

Figure A-1. S-191 Data Processing



flight log information this complement of data is computer processed and stored in the field measurements project spectrometer computer data library for subsequent analysis.

Airborne recorded 14-track digital tapes are reproduced at a JSC laboratory and converted to computer compatible tape (CCT) format. In addition, strip charts are generated and other outputs used for data quality evaluation. The strip charts are later edited to delineate scanes collected directly over the calibration panel for use in calibrating the field data into reflectance units. This edit is very critical and important since the helicopter can not always haver directly over the calibration panel because of winds. The editor selects a contiguous set of panel scans showing a peak response on the strip chart. The edit data is keypunched and input to the calibration/formatting processor.

Bore site photography collected coincident with spectrometer data is used by photo-interpreters to generate tape-to-film data sheets showing the time interval corresponding to the helicopter overpass of each ground scene field or object. The time is read from a precision clock mounted within the camera and viewed in each photo frame. The clock is synchronized with the spectrometer time code generation with an error not greater than two seconds. The tape-to-film sheets are transcribed to JSC DPAR data processing request sheets with modifications as dictated by data quality evaluations and other inputs. DPAR sheets are subsequently keypunched and input to the calibration/formatting processor.

The last bits of information needed by the calibration processor are calibration panel reflectivity data, supplied by LARS from the Exotech 20C system, and other miscellaneous processing parameters.

Information discusses above is used by the calibration/formatting processor to produce data calibrated to reflectance factor and record same on CCT's. Data scans within each time interval corresponding to a single contiguous scene type (field) are processed. Each spectral scan is calibrated into reflectance factor units by referencing the data to the most current (previous) calibration panel scan and the reflectivity table. Copies of the CCT's, DPAR sheets, flight logs, meteorological sheets, optical depth sheets, tape-to-film logs, and photographs are sent to LARS for further processing.

At LARS, Run Numbers are added to the tape-to-film log sheets and along with the meteorological, optical depth, and ASCS data sheets are keypunched and processed by the "ground observation data processor" to produce a ground observation tape. The processor generates a ground observation tape data record for each field (and time) for which FSS data were collected. This record contains all the information about a given field which can be found on the data sheets listed above.

Finally, the JSC CCT and ground observation are combined with program control data to produce the FSS field measurement project library tape. During this final processing step the scans of single fields (and times) are averaged to form a single scan after statistical analysis algorithms have omitted atypical scans or

portions of scans. Also during this step, the data may be recalibrated if updated and more accurate calibration panel reflectivity values are available.

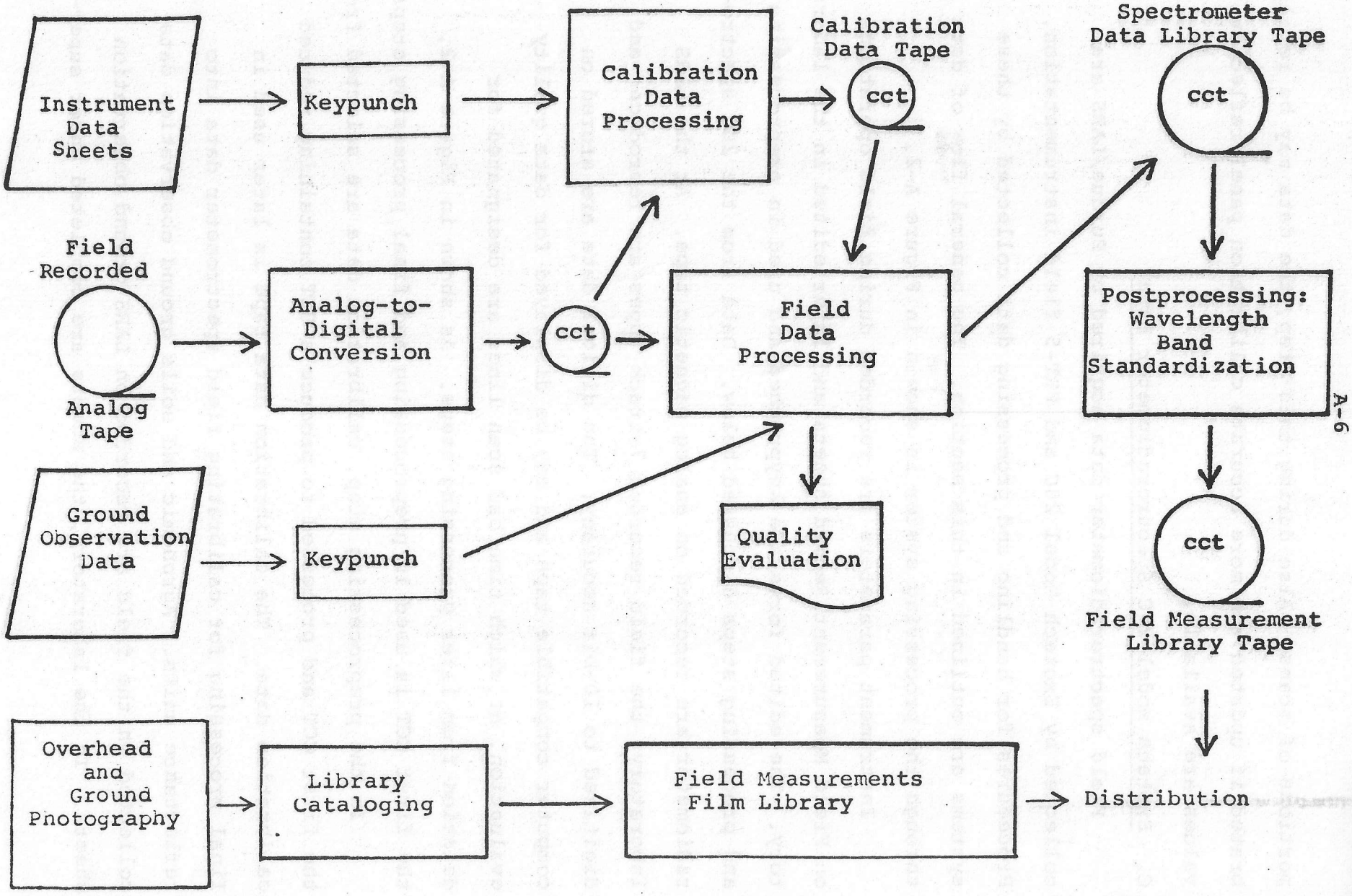
C. Exotech Model 20C Spectroradiometer Data

Field spectroradiometer data acquired by Purdue/LARS are collected by Exotech Model 20C and PRT-5 field instrumentation. Procedures for handling and processing data collected by these systems are outlined in this section. The general flow of data through the processing system is showin in Figure A-2.

Instrument parameters are recorded during field operations on Field Measurement Record sheets and later edited in the laboratory. The edited forms are keypunched and used in preprocessing and processing steps discussed below. Data from the 20C spectroradiometer are recorded on analog magnetic tape. At the LARS laboratory, the field recorded 7-track tapes are reproduced and digitized to 10-bit accuracy. The digital data are stored on computer compatible tape and may be displayed for data quality evaluation, at which time bad scan lines are designated for deletion from later processing steps. As shown in Figure A-2, the first CCT is used in preprocessing and final processing steps.

In the preprocessing step, calibration data are selected from the first CCT and processed to produce a CCT containing reduced calibration data. The calibration data tape is later used in final processing for calibrating field spectrometer data into reflectance units. Agronomic and soils ground observation data collected in the field are recorded on LARS ground observation sheets. In the laboratory, the sheets are completed under super-

Figure A-2. LARS Field Spectroradiometer Data Processing



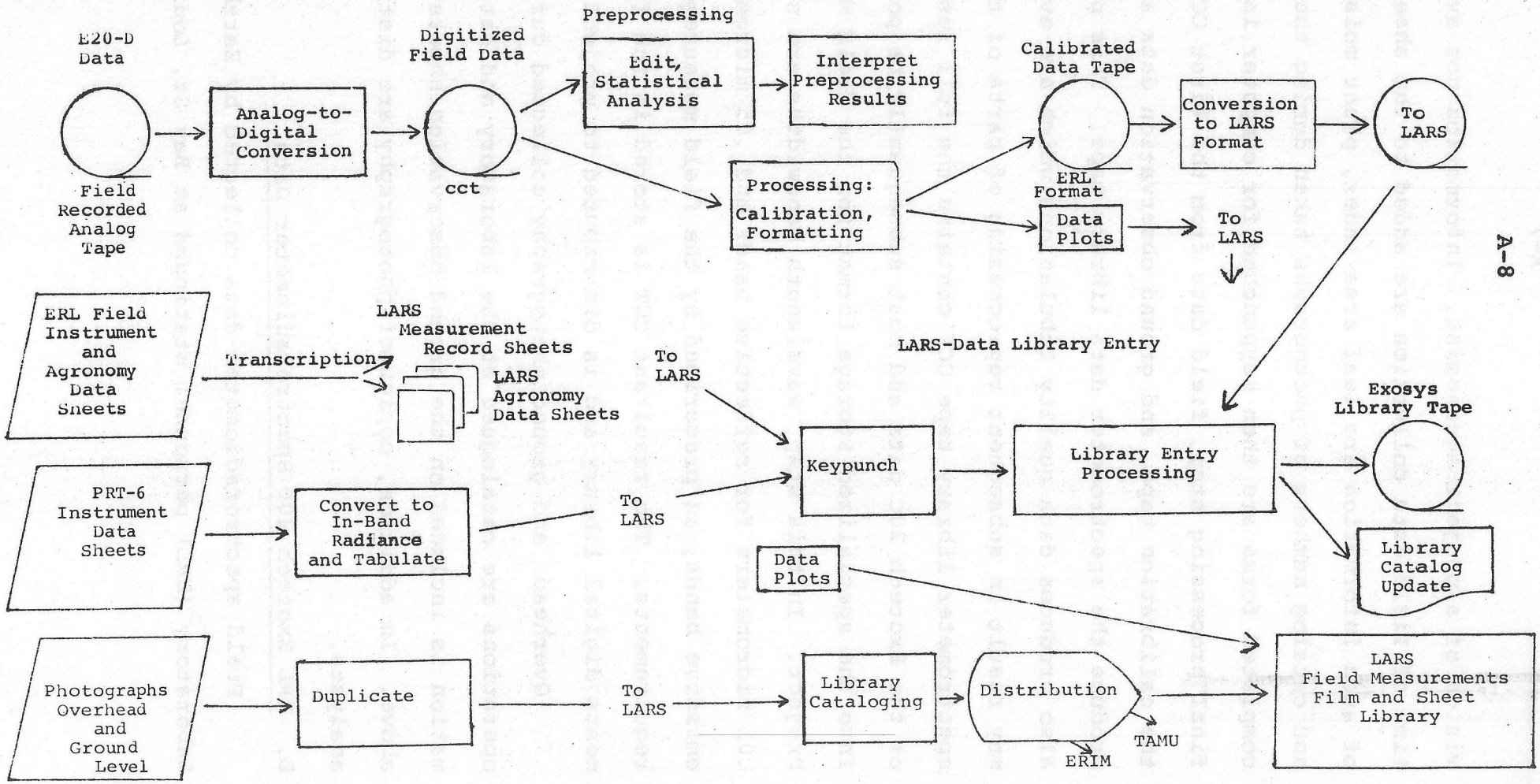
vision of a project agronomist. Information not available at the time of field data collection are added to the sheet. Examples of such information are leaf area index, plant moisture content, and catalog numbers of photographs taken during the mission. The completed forms are then keypunched for computer input. In the final processing step, field data from the first CCT, data from the calibration tape, and ground observation data are combined to produce the spectrometer data library tape. This processing step also produces data quality tabulations which are evaluated and may result in subsequent reprocessing of parts of the data. The spectrometer library tape CCT contains the full resolution form of the Exotech 20C data and must subsequently be postprocessed into the specialized storage format for the Field Measurements Project. In this step, wavelength bandwidths are standardized to .01 micrometers for reflective bands and .05 micrometers for emissive bands, as prescribed by the field measurements project requirements. The resultant CCT is stored in the field measurements digital library and is distributed to project analysts.

Overhead and ground photography collected during field operations are catalogued at the laboratory and cataloging information is included on the ground observation sheets discussed above. In addition, copies of photography are distributed to data analysts.

D. ERL Exotech 20D Spectroradiometer Data

Field spectroradiometer data collected by Earth Resources Laboratory (ERL) personnel stationed at Bay St. Louis, Mississippi,

Figure A-3. ERL Field Spectroradiometer Data Processing



are collected by Exotech model 20D and PRT-6 field instrumentation. Procedures for handling and processing data collected by this system are discussed in this section. The data processing flow is shown graphically in Figure A-3.

As shown in Figure A-3, four basic data sets are collected in the field; analog magnetic tape recordings, photographs, instrument and agronomy data sheets, and PRT-6 readings. At the conclusion of a mission, all data collected are returned to the ERL Laboratory for processing.

1. Exotech 20C Spectroradiometer Data

The data are recorded on analog magnetic tape and later processed in the laboratory. To provide reflectance calibration, as required for the Field Measurements Project, a reflectance standard is periodically scanned and resulting data recorded.

Analog magnetic tapes recorded in the field are reproduced at the laboratory, digitized into 8-bit binary form, and recorded on computer compatible tapes (CCT). In a subsequent job, the CCT's are read by preprocessing computer programs for editing and statistical analysis. Preprocessing results are reviewed by a data analyst who developes data parameters used in the subsequent processing step. To increase the accuracy of data, each subject scanned is repeated approximately eight times. During final processing, selected scans are averaged to form the subject spectral response. The primary concern of the preprocessing step is scan selection. Selection of uniform and representative scans is based on the analyst's interpretation of graphical and quantitative statistical printouts. The CCT's are again read into the computer

and processed along with preprocessing results, data storage and retrieval, and other instrument data to produce reflectance calibrated data in ERL CCT format. The processor also generates graphs and statistics to assist in data quality evaluation. The CCT's are later copied for transmittal to LARS. During the copy process, the data are translated from Varian internal code to Standard BCD to achieve capability with the LARS computer. At LARS the CCT's are processed by software developed to enter ERL spectrometer data into the field measurements project data library. This library entry processor reads ERL CCT's, agronomy and instrument data (discussed below) and formulates EXOSYS library data records. These records are written onto library CCT's for subsequent access and analysis.

2. Instrument and Agronomy Data Sheets

Standard ERL instrument and agronomy data sheets are completed by ERL personnel at the time observations are made in the field. When the sheets are returned to ERL for processing, the data are transcribed onto standard LARS instrument and agronomy data forms. The forms are forwarded to LARS, where certain library cataloging parameters are added such as the LARS Run Number. The completed forms are keypunched and murged with CCT data by the library entry processor discussed above.

3. Photographs

Photographs are duplicated at ERL and forwarded to LARS for distribution to analysts. The photographs are cataloged into the LARS film library and the computer data library discussed above.

4. PRT-6 Data

Measurements made by the PRT-6 instrument are recorded in tabular form. The measurements are later converted to in-band radiance form and transmitted to LARS. In general, an array of readings are recorded for each subject scanned with the Exotech 20D. The readings are keypunched at LARS and murged with CCT data during library entry discussed above. Alternatively, when the PRT-5 field instrument is substituted, resultant data are handled similarly, the difference being fewer spectral bands.

APPENDIX B: DATA QUALITY EVALUATION

The radiometric quality of the data produced by the two truck-mounted spectroradiometers, the helicopter-borne spectrometer, and the 24-channel aircraft scanner data have been evaluated.

A. Model 20C (LARS) Truck-mounted Spectroradiometer Data

1. Reflective Data

Examination of digital reflectance data taken from the field measurements data bank indicated that the measured spectral reflectance for a nominal 30% grey panel was within $\pm$1% for two different dates (June 23, July 10, 1975) and for a nominal 6% grey panel within $\pm$0.5% for the same dates. This indicates that the instrument produces repeatable data.

A minor instrument malfunction has been analyzed and a correction has been determined to produce 0.70 to 1.28 micrometer reflectances of higher accuracy.

In general, the estimated uncertainty of the data is 7% of value. This is based on uncertainties of 3% in the comparison of the painted reflectance panel to the pressed barium sulfate, 3% in the estimation of reflectance of the pressed barium sulfate, and 5% in the situational repeatability of the field comparison of the target with the painted panel.

2. Thermal Data

Use of the thermal unit was limited to specific measurements associated with canopy modeling. Analysis of the spectral radiance data indicates little difference between canopy spectra and black-

body curves. The data is felt to be adequate for analysis purposes and within previously determined specifications of 4% at 5μm and 2% at 10μm.

B. Model 20D (ERL) Truck-mounted Spectroradiometer Data

Examination of digital reflectance data at the ERL facility during June 1975 indicated that at some point the Model 20D had begun to measure inaccurately. In July, personnel from ERL and LARS investigated the problem and determined it to be mainly misalignment of the first mirror. It was subsequently determined that the system was stable in this alignment and that the solar port data, could be used to compute reflectances based on calibrations performed in July and prior to the difficulty.

After giving careful consideration to the actual location of the field of view of the instrument, a number of observations have been deleted. Fortunately, due to the procedure used in acquiring data over the plots, at least one observation per plot will be available for analysis.

In general, the estimated uncertainty for this data must be a priori very high, say 10 to 15%. However, it is felt that further analysis will enable this figure to be reduced. According to analysts at ERL, the corrected data appears to be similar in quality to previous data.

C. S-191 Helicopter Data

1. Reflective Data

Initial examination of the reflective data indicates that the noise levels and situational variations are not sufficiently large so as to preclude use by analysts. The use of a per-field spectra with variation bands provides insight into the real field situation.

While a thorough analysis of the data has not been performed, it is noted that the spectral reflectances of subject fields is measured higher than one might expect based on surface measurements. One possible explanation for this would be that the field of view of the S-191 may not be filled at all times during the calibration process. One check for this could easily be provided: each calibration run may be treated as a data run prior to entering it in the calibration table. Efforts are presently being made to recover this data from the header information to determine the uniformity of the calibration situation.

Given that the FOV of the S-191 is filled during the calibration process, it is estimated that the uncertainty is 9% of values. This is based on the uncertainties states in A, above, with 5% added for an additional transfer.

2. Thermal data

Some difficulty was experienced with the data from the thermal unit. JSC personnel analyzed the problem and corrected the data to account for the actual characteristics of the dichroic mirror. No analysis has been performed on the data in its corrected form; thus, no uncertainties can be meaningfully estimated at this time.

D. 24-Channel Multispectral Scanner

Initial examination of the 24-channel multispectral scanner (MSDS) data indicates the presence of problems which may significantly limit its usefulness; however, the true impact of the problem will not be known until final classification results are completed. Data quality problems present in the data collected on four dates are banding, bit errors, saturation, and inoperative bands.

Banding is evidenced in the imagery as alternating dark and light shading. The frequency of the banding is 3-16 scan lines per band cycle, depending on the flight line. The banding is evident in all reflective spectral channels (1-13) and channels 23 and 24 of the thermal data. The banding signal amplitute is 1-15 data counts with larger amplitudes noted in spectral bands 1-8. It has been learned that the problem resulted from a loose mechanical joint within the detector housing. Effective removal of the banding has not yet been demonstrated.

System bit errors were noted in all spectral bands. Histograms showed a much higher frequency of occurence of odd data counts than even. In addition, various higher order bit errors were indicated in different spectral bands.

Full scale saturation (data count 255) was noted in several spectral bands of several flight lines. Saturation occured not only for roof top and highway data, but also for agricultural areas which are of interest for analysis purposes. Saturated data points will be omitted from all analysis since their values do not reflect an accurate measure of relative scene radiance.

Sensor spectral bands 4 and 15 were inoperative for all data collection missions.

Data Received at LARS

Field Measurements Project--Intensive Test Site Data Record

Finney Co. Kansas

Mission	Ground Truth Data		Aircraft Data			Helicopter Data			LANDSAT Data		Other Data or Comments
	Per. Obs.	Met. Meas.	9-inch Photo.	MSS Data	Flight Logs	70-mm Photo.	S-191 Data	Flight Logs	Imagery	CCT	
Oct. 17-20		Not Collected									March Inventory
Nov. 4-7		✓				✓	✓	✓			July-Aug. Inventory
March 19-22	✓	✓				✓	✓	✓	✓		Precip. Apr.-Sept.
April 6-9	✓	✓	✓			✓	✓	✓			Yield Data
April 24-27	✓	Not Collected							✓		
May 13-16	✓	✓	✓			✓	✓	✓			
May 21-24	✓	✓	✓			✓	✓	✓			
May 30-June 2	✓	✓				✓	✓	✓			
June 8-11	✓	✓	✓	✓	✓	✓	✓	✓		✓	
June 17-20	✓	✓	✓			✓	✓	✓	✓		
June 24-26	✓	✓	✓			✓	✓	✓			
July 5-8	✓		✓	✓	✓	✓	✓	✓	✓	✓	

Data Received at LARS

Field Measurements Project--Intensive Test Site Data Record

Williams Co. North Dakota

Mission	Ground Truth Data		Aircraft Data			Helicopter Data			LANDSAT Data		Other Data or Comments
	Per. Obs.	Met. Meas.	9-inch Photo.	MSS Data	Flight Logs	70-mm Photo.	S-191 Data	Flight Logs	Imagery	CCT	
May 25-28	✓		✓			Not Collected					June Inventory
June 3-7	✓		Not Collected			✓		✓			Precip. June-July
June 12-15	✓					✓		✓			Yield Data
June 21-24	✓		✓	✓	✓	✓		✓		✓	
June 30-July 3	✓		✓			Not Collected			✓		
July 9-12	✓					✓		✓	✓		
July 18-21	✓		✓			✓	✓	✓	✓		
July 27-30	✓		Not Collected			✓		✓	✓		
Aug. 5-8	✓		✓								
Aug. 14-17	✓		✓	✓	✓	✓		✓	✓	✓	
Aug. 23-26	✓		✓								
Sept. 1-4	✓		✓								

Data Received at LARS

Field Measurements Project--Intensive Test Site Data Record

Hand Co.
South Dakota

Mission	Ground Truth Data		Aircraft Data			Helicopter Data			LANDSAT Data		Other Data or Comments
	Per. Obs.	Met. Meas.	9-inch Photo.	MSS Data	Flight Logs	70-mm Photo.	S-191 Data	Flight Logs	Imagery	CCT	
Oct. 15-16											1/24000 Scale Photo
Oct. 29-30											+overlay
Nov. 5			✓	✓	✓	✓	✓	✓			70mm multispectral photography

*** LISTING OF FIELD SPECTRORADIOMETER DATA ON TAPE 2625 ***

```
RUN SEQUENCER ..................                90
EXPERIMENT NUMBER ..............          75100213
DATE DATA COLLECTED .....              7/10/75
EXPERIMENT NAME ........   SPRING WHEAT ND
SCENE TYPE .............               PLOT 5
AIR TEMPERATURE ..................      18.3
RELATIVE HUMIDITY ................      56.0
WIND SPEED .......................        15
CLOUD TYPE AND ALTITUDE **************
REFORMATTING DATE ........          11/ 6/75
SIDE ANGLE .......................        00
FORWARD DIRECTION ................       225
FOCAL DISTANCE ..................*****
LOCATION LATITUDE ..............  481000N
FLIGHT LINE ..................... ********
NUMBER OF SAMPLE GROUPS ..............    3
LEVELS OF FACTOR 2 ...................    1
LEVELS OF FACTOR 4 ...................    1
LEVELS OF FACTOR 6 ..................*****
REPLICATION NUMBER ...................    1
SPECIES ..................          WHEAT
MATURITY .................    BOOT STAGE
ROW WIDTH ..........................   24
PERCENT GROUND COVER ...............   55
LEAF AREA INDEX ..................... 1.01
NUTRENT DEFICIENCY  ********************
DISEASE INFECTION   ********************
HAIL OR WIND DAMAGE ********************
LATEST ID UPDATE DONE ...      11/01/02
PLANTING DATE ............      5/15/75
PERCENT SAND CONTENT ..............******
PERCENT CLAY CONTENT ..............******
MUNSELL COLOR .........          10.0YR43
MOISTURE (LABORATORY) CONTENT ....******
DRAINAGE CLASS .....................****
NUMBER OF PHOTOGRAPH ROLL ..........****
TARGET TEMPERATURE ..................40.0
TARGET WIDTH .....................******
EXPERIMENTOR'S PARAMETER 01**************
EXPERIMENTOR'S PARAMETER 03**************
EXPERIMENTOR'S PARAMETER 05**************
EXPERIMENTOR'S PARAMETER 07**************
EXPERIMENTOR'S PARAMETER 09**************
DATA QUALITY FACTOR 1    ( 0.55,  0.0786)
DATA QUALITY FACTOR 3    ( 1.05,  0.1337)
DATA QUALITY FACTOR 5    ( 2.20,  0.5863)
DATA QUALITY FACTOR 7    (*****,********)
INSTRUMENT NAME .......   EXOTECH MOD 20C
CALIBRATION RUN NUMBER .....*********
HIGH SQUARE WAVE LEVEL ..... 5.000
COMMENTS -- SOLAR

RUN NUMBER ..................... 75606600
OBSERVATION NUMBER ..............  710096
TIME DATA COLLECTED ..................2010
PRINCIPAL INVESTIGATOR       BAUER,MARVIN
LOCATION ..............      WILLISTON,ND
BAROMETRIC PRESSURE ..............  29.65
CLOUD COVER ..........................    0
VISIBILITY ...........................   15
WIND DIRECTION ...................     360
REFORMATTING CALIBRATION CODE ........    3
SWING ANGLE ..........................   00
DISTANCE TO GROUND ..............  20.00
FIELD OF VIEW ...................  15.00
LOCATION LONGITUDE ..... 1034100W
PHOTOGRAPH SERIAL NO.............71075050
LEVELS OF FACTOR 1 ...................    2
LEVELS OF FACTOR 3 ...................    2
LEVELS OF FACTOR 5 ..................*****
FIELD NUMBER ........................*****
PLOT NUMBER ..........................    5
VARIETY ..................         ELLAR
HEIGHT ..............................  0.45
PLANT COUNT 53 IN 1.00METERS OF ROW
LEAVES PER PLANT .....................    6
MOISTURE STRESS ... **********************
WEEDY ..............  **********************
INSECT INFECTION ..  **********************
LODGING DAMAGE ....  **********************
ROW DIRECTION ..........................N-S
SERIES NAME .............        WILLIAMS
PERCENT SILT CONTENT ..............******
TEXTURE ..................... SILT LOAM
MOISTURE (FIELD) CONTENT             DRY
SURFACE CONDITION .....           SMOOTH
HORIZON ..........................********
PHOTOGRAPH FRAMES ..............  ********
TARGET LENGTH ....................******
FIELD ACREAGE ....................********
EXPERIMENTOR'S PARAMETER 02**************
EXPERIMENTOR'S PARAMETER 04**************
EXPERIMENTOR'S PARAMETER 06**************
EXPERIMENTOR'S PARAMETER 08**************
EXPERIMENTOR'S PARAMETER 10**************
DATA QUALITY FACTOR 2    ( 0.65,  0.0382)
DATA QUALITY FACTOR 4    ( 1.65,  0.0773)
DATA QUALITY FACTOR 6    (*****,********)
FACILITY NAME .........     PURDUE / LARS
SCAN RATE ..........................  0.50
IRRADIANCE CALIBRATION RUN ..... 75606501
LOW SQUARE WAVE LEVEL ..... 0.0
```

DETECTOR NAME	DETECTOR RANGE	DETECTOR EQUILIZATION	NUMBER OF SAMPLES	WAVE BAND COEFFICIENTS A	B	C	D	SAMPLE GROUP
SI	0.300	0.50	470	0.374	0.001	0.0	0.0	1
PB S	1.000	0.50	465	0.733	0.001	0.0	0.0	2
PB S	1.000	0.50	420	1.286	0.003	0.0	0.0	3

***** SAMPLE GROUP 1 SI RANGE 0.3751- 0.7223 MICROMETERS

RESPONSE,BI-DIRECTIONAL REFLECTANCE FACTOR

CLASS WHEAT

WAVE LENGTH MICROMETERS	RESPONSE	WAVE LENGTH MICROMETERS	RESPONSE	WAVE LENGTH MICROMETERS	RESPONSE	WAVE LENGTH MICROMETERS	RESPONSE
0.3522	.0	0.5594	8.2489	0.6150	8.1930	0.6705	8.259
0.3569	.0	0.5632	8.4302	0.6187	8.2358	0.6742	8.466
0.3775	.0	0.5669	8.4132	0.6224	8.1804	0.6779	8.634
0.3913	5.6739	0.5706	8.3452	0.6261	8.1570	0.6816	8.786
0.3959	5.7110	0.5743	8.5623	0.6298	8.3741	0.6853	9.176
0.3987	6.0819	0.5780	8.3793	0.6335	8.3708	0.6890	9.701
0.4024	6.0384	0.5817	8.1963	0.6372	8.1658	0.6927	10.15
0.4061	6.0718	0.5854	8.2326	0.6409	8.2386	0.6964	10.95
0.4098	6.7596	0.5891	8.3287	0.6446	8.3937	0.7001	11.76
0.4335	7.0664	0.5928	7.9967	0.6483	8.2253	0.7038	12.70
0.4372	7.3483	0.5965	8.0891	0.6520	8.1281	0.7075	13.61
0.4409	7.6528	0.6002	8.2902	0.6557	8.2069	0.7112	14.92
0.4446	7.7150	0.6039	8.0244	0.6594	8.2173	0.7149	16.08
0.4483	7.6125	0.6076	8.0485	0.6631	8.2534	0.7186	17.34
0.4520	8.1209	0.6113	8.1753	0.6668	8.2833	0.7223	18.51
0.4557	8.2795						

***** SAMPLE GROUP 2 PB S RANGE 0.7340- 1.2912 MICROMETERS

RESPONSE,BI-DIRECTIONAL REFLECTANCE FACTOR

CLASS WHEAT

WAVE LENGTH MICROMETERS	RESPONSE	WAVE LENGTH MICROMETERS	RESPONSE	WAVE LENGTH MICROMETERS	RESPONSE	WAVE LENGTH MICROMETERS	RESPONSE
0.7340	18.716	0.8781	29.916	1.016	32.563	1.154	31.73
0.7436	20.717	0.8841	29.515	1.022	32.682	1.160	31.75
0.7496	22.863	0.8901	29.758	1.028	32.588	1.166	31.71
0.7556	24.883	0.8961	31.844	1.034	32.327	1.172	31.39
0.7616	26.061	0.9021	30.008	1.040	33.629	1.178	31.76
0.7646	26.668	0.9081	30.963	1.046	33.821	1.184	31.63
0.7736	26.981	0.9141	30.807	1.052	33.753	1.190	31.42
0.7766	27.152	0.9201	30.760	1.058	34.287	1.196	31.42
0.7826	28.171	0.9261	31.195	1.064	34.150	1.202	31.46
0.7886	28.063	0.9321	31.191	1.070	34.696	1.208	31.95
0.7941	27.668	0.9381	31.069	1.076	34.944	1.214	31.80
0.8001	28.491	0.9441	31.290	1.082	34.913	1.220	32.11
0.8061	28.974	0.9502	31.230	1.088	35.132	1.226	32.22
0.8121	28.133	0.9562	29.746	1.094	35.157	1.232	32.26
0.8181	28.898	0.9622	30.132	1.100	35.199	1.238	32.69
0.8241	29.007	0.9682	31.020	1.106	35.161	1.244	32.66
0.8301	29.191	0.9742	30.151	1.112	34.385	1.250	32.70
0.8361	29.764	0.9802	30.298	1.118	33.900	1.256	32.58
0.8421	29.128	0.9862	30.843	1.124	34.265	1.262	32.02
0.8481	29.060	0.9922	31.198	1.130	34.404	1.268	30.53
0.8541	29.879	0.9982	31.873	1.136	33.537	1.274	29.77
0.8601	29.648	1.004	31.596	1.142	32.741	1.280	27.55
0.8661	29.438	1.010	31.609	1.148	32.271	1.286	25.20
0.8721	30.060						

***** SAMPLE GROUP 3 PB S RANGE 1.2890- 2.3863 MICROMETERS

RESPONSE,BI-DIRECTIONAL REFLECTANCE FACTOR

CLASS WHEAT

WAVE LENGTH MICROMETERS	RESPONSE	WAVE LENGTH MICROMETERS	RESPONSE	WAVE LENGTH MICROMETERS	RESPONSE	WAVE LENGTH MICROMETERS	RESPONSE
1.289	33.662	1.564	23.381	1.839	.0	2.114	18.24
1.302	33.370	1.577	24.929	1.852	.0	2.127	18.46
1.315	32.126	1.590	24.612	1.865	.0	2.140	19.01
1.328	30.771	1.603	25.343	1.878	.0	2.153	19.30
1.341	30.071	1.616	25.928	1.891	.0	2.166	19.36
1.355	.0	1.629	26.458	1.904	.0	2.179	19.35
1.368	.0	1.643	26.849	1.918	.0	2.193	19.61
1.381	.0	1.656	27.635	1.931	.0	2.206	19.57
1.394	.0	1.669	27.683	1.944	.0	2.219	19.63
1.407	.0	1.682	27.618	1.957	.0	2.232	19.76
1.420	.0	1.695	27.817	1.970	14.597	2.245	19.64
1.433	.0	1.708	27.749	1.983	15.104	2.258	19.40
1.446	17.237	1.721	27.306	1.996	14.852	2.271	18.80
1.459	18.069	1.734	26.873	2.009	15.469	2.284	18.24
1.472	17.900	1.747	26.563	2.022	16.244	2.297	18.05
1.485	18.049	1.760	26.398	2.035	16.259	2.310	17.94
1.499	19.412	1.774	25.720	2.048	16.812	2.323	17.35
1.512	19.827	1.787	25.380	2.062	17.163	2.337	17.64
1.525	20.599	1.800	25.098	2.075	17.393	2.350	16.66
1.538	21.362	1.813	24.464	2.088	17.544	2.363	18.71
1.551	22.178	1.826	25.686	2.101	18.011	2.376	17.30

RUN STATISTICS

CLASS NAME	RUN NUMBER	SPECTRAL BAND	MEAN	RANGE MINIMUM	RANGE MAXIMIM	VARIANCE	STANDARD DEVIATION	PERCENT DEVIATION	NO. PTS
WHEAT	75606600	0.520- 0.600	8.0	5.7	8.8	0.6964	0.8345	10.43	108
		0.630- 0.690	8.9	8.5	10.2	0.1582	0.3977	4.492	81
		0.740- 0.800	26.2	20.9	28.2	3.594	1.896	7.239	50
		0.800- 0.910	28.9	27.7	30.2	0.3008	0.5485	1.898	92
		1.550- 1.750	27.2	23.2	28.9	2.601	1.613	5.933	77
		2.250- 2.450	19.2	16.9	21.0	1.288	1.135	5.923	53
	75606700	0.520- 0.600	7.6	5.4	8.4	0.4692	0.6850	8.961	108
		0.630- 0.690	8.0	7.7	9.5	0.1460	0.3821	4.747	81
		0.740- 0.800	26.3	20.5	28.8	5.029	2.243	8.543	50
		0.800- 0.910	30.1	28.4	32.1	0.7864	0.8868	2.951	92
		1.550- 1.750	25.2	21.2	27.1	2.612	1.616	6.400	77
		2.250- 2.450	16.8	14.9	18.9	1.068	1.033	6.165	43
FALLOW	75612500	0.520- 0.600	14.8	13.4	16.6	0.6883	0.8296	5.594	108
		0.630- 0.690	18.7	17.2	20.3	0.6576	0.8109	4.341	81
		0.740- 0.800	23.5	21.9	24.8	0.6603	0.8129	3.465	50
		0.800- 0.910	26.2	23.9	28.5	1.264	1.124	4.288	92
		1.550- 1.750	42.3	40.1	43.6	0.9729	0.9863	2.347	77
		2.250- 2.450	38.4	35.9	40.8	1.936	1.392	3.623	53
	75612600	0.520- 0.600	14.0	11.6	16.0	1.203	1.097	7.832	108
		0.630- 0.690	18.6	17.0	20.2	0.8386	0.9158	4.928	81
		0.740- 0.800	23.0	21.3	24.2	0.6649	0.8154	3.546	50
		0.800- 0.910	26.0	23.7	28.0	1.271	1.128	4.329	92
		1.550- 1.750	42.9	41.1	44.3	0.6595	0.8121	1.892	77
		2.250- 2.450	40.2	37.2	44.1	2.739	1.655	4.120	53
ALFALFA	75613400	0.520- 0.600	6.6	4.7	7.7	0.6263	0.7914	12.03	97
		0.630- 0.690	9.4	8.5	10.5	0.2756	0.5250	5.558	81
		0.740- 0.800	15.1	13.7	16.2	0.6358	0.7974	5.294	50
		0.800- 0.910	17.8	16.1	19.7	1.065	1.032	5.790	92
		1.550- 1.750	29.2	26.9	30.6	1.146	1.071	3.664	77
		2.250- 2.450	21.1	19.6	23.0	0.8173	0.9041	4.291	48
	75613500	0.520- 0.600	7.7	6.4	8.9	0.4994	0.7067	9.186	100
		0.630- 0.690	10.7	9.9	12.1	0.3723	0.6102	5.719	81
		0.740- 0.800	17.7	15.8	19.0	0.8390	0.9160	5.188	50
		0.800- 0.910	21.1	18.8	23.8	1.746	1.321	6.264	92
		1.550- 1.750	31.3	29.1	32.5	0.9984	0.9992	3.197	77
		2.250- 2.450	21.7	19.4	25.0	1.235	1.111	5.127	48

CLASS STATISTICS

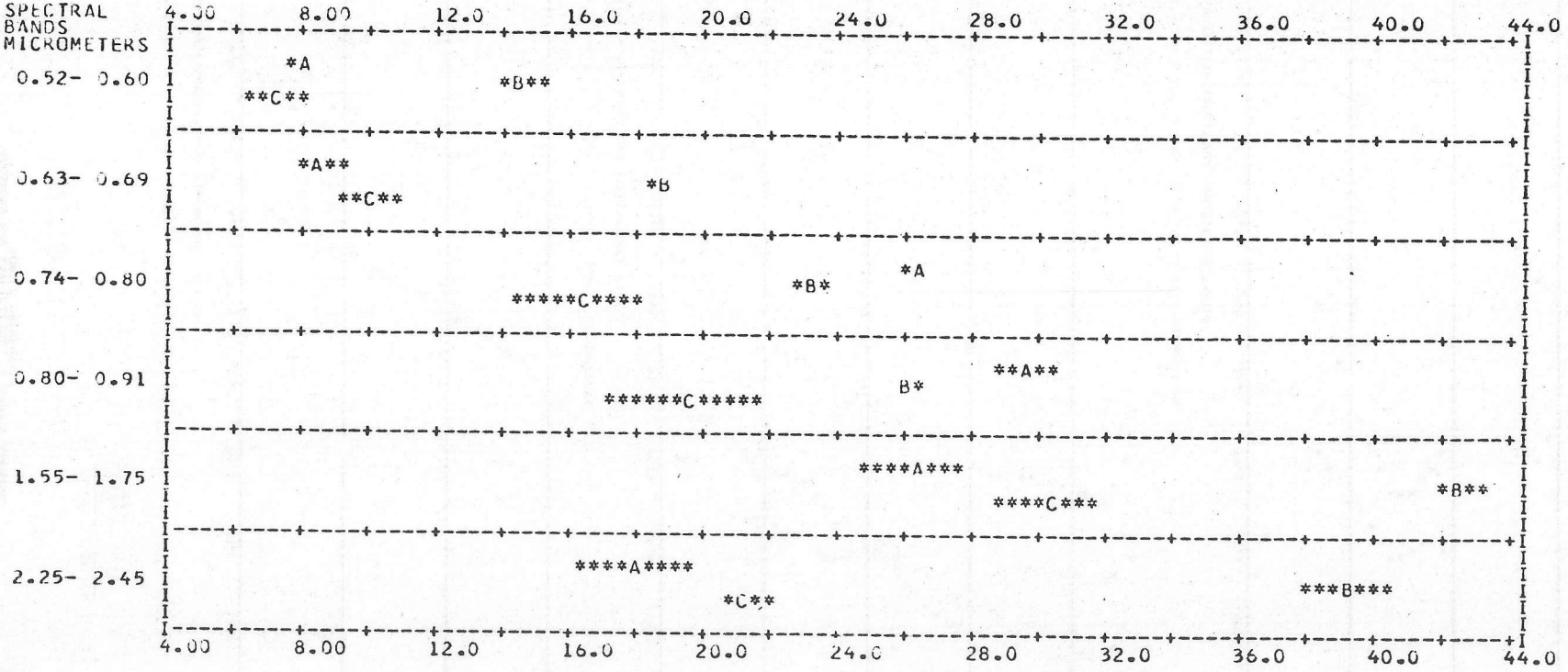
CLASS NAME	SPECTRAL BAND	--- BAND MEAN STATISTICS --- MEAN	RANGE MINIMUM	RANGE MAXIMUM	VARIANCE	STANDARD DEVIATION	PERCENT DEVIATION	NO. RUNS	POINT STATISTICS STANDARD DEVIATION	POINT STATISTICS PERCENT DEVIATION	PTS IN BAND
WHEAT	0.520- 0.600	7.82	7.64	8.00	0.6497E-01	0.2549	3.258	2	0.7827	10.00	216
	0.630- 0.690	8.45	8.05	8.85	0.3245	0.5697	6.740	2	0.5607	6.634	162
	0.740- 0.800	26.22	26.19	26.25	0.1953E-02	0.4419E-01	0.1686	2	2.066	7.880	100
	0.800- 0.910	29.47	28.89	30.06	0.6768	0.8227	2.791	2	0.9383	3.184	184
	1.550- 1.750	26.22	25.25	27.18	1.866	1.366	5.211	2	1.878	7.165	154
	2.250- 2.450	17.96	16.76	19.16	2.885	1.698	9.456	2	1.618	8.947	96

CORRELATION MATRIX

SPECTRAL BAND	0.52 0.60	0.63 0.69	0.74 0.80	0.80 0.91	1.55 1.75	2.25 2.45
0.52 0.60	1.000					
0.63 0.69	1.000	1.000				
0.74 0.80	-0.975	-0.970	1.000			
0.80 0.91	-0.999	-0.999	0.981	1.000		
1.55 1.75	1.000	1.000	-0.975	-0.999	1.000	
2.25 2.45	1.000	1.000	-0.976	-0.999	1.000	1.000

COINCIDENT SPECTRAL PLOT (MEAN PLUS & MINUS ONE STD.DEV.)

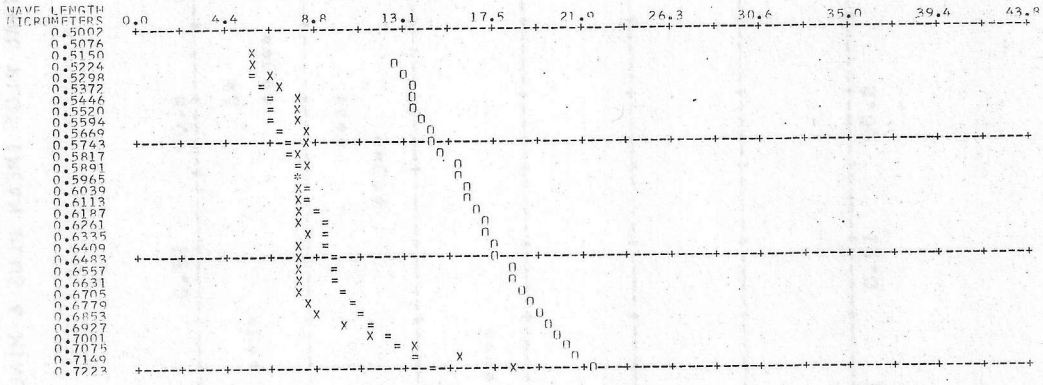
LEGEND
A = CLASS WHEAT
B = CLASS FALLOW
C = CLASS ALFALFA



CLASS	SYMBOL
WHEAT	X
FALLOW	0
ALFALFA	=

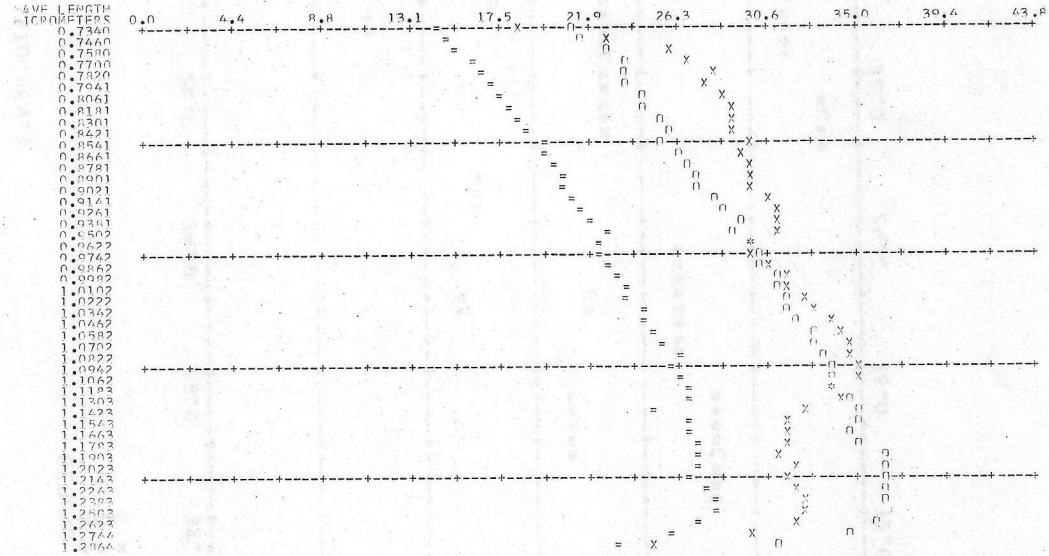
***** SAMPLE GROUP 1 SI RANGE 0.3751- 0.7223 MICROMETERS

RESPONSE,BI-DIRECTIONAL REFLECTANCE FACTOR



***** SAMPLE GROUP 2 PR S RANGE 0.7340- 1.2912 MICROMETERS

RESPONSE,BI-DIRECTIONAL REFLECTANCE FACTOR



***** SAMPLE GROUP 3 PR S RANGE 1.2890- 2.3863 MICROMETERS

RESPONSE,BI-DIRECTIONAL REFLECTANCE FACTOR